

TRANSPORTATION
RESEARCH

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CIRCULAR

Research Problem Statements

Design and Construction of Transportation Facilities

RESEARCH PROBLEM STATEMENTS

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GENERAL NOTE

This circular supersedes Circular 363, September 1990. Additional statements emanating from Group 2 Committees are contained in Circular 405, March 1993.

Subscriber Categories

IA planning & administration
IB energy & environment
II design
III materials, construction, maintenance
VII rail

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The **Transportation Research Board** is a unit of the National Research Council, which serves as an independent advisor to the federal government on scientific and technical questions of national importance. The Research Council, jointly administered by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, brings the resources of the entire scientific and technical community to bear on national problems through its volunteer advisory committees.

Research Problem Statements

Design and Construction of Transportation Facilities

TRANSPORTATION RESEARCH BOARD / NATIONAL RESEARCH COUNCIL

INTRODUCTION

Stimulation of research toward the solution of problems facing the transportation industry is an important function of the Transportation Research Board (TRB). Therefore, technical committees periodically develop and prepare research problem statements for dissemination by TRB. The aim of this activity is to provide guidance to financial sponsors such as governmental agencies, research institutions, industry, the academic community and others in allocating scarce funds and manpower to the solution of transportation problems. The Group 2 Council endorses this activity and has established a Standing Committee on Research Needs to provide guidance and direction to its committees and to coordinate their efforts.

The 229 problem statements in this circular represent a composite of efforts by 44 of the group's committees. They should not be considered an all inclusive recognition of research needs within the scope of Group 2's activities. Since many of the statements may touch upon the scopes of several other elements of TRB, the circular is being distributed to a wide range of interest areas.

Rating Priorities

Some of the contributing committees have given a priority rating for their problem statements.

Although a diligent effort was made by the committees to examine all pertinent activity related to each problem, it is likely that some current research in progress and recently completed research was overlooked which may have altered the recommended priorities. It should also be noted that subjective evaluation of research needs, in which "Urgency," "User Community" and "Implementation" were considered, probably created a bias in favor of applied research as opposed to theoretical studies.

While the problem statements have been assigned a number and arranged within categories by alphanumeric designation of contributing committees, this arrangement does not establish recommended priorities within categories. *The ordering of statements under individual committee listings does reflect that committee's priorities if indicated.*

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A2A01 COMMITTEE ON PHOTOGRAMMETRY, REMOTE SENSING, SURVEYING, AND RELATED AUTOMATED SYSTEMS

PROBLEM #1: OPTIMAL DATA MODEL FOR A TRANSPORTATION LOCATIONAL DATA ACQUISITION AND MANAGEMENT SYSTEM

There are currently no comprehensive data models for the design of a framework for collecting and managing the vast amount of locational data being generated by new technologies in support of various transportation information systems. These new technologies include electronic field survey recorders, the Global Positioning System (GPS), softcopy photogrammetry, photogrammetric digital terrain models, digital satellite imagery, digital orthophotography, digital photolog imagery, real-time telemetry, and "smart" sensors. Because these data are critical in supplying the information to support new information systems such as Geographic Information Systems (GIS), an efficient and effective approach is needed to organize and manage the data.

Objectives

The proposed research will define an optimal data model and institutional framework for collecting and managing field-derived locational data in support of transportation information systems.

Related Work

NCHRP Project 20-27 defined a top-level design and implementation plan for GIS as applied to transportation which would be responsive to technical, economic, social, and institutional needs of the transportation industry. Some of the conclusions in the interim findings of that project, released in 1991, were:

- Work must be done to integrate advanced data collection technologies and GIS-T. These include GPS and real-time telemetry systems such as those for traffic counts or weather conditions (NCHRP Research Results Digest Number 180, August, 1991, page 9).

- New data collection technologies that can be expected to impact GIS-T are currently being adopted by DOTs. They include automation of engineering surveys, real-time telemetry of traffic counts, and various aspects of imaging (including video) for bridge inventory. Some agencies with GIS-T experience see the need for

institutional change in the management of data collection and maintenance (Ibid., page 7).

- Advances in data gathering and information processing technologies have the potential to reduce costs and reporting burdens while improving the speed and reliability of data collection and analysis. The areas of greatest opportunity . . . , such as automated surveying methods, electronic linking of records through EDI, automated vehicle and traffic monitoring through IVHS technologies, and integration of data into GIS for analysis, should be carefully investigated (Data for Decisions: Requirements for National Transportation Policy Making, TRB Special Report 234, 1992, pages 68-69).

NCHRP Report Number 334, "Improvements in Data Acquisition Technology for Maintenance Management Systems," December, 1990 describes the application of new electronic field data collection devices, including bar coding, electronic distance measurement devices, and GPS, to enhance highway maintenance management. The research report includes a description of requirements for maintenance field data collection, assessment of alternative data acquisition technologies and procedures, and system designs for six areas of maintenance data collection. These research results will provide very useful input to defining a more comprehensive data collection and management model for other areas of transportation systems support such as planning, design, construction, and operations.

Urgency

The urgency is high. The collection of locational data in DOTs using advanced technologies is growing exponentially. Even now, gigabytes and terabytes of data are being accumulated and backlogged. Without an effective data collection and management framework, in a proper institutional framework, these data will quickly become unmanageable and thus unusable. Without effective data input to advanced information systems such as GIS, effective analysis and decision making based on those systems is precluded.

Cost

\$200,000

User Community

This problem statement should be of use to state transportation agencies, AASHTO, and FHWA.

Implementation

The resulting data model would be used by state transportation agencies to design a proper framework, both technical and institutional, to collect and manage all of its field-derived locational data.

Effectiveness

This research will be key to addressing a prevalent and increasingly serious problem in the handling of field-derived locational data. Using location as the common denominator, a comprehensive data model using all types of data will be much more effective in dealing with these data than uncoordinated, type-dependent, individual approaches. Considering the amounts and disparate nature of the data, such a model offers significant efficiency gains.

PROBLEM #2: AUTOMATIC FEATURE EXTRACTION FROM DIGITAL IMAGERY

The discovery and growing use of charged-coupled devices (CCD's) has made the acquisition of digital imagery a reality! The future promises to provide us with accelerated growth, use, and enhancement of CCD technology. However, the problem of dealing with digital imagery is that one must manually digitize features from a screen in order to spatially reference them. This process is labor intensive and is the most time consuming component of the process of compiling digital imagery.

Information can be extracted from digital imagery automatically. A trivial example of this idea is optical character recognition. As a result of research at the university and in the private sector, significant progress has been made and numerous features (road signs, bridge structures, etc.) can now be extracted from digital imagery without human intervention. However, much needs to be done. Specifically, we need to focus on the application of expert systems and recently developed theoretical algorithms and models for feature extraction to the transportation problem.¹

Objectives

The proposed research would result in the capability of automatically extracting a well-defined set of transportation-related features from aerial and/or terrestrial imagery. This set of features should be agreed to by the researchers and TRB Committee A2A01.

Key Words

Feature extraction, digital imagery, computer recognition, transportation features, expert systems.

Related Work

Today, available software exists to automatically form digital elevation models from aerial imagery, to perform aero-triangulation, to extract features such as signs, road edges, buildings, etc. What does not exist is the ability to extract potholes, types of buildings, classify vehicles, and extract other important transportation features.

Urgency

This research is urgent in the sense that it is one of the most inhibiting factors in the use of digital imagery. Like most new technology, an iterative process between hardware, software, modeling, and utilization is required. In this instance, it is overdue to have better software and modeling in order to exploit new solid state technology.

Cost

The cost of the research could be constrained by the number and complexity of the features requested, however, \$100,000 - \$150,000 seems reasonable.

User Community

FHWA, AASHTO

Implementation

The implementation of this research would be carried out at the state (DOT) level. Users who are involved with digital imagery would receive documented software

and published algorithms to use during the compilation of aerial and terrestrial images. As time goes on, more and more of the mapping community will be using digital imagery, and hence this work will become more and more relevant.

Effectiveness

The impact of this work will be enormous in as much as digital imagery can be used to monitor the infrastructure along railroads, waterways, highways, and nearly every type of transportation methodology. The revolution in solid state electronics has enabled us to produce chips in a tailored fashion and hence the use of CCD's will increase dramatically. Therefore methods of extracting information from data, minimizing labor costs will be of increasing importance to society.

¹ References:

Schenk, T, and C. Toth, 1991, *Knowledge-Based Systems for Digital Photogrammetric Workstations*, Digital Photogrammetric Systems, Wichmann, pp 123-139.

Boyer, K., and N. Vaidya, 1991, *Stereopsis and Image Registration from Extended Edge Features in the Absence of Camera Pose Information*, 1991 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, pp 76-82.

PROBLEM #3: UTILIZATION OF DIGITAL IMAGERY IN TRANSPORTATION CORRIDOR MANAGEMENT

Transportation system managers increasingly need tools that let them collect, display, and use visual images for corridor planning, design, construction, operation, and maintenance. In the past photographic images such as aerial photography and vehicle based photologs have partially served this purpose, but have been costly to produce and generally limited to specific applications such as for map production in stereoplotters. In recent years cost effective techniques have been developed in a number of areas to produce digital imagery through direct digital collection such as with video cameras, through digitization of photographic images such as continuous tone scanning or through digital data collection from visual imagery as in digital terrain

modelling on a stereoplotter. Most of these techniques have been developed independently. Research now needs to be done to see how the various sources and methods of visual digital information can be integrated to aid in transportation corridor management.

Objectives

The proposed research will evaluate all the methods and techniques for obtaining, displaying, and using visual imagery and then recommend ways to integrate them to form essentially a solid model of the transportation corridor to be used in planning, design, construction, operation and/or maintenance.

Key Words

DTM (digital terrain modelling), satellite imagery, video imagery, scanning, GPS (global positioning system), soft copy photogrammetry, image correlation, and visualization.

Related Work

Development of hardware and software for direct viewing and data extraction from digital stereo models of scanned aerial photography, collection of direct digital stereo imagery written directly to laser disk from a photolog van, direct digital imagery collection from aerial scanners (both satellite for small scale and aircraft for large scale), use of GPS to accurately position imagery location, visualization software from major vendors allowing integration of potential design data and existing condition imagery, use of Geographical Information Systems (GIS) to organize, correlate, and analyze geographical information.

Urgency

Transportation agencies are rapidly becoming overloaded with data - they are data rich but information poor. This research hopefully will result in the ability for transportation managers to "see" existing conditions and results of the various decisions they might make on the systems. The phrase "a picture is worth a thousand words" applies here. With the large investment needed for our transportation infrastructure, it is imperative that the managers be provided the best integrated tools possible to aid in the decisions.

Cost

Because of the diversity of digital imagery sources and collection techniques, the amount of research time could be extensive as could the development of integrating software. Much of the cost will depend on the ability of the researchers to gain access to the existing and developing technologies. As an estimate, \$250,000.

User Community

FHWA, AASHTO, ASPRS

Implementation

The possibilities for utilization of digital imagery developed by this research should encourage transportation agencies to either work towards systems integration in-house or through vendor contracts. Implementation should occur through all parts of the organization but will most likely start with the data collectors, then migrate to the data users.

Effectiveness

A revolution is occurring in data collection, management, and display. The price reductions in computer data storage and manipulation coupled with increasing processing speeds is allowing for the cost effective collection and use of digital imagery. Results of this research will identify integrated means to deal with this data and will have a large impact on how transportation systems are managed in the future. A measure of the effectiveness will be the speed that various alternative design, construction, operation, or maintenance choices can be analyzed using visual model compared to previous numerical and line drawing methods.

PROBLEM #4: USE OF GPS, GIS AND CCD CAMERA TECHNOLOGY AS CONTROLLING DEVICES AND TECHNIQUES FOR THE USE OF ROBOTICS TO CONTROL CONSTRUCTION EQUIPMENT IN THE CLEANUP OF HAZARDOUS WASTE AREAS

Global Positioning Systems (GPS), Geographic Information Systems (GIS) and Charged Couple Device (CCD) cameras have become sophisticated tools in depicting real estate and its particular characteristics.

The CCD can also be the eyes of the construction equipment and along with real time positioning using GPS cleanup of sites could be accomplished with minimum human exposure to the effects of the waste.

Objectives

- Perform necessary literature search;
- Develop alternative strategies for packaging the technologies;
- Develop minimum requirements for each technology for this use;
- Develop list of software requirements that need developing; and
- Prepare a proposal for the most promising technology package that would allow for final development of a system package.

Key Words

CCD cameras, GIS (Geographic Information Systems), GPS for vehicle control, transportation monitoring, construction control.

Related Work

Universities are doing some independent work on part of the puzzle. Wong at the University of Illinois is doing work on robotics, Bossler at Ohio State University is doing work in GPS control of heavy construction equipment, University of Kansas has some work in progress in remote control of trucks. Some work has been done in control of farm field spraying equipment. More will be discovered during literature search.

Urgency

Superfund allocation of Federal funds makes this project of high priority. The technology that this study can represent will save considerable funds in the disposal of waste that will be involved in Superfund projects. This technology will also make the waste disposal work safer for the worker.

Cost

Research in the problem area is relatively inexpensive, especially when the returns in savings are high. This

project should be completed in less than a year and be operational within two years, a quick payoff!

- Literature Search, \$35,000
- System investigations, \$55,000
- Testing with cooperative manufacturers, \$100,000
- Technology transfer via manufacturers, \$55,000

Total Cost, \$245,000.

A2A02 COMMITTEE ON GEOMETRIC DESIGN

PROBLEM #5: INTERSECTION SIGN & DISTANCE REQUIREMENTS

The existing AASHTO models for intersection sight distance use the assumptions in the "Green Book" and result in very long minimum sight distances for higher speeds. There is a need to compare the existing model with what actually occurs at intersections including those used by large trucks. All assumptions used in developing the existing model should be examined including acceleration rates of vehicles and whether it can be assumed that vehicles will slow down to allow vehicles to enter or cross a highway. Perhaps new models for determining intersection sight distances can be developed to replace those used in the existing "Green Book" that would be more appropriate.

There are a number of inconsistencies in the present model for determining stopping sight distance as developed in the "Green Book." For minimum values of stopping sight distance the "Green Book" assumes that vehicles reduce speed in wet weather conditions although a number of research studies have found otherwise. The "Green Book" assumes a 6 inch height of object and uses this to determine lengths of vertical curves. It is unlikely a person can see the top of an object (not a 6-inch object) at the distances required for stopping given in the "Green Book." Furthermore, headlights do not illuminate pavements at the stopping distances required for higher speeds. Although there are the above inconsistencies with the present model used for determining sight distance and vertical curve design there is no definite proof that present design is deficient.

The adoption of low order geometry in the design of horizontal and vertical curvature, requires if stopping sight distances are to be provided, either the widening of roadway or the enlargement of the adjacent land clear zone. The situation often occurs at intersections on elevated structures and the effect on construction costs is considerable, apart from the fact that there is a large area of elevated roadway provided which cannot be utilized.

The eight seconds required to execute a left turn, right turn, or through movement from a stop condition onto a two-way, two-lane roadway seems excessive. The maneuver involves identifying a gap in two-way traffic, responding to the opportunity to execute the movement, and then executing without collision of vehicles. Perception/reaction time is not necessary because the time needed should not start until the vehicle starts moving. Also, in measuring intersection sight distance,

AASHTO prescribes 18 feet of driver-eye set-back from the edge of the through roadway. Shorter distances maybe appropriate for current vehicles that are shorter and have higher acceleration capability that is shown in AASHTO criteria. It appears that the approaching vehicle (from the left) should afford some degree of evasive action; reduce speed to something less than design or operating speed.

Many of the available references have addressed the problem of the drivers' needs for sight distance when he is entering a through road from a side road. Guidance is not as easily available to help the designer evaluate the adequacy of a design in connection with sight distance needs when a driver on the through highway is turning left into an intersecting street, road or driveway. The problem becomes particularly acute when a sight restricting crest vertical curve exists just beyond the intersection.

Objectives

1. Literature review.
2. Examine the existing models and the values used in those models for determination of intersection sight distance to determine their appropriateness.
3. Verify or otherwise that stopping sight distances are necessary on the approaches to and through junctions.
4. Determine absolute minimum stopping sight distances appropriate to the various design speeds.
5. Determine the most appropriate eye height and object height these should be measured over.
6. Determine the importance of stopping sight distances at non-junction situations, and appropriate values that should be used.
7. Determine the effects of parapets or similar low continuous obstructions, on stopping sight distances, and whether these should be taken into account when determining visibility requirements.
8. Identify the minimum (an allowable 10 mph) reduction in the speed of the approaching vehicle) and desirable intersection sight distances for cars, single unit and WB-50 vehicle designs that will cross or turn onto multilane or divided highways having a variety of design or operating speeds.
9. Determine currently realistic and practical stopping location (driver-eye distance from edge of through roadway) for a purposes of calculating required intersection sight distances in choosing traffic gaps for proceeding from a stop condition.

10. Determine currently realistic time to complete the following maneuvers from a stop condition:

- Left turn onto a two-lane, two-way roadway.
- Right turn onto a two-lane, two-way roadway.
- Through movement across a two-lane, two-way roadway.
- Additional time for entering onto or across multi-lane facilities.

11. Consider the need for a modified or new intersection model for the determination of stopping sight distance and the design of vertical curves associated with the intersection.

Key Words

Intersection sight distance, driveway sight distance, vehicle acceleration rates, average running speeds.

Related Work

FHWA Research Project "Development of Truck Characteristics for use in Highway Design and Operation" is among other things looking at intersection sight distance as it relates to large trucks.

NCHRP Report 270, "Parameters Affecting Stopping Sight Distance" was recently completed, but didn't address the need for a new model for determining stopping sight distance and additional data is needed to determine if the values used in the existing model are correct (if the existing model is retained).

Urgency

Due to the safety implications and lack of existing guidance, urgency is high. There are numerous interchanges and intersections that are in need of some modification because of sight distance restriction. Reconstruction may be ideal, but not always feasible nor necessary with more conservative and perhaps more realistic design criteria.

Cost

\$300,000 - 400,000

Implementation

The study results will assist in appropriating funds for highway improvements in a systematic priority basis to maintain safe and effective highway system.

The research could be incorporated into AASHTO Policies and Guides and to design highways for proper intersection sight distance. Upon verification, reduced standards could be adopted, having a considerable effect on the cost of major roadways. If verified that present stopping sight distances are appropriate, it would confirm the importance of these and that such requirements must be taken into account in the design process.

Research results could have an effect on any intersection where one of the approaches of the through highway have sight restricting features near the intersection.

PROBLEM #6: MEDIAN DESIGN

The design of median widths and shapes to meet rural and urban traffic needs continues to be a problem. As noted in the 1984 edition of the Policy on Geometric Design of Highways and Streets, the width of medians at intersections on partially controlled access, medium or high speed arterial highways is critical to the operation and safety of such highways. Medians 12 ft. to 30 ft. wide protect left turning vehicles on the through road, but no storage is provided for crossing or left turning movements from the cross road.

"Median widths from 30 ft. to 50 ft. do not provide storage for longer vehicles crossing the median", but "these widths normally operate quite well and apparently are within the realm of normal operational expectations of the drive. Widths in the range of 50 to 80 feet have develop accident problems in some areas as the drivers apparently tend to become confused about the intended operational characteristics of the multiple intersections encountered. Medians wide enough to assure the driver that the intersection with the two sets of lanes operate separately have worked quite well. Research may prove that wider medians are not desirable for some facilities with at grade intersections."

Median width research efforts have, for the most part, addressed (full) freeways. These efforts have provided a significant amount of information concerning cross sectional design and optimum width necessary for motorist safety. Little or no closely related efforts have been directed towards optimizing median widths for partial-access controlled expressways with major at-grade intersection influences.

Partial-access controlled expressways with wide medians (over 45 feet) pose peculiar operational problems in the vicinity of intersections. Of particular importance are the problems of accommodating left turns from the expressway at both signalized and unsignalized intersections, and crossing or left-turning

traffic from crossroad facilities at non-signalized intersections.

These problems are created by the large expanses of pavement area, which complicate design, operations, and traffic control. Opposing left turns from expressways, with wide medians, encounter overlapping turning paths and conflicts when normal, parallel 12 ft. bays are "slotted" in the median. Without signals, these turning conflicts are uncontrolled. Also, stored vehicles in the left-turn bays block the sight lines for left turns and accentuate the probability for collision with high-speed, through vehicles. With signals, the turning conflicts can be controlled, but the left turns cannot be phased for simultaneous operation. Also, with signals, the left-turning driver, is often confused by his ability to clearly see the red signal on the crossroad and having to turn directly toward it to complete his maneuver.

To minimize the operational and safety problems described, it is necessary to construct expensive, channelized (buried) left-turn bays to laterally offset the turning paths of left-turning vehicles and improve the sight lines to through vehicles in the high-speed (median) lane. Without these special design treatments, it would be necessary, in some cases, to install signals for control and safety purposes, whether or not volume warrants are met.

There is also increased potential for accidents involving crossroad traffic since:

- The expressway driver may not anticipate crossing or turning traffic because the wide median has given the driver the expectancy of a freeway.
- The driver on the Crossroad may "check" only once before making the crossing or left-turning maneuver. The wide median may allow time for a vehicle in the "far lane" of the expressway to enter the intersection area after the maneuver has begun.
- The wide median may increase the potential for wrong way movements as the far lane may not be plainly visible to the driver on the crossing highway.

The prevention of vehicles crossing open medians and traversable medians is the cause of many accidents. The development of rural undivided multilane highways and their reconstruction create costly alternative median treatments including abandonment of one roadway, complete reconstruction of the other and difficult traffic control during construction. Median design, including widths, and corresponding grading, need to be analyzed to determine if a traversable median is better than a non-traversable median.

Objectives

The objectives of the proposed research would include:

1. Investigation of the use of mounded medians or those with ditches or swales.
2. Investigation of the use of combinations of mounds in cuts and ditches/swales in fills to reduce construction costs, and development of a ditch located adjacent to a mounded median, designed to be traversed before contact is made with the mound.
3. Establish parameters and guidelines to determine the widths and type of median treatment to be used with various traffic levels and existing highway geometric and safety standards.
4. Determine the appropriate traffic control devices and markings for partially controlled access and arterial highways that will provide safe operations at and between signalized and nonsignalized intersections that employ medians.

It is anticipated that the proposed research will include at least the following tasks:

1. Review and analyze the current state-of-the-art by reviewing agency policies pertaining to expressway median widths, intersection geometric and traffic control for partial-access controlled conditions.
2. Prepare a study plan and conduct a field evaluation of preselected intersection sites.
3. Analyze in a cost-safety framework the effect current and/or modified policies will have on traffic operations.
4. Prepare a project final report documenting the study findings and presenting design and traffic control criteria recommendations.

Key Words

Medians, median width, traffic control.

Urgency

Extremely urgent. With the Interstate highway system almost completed, many states are developing supplementary highway systems that will connect cities and regional areas previously bypassed. Many partially controlled access high speed highways have been constructed in the last 30 years and many have relatively

high accident rates at the intersections. Guidance is needed for retrofitting those intersections as well as for the design of future facilities.

Additional new systems will probably be constructed using somewhat lower design standards than required for the Interstate system. It is likely that existing major highways will be upgraded to multi-lane, partially-access controlled expressways.

In the absence of relevant data, it also seems likely that expressway designs will be developed utilizing present median width and design criteria, which largely ignores potential and real operational problems at intersections. Since expressway designs in many states are still in the early planning stages, there exists an urgent need for research in the area of median widths and attendant design and traffic control criteria for partial-access controlled expressways.

This information is needed for the next issue of the Policy on Geometric Design.

Cost

\$250,000-400,000 over two years

Implementation

Research results could be implemented immediately by incorporating appropriate median designs into new and rehabilitation/reconstruction roadway projects and by retrofitting medians of existing facilities.

PROBLEM #7: SURFACE DRAINAGE OF MULTILANE PAVEMENTS

Multilane single pavement roadways typical of urban areas, generally sheet runoff across the entire surface. Using normally accepted cross slope rates, water build up on the outer lanes can be troublesome. On curving roadways where the entire runoff sheets to the low side, the problem is greatly increased. The type of pavement must be considered when addressing drainage. Several other factors enter the equation - the cross slope/superelevation rates in urban environments, design speed, normal operating speeds, allowable water depth, allowable spread and catchments. While drainage design is usually the preview of hydraulics people, it is the geometric design that can solve the problem.

Objectives

Conduct a synthesis of existing practices relating to the geometric designs features that enhance drainage of multilane pavements. The research should identify effective means for handling sheet flow across wide multilane pavements. Possible consideration should include greater cross slope rates, interceptor catchments within the pavement area and other combinations of design pavement type and drainage interception.

Key Words

Pavement drainage, crossslope.

Related Work

Past efforts have focused on small parts of the pavement drainage problem. Hydraulic design alone does not provide the answers.

Urgency

While the priority for this research may be low compared to other research needs, there are many miles of roads inadequately drained. These cause accidents and high maintenance costs that could be reduced with good solutions.

Cost

\$75,000

Implementation

This is an important issue in geometric design of urban highways. Highway operations and safety are significantly impacted by water on the pavement surface.

PROBLEM #8: DRIVEWAY PROFILES

AASHTO vertical geometric design guidelines for driveways are nonspecific. Driveway profiles are a concern in new construction and in projects involving

realignment or widening where driveway redesign is often necessary. Guidelines should ensure that all driveways, including those constructed under the permit process, are uniform in design and contribute favorably to the overall operational efficiency of the roadway.

Objectives

Establish profile guidelines for driveways. The guidelines should include the following considerations:

1. Geographic region;
2. Recommended maximum gradients;
3. Vehicle ground clearance;
4. Vehicle storage capacity at entrance;
5. Use of vertical curves to mitigate gradient break angles;
6. Urban vs. rural conditions; and
7. Control of drainage.

Key Words

Driveway, driveway profile, driveway design.

Cost

\$150,000

Implementation

The impact of these guidelines will be identified in the positive effects or limitations that arise with pavements are overlaid or rehabilitated in some manner that changes the relationship between the driveway and the pavement, creating problems for the vehicles using the driveway.

PROBLEM #9: CLEAR ZONE REQUIREMENTS

The current clear zone standards are very conservative. In view of the extra millions of dollars required to design to the present clear zone standards, a comparison of the cost of construction vs. the improved safety provided by these standards should be investigated.

Objectives

The proposed research should identify the cost effectiveness of clear zones for various traffic levels and mixes. Probabilities of accidents and the severity of the accidents using various widths and slopes of clear zones should be investigated.

Key Words

Clear zones, benefit cost ratios, clear zone construction.

Related Work

NCHRP C22-9.

Urgency

High.

Implementation

Results can be incorporated into actual construction projects. Significant savings can be achieved if less clear zone or greater slopes can be used than present day standards.

PROBLEM #10: INTERSECTION DESIGN TO ACCOMMODATE LARGE TRUCKS

The Surface Transportation Assistance Act (STAA) of 1982 required all states to allow tractors with 48' semitrailers, double-trailer combinations with 28' trailers, and vehicles 8.5' wide on the designated National Network system. The designated National Network system consists of the entire Interstate system and portions of the Federal-Aid Primary system designated by the Secretary of Transportation. The states are also required to provide access routes from the National Network system to terminals, as well as to fuel and rest areas. Inadequate intersection design at Interchanges and along the National Network system make it necessary for large trucks to encroach on adjacent traffic lanes, drive on the shoulders, off track onto the

shoulders, and/or turn very slowly. Inadequate intersection design can cause safety, operational, and maintenance problems. Accidents involving large trucks within interchange/intersection areas can cause significant traffic delays as well as considerable property damage to trucks and cargo, injuries and even fatalities. A number of these truck accidents could possibly be avoided by a combination of actions including possible modification of existing design criteria to insure that large trucks can be accommodated through interchange/intersection areas. An examination of ramps, interchanges, and intersections with high rates of truck related accidents is needed to determine specific factors or combination of factors related to geometric design, which are contributing to large truck accidents and what remedial action possibly could be taken where these geometric features exist which could reduce large truck accidents.

Objectives

1. Evaluate existing interchange ramps at various locations throughout the country where large truck accidents are occurring to determine geometric features or combinations of features that should be avoided or should be provided, and to develop cost-effective and corrective actions to reduce large truck accidents at interchanges.
2. Determine the safety effects of physical and operational elements of urban and rural intersections that accommodate truck movements and develop design guidelines for such intersections based on safety, operations, and cost-effectiveness.
3. Determine lane width, turning radius, and the effect on intersection capacity, if consideration should be given to signing a particular lane for truck use.

Key Words

Trucks, intersections, offtracking.

Related Work

1. FHWA research project report "Impact of Specific Geometric Features on Truck Operations and Safety at Interchanges" was recently published.
2. Related work includes NCHRP 279, Intersection Channelization Design Guide, TRB, November, 1985, and several references related to trucks are listed in TTI Research Report 397-1, Study 2-18-85-397, Annotated

Bibliography of Research On Operational Characteristics and Geometric Implications of Longer and Wider Trucks, February, 1986.

Urgency

Priority is high. This research should provide basic guidelines for various types of intersection designs for large trucks and would be immediately useful to highway agencies.

Cost

\$300,000 - \$400,000

Implementation

Research results could be included in an NCHRP report, AASHTO policies and guides (such as the design guide) and eventually be incorporated in new interchange/intersection and intersection rehabilitation designs. Guidance could be provided on cost-effective measures to correct existing interchange ramp intersections, and rural/urban primary intersections where large truck accidents are occurring.

The wide intersection pavement areas necessary for large trucks may also create operational and safety problems. Wide pavement areas make sign placement difficult, increase the chance for wrong-way movement at ramp terminals; inadequately define vehicle paths, and require longer pedestrian travel distance. Construction costs as well as right-of-way costs increase. Large interstate trucks are on the increase and design consideration must be given them at intersections where they are legally allowed.

PROBLEM #11: SUPERELEVATION

The development of superelevation and associated runoff continues to be a problem in specific instances that current AASHTO Guide does not fully address. These particular areas include the following:

- Urban areas where low speeds and physical limitations such as curbs and utilities restrict the development of superelevation.
- Rehabilitation of existing urban pavements in both high and low speed situations where no new right of way is to be purchased.

• High speed rural expressways with steep grades.

Physical limitations occurring in some locations result in the acceptance of much smaller values of horizontal curvature for particular design speeds than are normally accepted or used. Generally the very minimum radii are adopted for less important roads, but with the development of urban Expressway Systems through existing developed areas or reclaimed areas, difficulty is being experienced in providing desirable minimum radii, particularly at intersections due to land required. These absolute minimum local design standards require superelevation in the order of 10%. This can result in loss of control in wet weather, and the appearance of such steep crossfall may adversely affect driving performance.

Superelevation and the associated runoff area in urban areas continues to be a major problem in dealing with street intersections, developed property, curbs, storm sewers, other utilities, and restrictions. In many of these areas, traffic volumes are increasing and speeds must be maintained at the highest practical level to move this traffic safely.

Superelevation on many current highway curves does not meet current AASHTO standards. Economic considerations dictate that design exceptions be requested when resurfacing or otherwise preserving the pavement of these highways.

Curves on relatively steep grades on high speed expressways, are causing large trucks to leave the roadway on the outside of the curve in large numbers. Due to the increased length of semitrailers, the effect of superelevation may be negated by the grade and length of the trailer, thereby reducing the resistance to the centrifugal force provided by the superelevation.

EXAMPLE Curve to left

Superelevation	0.08	1/1
Truck length		65'
Grade		6%
Wheel Gauge		7'
Distance front to rear axle		55'

ELEVATION

Left rear wheels		100.00
Right rear wheels	7 x .08	100.56
Left front wheel	55 x .06	96.70
Right front wheel		97.26

With the right front wheel 2.74' below the left rear wheel, has the effective superelevation been diminished

to a point where the horizontal forces resisting the centrifugal forces are overcome at legal speeds and loads?

Objectives

1. Establish absolute minimum radii that could safely be adopted for the AASHTO design speed criteria and the appropriate maximum superelevation for that curvature in rural situations where physical or geographical limitations exist.

2. Establish absolute minimum radii and associated design speeds and conditions at which superelevation should be applied and how the runoff should be developed, to be compatible with other urban design features and restrictions.

3. Develop empirical data on side friction for different surface types. Many new asphaltic concrete surfaces are in use. The data should be developed for all pavement surfaces in each general type (high, intermediate, and low).

4. Relate side friction to accident history at sites, weather conditions, adjacent roadway geometric, driver condition, and other pertinent factors to enable recommendations for correcting inadequate superelevation.

5. Develop design guides for the application of superelevation and runoff distances to be used on high speed roads with steep grades and maximum curvature. Develop procedures for locating these problem areas in design and in the field.

Key Words

Superelevation, safe speed levels, urban design features, curbs, intersections, storm sewers, utilities, design consistency.

Related Work

Research work has been done in the areas of superelevation, but not a great deal in the particular areas noted and especially in the areas of steep grades and superelevation. Limited information can be found in the following:

• There are some side friction factor values listed on page 219 of the 1984 AASHTO "Green Book".

• The effect on safety of marginal design elements, 1981, Halcrow Fox and Associates, for the U.K. Department of Transport.

- The effect of road curvature on vehicle/driver behavior, 1982, Southampton University for U.K. Department of Transport.

- Highway Link Design, Departmental Advice Note TA 43/88, and Departmental Standard 9/81, U.K. Department of Transport.

Urgency

Decisions are being made regarding the operational adequacy of our highways which could be improved if this information were available. The need for the results of this study data increases daily, and in urban areas, the need for new highways to be designed increases just as fast. As trucks become longer, it is imperative that consideration be given to the geometric combination of vehicle length, curvature and grade creating hazardous conditions at high speeds.

Cost

\$200,000-300,000

Implementation

If the results verify existing standards there would be very little impact, but the results would be of value to other countries presently using higher standards. If the results indicate lower order geometry and superelevation than presently used is appropriate, considerable savings in project construction costs could be achieved.

If the results indicate the present standards were not adequate, this could have a dramatic impact on road system development, resulting in the construction of fewer higher standard roads, and necessitating positive steps in enforcement of physical measures to reduce the actual vehicle speeds on these facilities. It is unlikely that such findings would result in an upgrading of standards, due to economic concerns in right of way acquisition.

Empirical data on side friction would facilitate the design of curves with non-standard conditions. The information on side friction would have possible benefits in pavement research. States could more logically decide how to spend limited funds for reconstruction of inadequately superelevated curves.

Implementation would be accomplished by issuing AASHTO guidelines to be used in identifying the problem areas and to treating them in the design process. Also, the guidelines and field procedures would provide a check on existing roads prior to highway design. Verification of the problem by using the

guidelines and procedures after accidents would lead to other controls being instituted on existing roads.

PROBLEM #12: DESIGN CONSISTENCY

Traffic Studies have identified many high accident locations on two lane state highways. Many of these locations have similar characteristics typified by a steep downgrade roadway leading into a sharp curve. Most often this sharp curve is the first one of such intensity in the stretch of roadway. Motorists lose control part way through the curve and run off the road. Flattening the curve is a very expensive option and often steepens the grade and/or merely improves the roadway geometric enough to transfer the problem to the next sharp curve down the road.

Another related problem is knowing the effect of combinations of vertical and horizontal curves on sight distances. Design aids treat both types of curves separately to determine independent sight distances, but what is the effect of them in combination.

Objectives

Find out what kinds of improvements have been most cost effective in reducing the accident severity. Improvements such as advance warning signs, rumble strips, steeper superelevations, wider roadways at wires, guardrail, removing obstructions (e.g., rock weights), etc. could be investigated and weighted for effectiveness.

Determine if combinations of vertical and horizontal curves further reduce sight distance and, if so, to what extent.

Phase I:

1. Conduct a search of several state highway department, highway accident records to identify the combinations of vertical grades and curves, that in conjunction with vertical curves, provide the highest accident rates.

2. Summarize the techniques that have been used and the effectiveness of each in reducing accident experience. Tabulate and rank the effective treatments.

Phase II:

1. Use computer modeling to determine potential new treatments for such problem areas involving various combinations of grade and vertical and horizontal curves and their effect on sight distance.

Key Words

Design consistency, horizontal curvature, vertical curves.

Related Work

No documented research. The insurance industry and the states have worked to develop some of the data in specific areas of the problem or geographically.

Cost

\$150,000

Implementation

The results of the research can be used as guidelines to determine the cause of accidents at a site and offer a procedure on how to most economically provide improvements to warn motorists of the impending danger and reduce its effects. The computer model can be used assist designers in determining sight distances on combination vertical and horizontal curves if different than for values determined separately.

PROBLEM #13: GEOMETRIC DESIGN AND THE AGING DRIVER

As this country's population ages, so too are its licensed drivers. Reaction time, eyesight, etc. deteriorate with the aging process in some individuals to a point where the existing design standards are no longer safe. Should the design standards be revised to accommodate the substandard driver or should educational methods be developed to help the marginal driver compensate for his condition or should the marginal driver have their license revoked?

Objectives

Study the financial, moral, and safety aspects for each of the three above listed solutions. Develop ways to mitigate the reduced reaction time of the aging driver through improved signing or increased lighting as opposed to more costly geometric changes in roadway design. Recommendations based on the above results should be developed.

- Phase I - Literature review of the existing research that has been completed or is underway by other federal agencies or TRB.

- Phase II - Develop mitigation procedures that apply to the determination of improvements in lighting or signing as related to the limitations of the aging driver on the various levels of highways.

Key Words

Aging driver, vehicle operator, motor vehicle licensing.

Related Work

The 70th annual TRB meeting, January 1991 included special session #3 sponsored by the Task Force on safety and Mobility of Older Drivers and Committee on Vehicle User Characteristics. Five papers and a panel discussion were presented at that session. The task force also sponsored six additional papers in session #32.

The Committee on Operator Education and Regulation also sponsored session 82 which included papers on this subject from the licensing perspective.

Session #105 of the same meeting featured papers dealing with the transportation needs of the elderly and was sponsored by the Committee on Rural Public Transportation and the Committee on Specialized Transportation.

The Committee on vehicle User Characteristics and Committee on Pedestrians and Committee on Bicycling and Bicycle Facilities sponsored session #112 that dealt directly with the highway driver and pedestrians.

Cost

\$150,000

Implementation

The results can provide alternative actions for the geometric design practices and highway operations that deal with the aging population.

PROBLEM #14: DETOUR DESIGN

Design of detours is a continuing area of concern where further AASHTO guidance is required, since there is

little or no information contained in the 1984 "Green Book." Existing highway department standard drawings contain certain design parameters which need to be reevaluated. However, there seems to be a vast difference in philosophy regarding detour design, including what design speed should be provided, if and how necessary speed reduction can be obtained, and the cost vs. benefit of a detour comparable in design to that of the permanent roadway.

The problem is compounded in many instances where desirable or optimum guidelines can't be followed due to pre-existing conditions which restrict the design. This is particularly evident for detours on existing divided highways where full closure is necessary in one direction. Median widths, rock cuts, obstructions, crossroads, etc., adversely affect horizontal alignment, entrance taper rates and superelevation.

Objectives

Develop a policy on geometric design of detours including general alignment controls and operational considerations. To accomplish this objective, the following tasks will be conducted

Phase I:

- Conduct a review of existing state highway department geometric design policies for construction area detours to include the criteria behind each of the policies. Include a review of the pavement designs used in each geometric design.

Phase II

- Analyze the existing detour design policies to determine the common decision criteria and levels of geometric requirements vs. the traffic levels to be considered.

- Develop a series of geometric designs for detours and a method for selection of the appropriate detour design to meet the existing conditions and time limitations. The designer should be able to use the research output as a guide to determination of allowable and optimal detour designs.

Key Words

Detour, pavement design, benefit/cost ratio.

Cost

\$100,000

Implementation

States and local governments could use the recommendations set forth to develop guidelines for reasonable, safe and cost effective designs. Traffic control in the construction area makes up a very sizable portion of the construction costs in many high traffic areas and is a very real risk factor in development of construction staging plans. This type of guides should prove to be a vital part of the state highway department design process.

PROBLEM #15: PAVEMENT FRICTIONAL VALUES

Several recent research investigations indicate that frictional resistance must be the main safety consideration in designing new highways or rehabilitation projects. It is a critical question for the highway engineers now to evaluate which level of frictional resistance that should or must be provided and maintained for safety reasons.

Since up to now an objective scale which to compare frictional resistance does not exist in the U.S. as it does in other countries, the main problem is to develop an objective scale for expressing frictional resistance (coefficients of friction) in relation to speed by frequency distribution curves which are derived from a reliable data bank for a wide range of road surfaces in the U.S.

Objectives

1. Determine the actual, not the hypothetical, relationship between coefficient of friction and speed by developing a reliable data bank.

2. Develop frequency distribution curves and prediction equations for friction vs. speed representing a wide range of road surfaces in the U.S.

3. Determine to what extent the recommended AASHTO friction values represent typical road surfaces in the U.S.

4. Evaluate Appropriate design values of friction in relation to speed to account for surface deterioration

and possible increases in speed, for example, in the case of RR projects.

5. Evaluate appropriate lower levels of friction in relation to speed for the initiation of maintenance and/or rehabilitation work.

6. Evaluate the distribution of friction for different road systems to account for different operation speeds.

Key Words

Skid numbers, friction, highway safety.

Related Work

- Brinkman "Safety Studies Related to RR-Projects," ASCE, Vol. 108, 1982.

- Glennon, Neumann, Leisch "Safety and Operational considerations for Design of Rural Highway Curves," contract No. DOT-FH-11-9575, 1983.

- Lamm "Driving Dynamic Considerations - A comparison of German and American Friction Coefficients for Highway Design," TRC, Vol. 960, 1984.

- German Road and Transportation Research Association "Geometric Design Standards for the Design of Roads, RAS-L-1" 1973, 1979 (commentary), 1984.

- Goyal "Friction Factors for Highway Design Regarding Driving Dynamic safety Concerns in the State of New York," Masters Thesis, Clarkson University, Postdam, New York 13676, Advisor Lamm, 1982.

- Lamm, Choueiri, Tiouy, Hailaender "Design Friction Factors of Different Countries vs. Actual Pavement Friction Inventories," paper will be submitted

for presentation and publication at the 1990 Annual Meeting of the Transportation Research Board.

Urgency

Providing state design and maintenance agencies with actual, not just hypothetical, frictional coefficients in relation to speed is very urgent to enhance traffic safety and to ensure that restricted available funds use can be optimized.

Cost

\$150,000 to collect and analyze existing data. \$200,000 to collect additional skid resistance measurements.

Implementation

The research could be included in a course dealing with highway design and maintenance procedures, packaged as a design and/or distributed through articles in professional publications. By establishment of an objective scale for friction vs. speed with recommendations for appropriate upper levels for geometric highway design and lower levels for the initiation of maintenance work, it is anticipated that the findings will help in the future to ensure friction supply will be more often greater than friction demand for safety reasons. In addition, the findings may lead to reconsideration of the AASHTO tangential and side friction coefficients for upper design speed classes (V design greater than or equal to 45 mph estimated).

A2A03 COMMITTEE ON HYDROLOGY, HYDRAULICS AND WATER QUALITY

**TWENTY-NINE RESEARCH PROBLEM
STATEMENTS FOR THIS COMMITTEE ARE
CONTAINED IN TRANSPORTATION RESEARCH
CIRCULAR 405, DATED MARCH 1993.**

A2A04 COMMITTEE ON ROADSIDE SAFETY FEATURES

The research problem statements appear in the order of priority established by the committee.

PROBLEM #16: SITE SPECIFIC GUIDELINES FOR THE SELECTION, INSTALLATION AND MAINTENANCE OF HIGHWAY SAFETY FEATURES

According to the recently published NCHRP Report 350, "Recommended Procedures for the Safety Evaluation of Highway Safety Features", a safety feature may be developed to meet one of up to six "test levels" (TL) (test levels are equivalent to service levels or performance levels), depending on the type of feature. For example, a longitudinal barrier, such as a guardrail, can be developed for one of six TLs, a crash cushion for one of three test TLs, and a Truck Mounted Attenuator (TMA) for one of two TLs. The feature may be designed for temporary (work zone applications) or permanent applications. Features developed for the lower TLs may be applicable for low speed, low volume conditions and will have minimal containment capabilities; features developed for the higher TLs may be applicable for high speed, high volume conditions and will have high containment capabilities, i.e., for heavy trucks.

Report 350 has no selection guidelines for safety features. User agencies (federal, state, and local transportation agencies) will be required to make decisions as to the development and/or use of features developed within Report 350 recommendations. In general, there is an absence of objective guidelines from which these agencies can determine which of the multi-service level features are most appropriate for given site conditions.

Guidelines are needed that take into account site specific issues. In other words, the guidelines should not only identify conditions where a safety feature is needed, they should preferably identify the more appropriate feature for that site. For example, both redirective and nonredirective operational crash cushions are available; at some sites, one type will be more appropriate than the other. There are various types of end treatments for guardrail and one design may be more appropriate than the others, depending on site conditions. The inappropriate use of a highway safety feature at a particular site can be detrimental to the overall safety of the roadway.

Also, there is an absence of objective guidance for upgrading existing systems, and for design deviations or field modifications. There is a general policy of replacing in-kind those features requiring repair or rehabilitation, even though the feature may be substandard.

Objectives

To develop objective guidelines for the selection, installation, and maintenance of multi-service level highway safety features. The guidelines should include recommendations concerning upgrading/retro-fitting substandard systems when repair or rehabilitation is required. The guidelines should take into account roadway and traffic conditions, and characteristics (impact performance, life-cycle costs, durability, maintainability, etc.) of candidate safety features.

Related Work

The current NCHRP Project 22-9, "Improved Procedures for Cost-Effectiveness Analysis of Roadside Safety Features," is scheduled for completion on November 30, 1993, and has as its basic objective the development of improved microcomputer-based cost-effectiveness analysis procedures. These procedures will likely play a major role in development of the needed guidelines outlined in this problem statement.

AASHTO developed "Guide Specifications for Bridge Railings" in 1989. The specifications contained, among other things, selection guidelines for bridge railings, taking into account site and traffic conditions. However, further analysis of the guidelines found errors in the procedures used in development of the guidelines. Furthermore, these guidelines were intended for bridge railings only, and are not applicable to other types of safety features, such as guardrails, median barriers, crash cushions, etc.

The AASHTO "Roadside Design Guide," published in 1989, contains very general selection guidelines for roadside safety features, primarily those used on high-speed, primary roadways. The Guide does not address the multi-service level issue that will arise as a result of publication of NCHRP Report 350.

Urgency

This research is of immediate need. Transportation agencies are faced with difficult decisions regarding selection and upgrading of highway safety features. These features are often cited in tort claims as being substandard, improperly installed, improperly maintained, etc. The availability of an array of multi-

service level safety features, each having specific characteristics, makes the decision process more difficult.

Cost

Approximately \$500,000

User Community

FHWA, AASHTO and other transportation agencies at all levels.

Implementation

Results of the research could be published in a user's manual containing guidelines that could be easily adopted by transportation agencies (federal, state, and local). A final report should also be available to document the procedures and assumptions used in development of the guidelines. As such, the results would be available for immediate use for purposes of developing policies within the agencies. Another option would be to publish the results as an addendum to the 1989 AASHTO Roadside Design Guide. The Guide was published in a loose-leaf format to allow updates of the type envisioned herein.

PROBLEM #17: PERFORMANCE OF ROADSIDE BARRIERS

More motorists are killed annually as a result of impacts with guardrails and guardrail terminals than any other man-made roadside obstacle except utility poles. This is particularly disconcerting since the primary reason for installing a guardrail is to reduce accident severity. The reasons for such a large number of "failures" are largely anecdotal and not the result of a comprehensive monitoring and evaluation effort. A systematic approach towards quantifying the performance of existing installations, as well as experimental barriers and terminals, is sorely needed.

Objectives

The objective of this study is to design and implement a comprehensive review of barrier performance along selected highway facilities in several states. The study would focus on longitudinal barriers and their end

treatments, and would collect data on both reported and unreported accidents.

Proposed research is as follows:

1. Literature review. The current literature will be surveyed to identify results from recent or ongoing studies (FHWA, NCHRP, state level, large metropolitan, etc.).

2. Identify states/data bases. A critical part of the process is to identify States and/or data bases that can participate in the process. For example, the five states in the Highway Safety Information System (HSIS) would be potential candidates. Michigan is a state with a guardrail inventory and is included in HSIS.

3. Determine data to be collected. Data should concern performance of the barrier, the trajectory of the vehicle, and the injury to the occupants. So that the process is manageable, the items to be collected will be rigorously reviewed.

4. Select sites. Sections of roadways within participating states will be identified. The sites should include various types of roadways and barriers.

5. Train data collectors. Special follow-up accident investigators will be trained to supplement the data from police reports. Forms will be developed and persons trained.

6. Collect data. Following the development of appropriate protocols, data will be collected for accidents on barriers of interest. Samples of 1,500 to 2,000 cases are recommended.

7. Analyze the data. Data collected will be analyzed both clinically and statistically to compare performance of different barriers and end treatments.

8. Prepare draft and final reports. A draft report will be prepared and reviewed and suggested changes incorporated into the final report.

Cost

\$500,000 for 36-60 months.

PROBLEM #18: DEVELOPMENT OF VEHICLE PERFORMANCE CRITERIA FOR SAFETY APPURTENANCE EVALUATION

Out-of-control trajectories of errant vehicles following impacts with roadside safety hardware often lead to serious secondary collisions. Longitudinal barriers are designed to change the vehicle's direction with minimal change in velocity. Breakaway signs and luminaire

supports are required to satisfy demanding velocity change guidelines. The basic philosophy has been to dissipate as little energy as possible during the collision.

Some analyses of longitudinal barrier collisions have shown that most of the serious and severe injuries suffered by vehicle occupants are caused by events that occur after being redirected from a longitudinal barrier. The drivers of these vehicles have presumably lost control of the vehicle and are not able to regain control before striking another fixed roadside feature or vehicle. Breakaway pole and post accidents can often result in severe secondary collisions when the vehicle strikes another fixed object after its interaction with the breakaway appurtenance. Such scenarios raise questions about whether redirecting vehicles is always the best strategy for reducing occupant injury.

Objectives

To investigate the effectiveness of safety hardware which function by minimizing velocity reduction and the amount of kinetic energy dissipated. Research proposed:

1. Review NCHRP Reports 230 and 350 and specify the criteria which meet the project objectives. Redirection and energy dissipation criteria will be of particular importance.
2. Identify novel design concepts which would result in controlled velocity reduction during impact events.
3. Perform simulation and analytical analysis on the design concepts to determine their feasibility.
4. Fabricate up to two of the concepts identified as feasible.
5. Test and evaluate the design concepts with particular attention devoted to the trajectory of the vehicle after its interaction with the safety appurtenance.

Cost

\$300,000 for 24 months

PROBLEM #19: DEVELOP IMPROVED ACCIDENT REDUCTION FACTORS

One of the factors which directly affects outcome of a benefit/cost analysis is the reliability of the estimate of the benefits of the proposed safety improvements. At the present time there are some studies available, based on very limited data, that may or may not reflect the real-world situation. Further evaluation of the reliability of

existing studies or development of new reduction factors is needed.

Objectives

To validate or develop reliable accident reduction factors for use in accident analysis, which reflect the influences of highway features through the following research:

1. Compile the accident reduction factors currently being used by agencies and review literature to determine other factors. Evaluate the data sources, statistical methods, and categorization of these factors.
2. Develop categories of accident reduction factors that would support broader applications. These categories should consider stratifications by roadway type, region, facility speed, area types, and other factors.
3. Determine the level of detail needed for the types of accident reduction factors.
4. Recommend a methodology for determining what category, or combination of factors, should be used in benefit/cost analysis for multiple treatments.
5. Gather project evaluation data needed to develop accident reduction factors from available sources. Develop a database and establish procedures for continual updating.
6. Develop accident reduction factors (including ranges) using appropriate statistical methods. Compare the values derived to those from previous efforts to assess viability.
7. Submit results for review by potential users to determine adequacy. Consider modification of the categories or reassess the factors where necessary.
8. Prepare final report and disseminate information through appropriate channels.

Cost

\$300,000 for 2 years.

PROBLEM #20: SAFETY EVALUATION OF WORK ZONE TRAFFIC CONTROL DEVICES

A critical element in efforts to rebuild the nation's highway infrastructure under traffic is the assurance of acceptable safety for the traveling public and constructions workers. To accomplish this, complex traffic control plans, utilizing large quantities of temporary traffic control devices (TCDs), are typically implemented in highway work zones.

A wealth of recent research is available documenting the problem of work zone traffic accidents and describing the traffic control characteristics of typical work zone TCDs. Because of the restricted space available in work zones and the close proximity of traffic to the construction activity, work zone TCDs are often struck by errant vehicles. Recent tests, reported by the New York State Department of Transportation, and limited unpublished tests by others, indicate that many typical devices may not perform acceptably if impacted, and present unacceptable and unnecessary risks both to workers and the traveling public.

Objectives

To determine the scope and magnitude of traffic safety problems created by impacts with work zone traffic control devices and to develop test procedures, performance criteria, and hardware to solve identified problems. Proposed research is:

1. Review available work zone accident data, test results, and other available information to determine whether impacts with temporary traffic control devices constitute a significant safety hazard in highway work zones.
2. Develop proposed test procedures and performance criteria to evaluate the impact performance of work zone traffic control devices.
3. Apply the test procedures and performance criteria to a range of typical temporary TCDs to determine which types of devices appear to perform acceptably as well as those that present unacceptable risks. Determine specific traffic control needs for which acceptable temporary devices are not available.
4. Develop and evaluate temporary TCDs to meet any situations identified in Task 3 for which acceptable devices are not currently available.

Cost

\$200,000 for 24 months.

PROBLEM #21: DEVELOPING MEASURES OF EFFECTIVENESS FOR SAFETY MANAGEMENT SYSTEMS

The Intermodal Surface Transportation Efficiency Act (ISTEA) requires the development of several management systems, including a Safety Management

System (SMS). A critical aspect of a SMS is determination of program effectiveness. This information will be used by safety managers to determine how well safety goals are being met. What are appropriate measures of effectiveness for a SMS? How are measures of effectiveness incorporated into a SMS? These questions may involve programs, actions, and policies related to the vehicle and driver as well as the roadway.

Objectives

To identify the critical elements of a safety management system including appropriate measures of effectiveness. Achievement of this objective will assist in the allocation of resources and continuing self-appraisals. Suggested research:

1. Develop a synthesis of State practices and identify elements of a Safety Management System, including measures for each element.
2. Determine other confounding factors and their measurement that may contribute to safety improvement or decline outside the scope of the Safety Management System, such as demographic changes and economic fluctuations.
3. Relate the effectiveness measures between roadway, vehicle, and driver elements.
4. Identify improved surrogates for total system-safety performance. This surrogate could relate to only one contributing element or all elements.
5. Develop necessary documentation to assist States in incorporating appropriate measures of effectiveness in the Safety Management Systems.

Cost

\$275,000 for 18 months.

PROBLEM #22: ASSESS THE APPLICABILITY OF BENEFIT/COST MODELS TO SUPPORT SAFETY MANAGEMENT SYSTEMS

There are numerous B/C models available to assist designers, planners, and administrators in making specific safety related decisions. The SMS requires "safety" to be incorporated into the decision making processes at all levels. This includes design, construction, operation, and maintenance. A comprehensive SMS would also include driver and vehicle related elements.

Objectives

To evaluate benefit/cost models as they relate to the requirements of a Safety Management System (SMS), and to develop those benefit/cost models that appear to have the most promise to meet expanded SMS applications. For example, maintenance related B/C procedures would be assessed to determine their safety management impacts. Evaluate the merits of the existing B/C models as they relate to the requirements of a SMS. List and describe those that appear to offer the best chance of supporting a SMS. Identify any missing data or B/C model components that may be necessary, and make recommendations for the development of them. This can be accomplished by the following tasks:

- Review existing literature and survey states for current methods of making safety related decisions based on B/C procedures.
- Compare existing procedures to the requirements of a comprehensive SMS and conceptualize other needed applications, sources, and data format.
- Develop new procedures and information, as needed, in prototype form, including the appropriate linkages to an SMS.
- Test the functionality of the procedures in a typical transportation agency to assess its practicality. Revise procedures on the basis of feedback from agency personnel.
- Document the efforts of the study and prepare appropriate guidelines and user manuals to facilitate implementation.

Cost

\$250,000 for 24 Months.

PROBLEM #23: HIGHWAY SAFETY FEATURES INFORMATION DISSEMINATION AND TRAINING MATERIALS

There are many problems in installing and maintaining highway safety features. Some of these problems could be alleviated by training materials and dissemination of these materials. Highway agencies and industry have created videotapes and other training materials that aid in the installation and maintenance of highway safety features. There is a need to identify the materials that exist and disseminate a catalog of these materials to all highway agencies and industry.

Objectives

To develop a library listing of available resources and training materials for installing and maintaining highway safety features, to categorize these resources by device type, and to disseminate the library listing. Suggested research is:

1. Survey all agencies and industry for available materials.
2. Catalog the material.
3. Prepare final report and disseminate the library listing.

Cost

\$10,000 for 12 months.

PROBLEM # 24: COST EFFECTIVE ANALYSIS PROCEDURES

The safety management emphasis requires that cost-effectiveness analysis be used for many applications, some of which may be new or expansions of current applications. The current methods of analysis may or may not be adequate to meet the needs of all the applications. Existing procedures can possibly be improved or new methods of cost-effectiveness may be required. Improved data may also be necessary for existing procedures. The need exists to evaluate the appropriateness of existing cost effectiveness methods for different roadside applications to determine whether new procedures and new data are required.

Objectives

To evaluate existing processes for cost analysis to assure that proper and effective analysis methods are considered, and to develop new methods, if required. To further determine when non accident costs methods/analysis are applicable. To develop guidelines for conducting sensitivity analysis that considers data inconsistencies, unknowns, or other factors inherent with accident data. The guidelines and synthesis applications should be presented in a format conducive to a users manual. Proposed research:

1. Identify the various applications of cost-effectiveness analysis that may be required in a Safety

Management System. Conduct a survey of selected States to identify the applications.

2. Review existing cost effectiveness analysis procedures as to their suitability and applicability to the identified applications. For each identified application, recommend the cost effectiveness procedure deemed most appropriate. For applications that cannot be adequately addressed with existing cost effectiveness procedures, develop others that are more appropriate.

3. For each identified application and associated cost effectiveness procedure, determine the data needed for the analysis, the availability of the required data, and the reliability and validity of the available data. Conduct sensitivity analysis of the cost effectiveness procedures and data elements. Identify data gaps and required improvements.

4. Prepare an interim report which will include:

- Summary of findings from Tasks 1, 2, & 3.
- A proposed plan outlining the work needed to fill the data gaps and incorporate the refined improvements for existing cost effective procedures, and work required to develop new cost effective procedures. The interim report will be reviewed and approved prior to proceeding with Phase II.

5. Conduct the research in accordance with the approved work plan.

6. Evaluate the feasibility of developing an expert system for use with cost effectiveness analysis in Safety Management Systems.

7. Prepare final report which will include:

- A technical report summarizing results of the study.
- A users manual outlining the applications and the associated cost effectiveness procedures.

Cost

\$275,000 for 30 months.

PROBLEM # 25: TECHNOLOGY TRANSFER PROCEDURES FOR INSTALLATION, MAINTENANCE, AND DESIGN MODIFICATION FOR HIGHWAY SAFETY FEATURES

Many agencies do not have good formal or informal procedures regarding interaction, information exchange, or technology transfer among design, construction, and maintenance activities. For example, critical design changes for a guardrail end may not be disseminated to maintenance personnel, who are responsible for the repair of these devices. Another example is the lack of

communication among field personnel to report deficiencies or discuss remedies in the construction and maintenance of these features. Information exchange is beneficial for ensuring safe installations and reducing overall costs.

Some agencies have good procedures for information exchange, and this results in properly installed and maintained highway safety features. A need exists to identify these good practices and disseminate these practices to all agencies.

Objectives

To improve the quality of the installation and maintenance of Highway Safety Features. Suggested research:

1. Survey technology transfer practices;
2. Interview those that have good and innovative practices;
3. Develop a guide for implementation of good practice; and
4. Disseminate guide to all agencies.

Cost

\$25,000 for 12 months.

PROBLEM #26: DEVELOPMENT OF NEW CRASH TESTING TECHNOLOGIES

Most of the basic techniques used in crash testing roadside safety appurtenances are rooted in the technology of 30 years ago. The basic cable-guidance/cable-towed method of vehicle guidance has been a standard testing technique for many years. This technique has, without doubt, been very effective in the past decades in terms of simplicity, cost, and utility.

As the roadside safety field has matured, however, the types of testing methodologies has limited progress. Current vehicle guidance methods, for example, cannot effectively replicate many common accident situations. Side impacts with fixed roadside objects, non-tracking pre-impact vehicle trajectories, and driver braking and steering prior to impact cannot be explored using the standard techniques. These types of accidents, however, comprise the majority of real word accidents. Side impacts account for almost 30 percent of the fixed roadside object accidents, non-tracking accidents account for approximately 50 percent of all longitudinal barrier

accidents, and drivers are involved in avoidance maneuvers in the a majority of accident cases. Before these issues can be effectively addressed, new testing technologies must be developed.

Objectives

To investigate what new technologies could be effectively utilized in roadside safety appurtenance testing. Technologies which can provide more flexible and realistic testing techniques, while remaining relatively cost effective, should be identified and developed. Proposed research path:

1. Identify existing technologies which have applicability to roadside safety hardware crash testing.
2. Evaluate identified technologies in terms of availability, effectiveness, future obsolescence, durability, and cost.
3. Procure at least two promising systems and evaluate test results, cost, data accuracy, etc. using these systems to test results, cost, data accuracy, etc. using existing testing technology.
4. Recommend changes to testing technology.

Cost

\$400,000 for 24 months.

PROBLEM #27: DEVELOPMENT OF A STOCHASTIC ACCIDENT COST AND BENEFIT ANALYSES TOOL

There are many factors used in the analyses of the costs and benefits associated with safety projects and programs. Many of the factors have broad ranges of uncertainty associated with them. For example, accident histories reflect the cumulative result of many random events; there is no agreement on the value of a life to be used in computations; and accident reduction factors reflect the effects of many situational factors. Given this uncertainty exists, it is unreasonable that safety analyses be conducted in a deterministic mode based upon single values of the input data items.

Other research (NCHRP 2-18) has shown the feasibility of applying stochastic methods to consider the effects of the uncertainty and to generate a mean outcome as well as the standard deviation, range, and distribution associated with the mean. The stochastic models provide enhanced analyses information by using

the mean, standard deviation, range, and distribution of the values for each of the factors considered in the model. By repetitive simulations, the full range of values for each factor is considered in combination with all other factors. This additional information provides the basis for better understanding the risk in decisions, judging the relative importance of factors, and focusing on the sources of uncertainty.

Objectives

To develop a model for analyzing accident costs and benefits for a range of applications that addresses the uncertainty associated with the various factors that are considered in the analyses. The model should be applicable to various types of roadway and roadside safety issues and provide a range on the outcome to readily permit assessment of the uncertainty effects. The research should also include the development of guidelines for the application of the model.

The need exists to develop a stochastic model for application to highway safety analyses. The development of such a model would provide an enhanced capability in an Highway Safety Management System (HSMS) to consider the costs and benefits associated with a full array of safety management actions at both the site and system levels.

To develop a stochastic accident costs and benefits model the following tasks would be necessary:

1. Formulate the functional relationships between the various factors that need to be considered.
2. Develop, by consensus or other appropriate methods, the mean, range, and form of the distribution for each factor.
3. Develop a stochastic model on a PC platform to provide a flexible means to input functional relationships and data, conduct the simulation runs, and present the results.
4. Demonstrate the applicability of the process through a series of case studies that reflect different applications within an HSMS.
5. Develop users guides and reference materials to facilitate expanded use of the software in an HSMS.
6. Prepare a final report documenting the efforts of the study and highlighting further applications and development of the tool.

Cost

\$300,000 for 24 months.

A2A05 COMMITTEE ON LANDSCAPE AND ENVIRONMENTAL DESIGN

The research problem statements appear in the order of priority established by the committee.

PROBLEM #28: DESIGNATION CRITERIA FOR SCENIC BYWAYS

The scenic byways program is emerging into a system of highways that have inherent scenic qualities that sets them apart from other routes. The states are establishing and expanding scenic byways programs that incorporate varying criteria and standards. In as much that the states are independently developing designation criteria, there is no assurance that the designated routes will possess the same or similar visual experiences or standards. Once designated, these routes are to present the motorist with unique visual and scenic experiences. The byways that are designated using the varying designation criteria established by the states may or may not meet the motoring public's expectation.

Objectives

The proposed research will produce minimum designation criteria for scenic byways that incorporate planning, safety, design standards and other pertinent elements that should be inherent in scenic byways.

Related Work

The National Scenic Byways Study conducted by FHWA and reported to Congress in February 1991.

Urgency

High. Application of designation criteria is essential for the Scenic Byways Advisory Committee to use in the eligibility and prioritization of candidate roads in accordance with the Intermodal Surface Transportation Efficiency Act (ISTEA).

Cost

\$200,000

User Community

This problem statement will be of use to state transportation agencies, AASHTO and FHWA.

Implementation

The designation criteria would be used by state transportation agencies to determine applicability of candidate roads for scenic byways designation. Similarly, the Scenic Byways Advisory Committee could use the national designation criteria as eligibility and priority criteria for candidate roads.

Effectiveness

This research effort is focused on identification and comparison of criteria and standards being used by federal, state and local governments as well as those used by private sector organizations. It will examine the visual quality characteristics associated with the scenic and aesthetic quality of unique landscape components and will identify acceptable criteria for identifying the scenic quality of scenic byway corridors. Consideration will be given to the coordination of safety with the aesthetic values of routes having scenic qualities as well as geometrics and specific road features and elements that should be associated with routes being considered for designation.

PROBLEM #29: MANAGEMENT AND OPERATING STANDARDS FOR SCENIC BYWAYS

A key problem for many states and federal agencies is balancing the desire for pleasing visual aesthetics with the requirement for safety in the design of scenic highways when determining what standards are appropriate for their management and operation. Once designated, scenic byways should maintain the qualities and elements that were important to their initial design. There are various activities associated with the operation and management of scenic byways that could affect these

qualities. Standards have not been developed to identify the actions or activities that can be undertaken along scenic byways without jeopardizing scenic integrity.

Objectives

The proposed research will identify the types of controls that should be in place to protect scenic byways. It will also examine the changes that roadside vegetation, maintenance activities, signing, land use, overlooks, interpretive centers, waysides and rest areas have on scenic quality of byways.

Related Work

The National Scenic Byways Study conducted by FHWA and reported to Congress in February 1991.

Urgency

High. Management and operating standards are required to ensure that designated scenic byways and related corridors are not destroyed by application of generic road maintenance activities or the introduction of non-compatible adjacent uses.

Cost

\$300,000

User Community

This problem statement will be of use to state transportation agencies, AASHTO and FHWA.

Implementation

The management and operating standards would be used by state transportation agencies to determine allowable and compatible maintenance activities and corridor modifications.

Effectiveness

This research effort is focused on the development of management and operating standards that should be

used by state and local governments to control the scenic integrity of scenic corridors. It will examine the impact increased traffic volume has on qualities that are viewed as unique and sensitive elements of byways. The research will examine maintenance practices and right-of-way modifications to determine their effect on scenic character.

PROBLEM #30: COST EFFECTIVE DESIGN, CONSTRUCTION AND MAINTENANCE CRITERIA FOR ROADSIDE VEGETATION

Landscaping of the roadside corridor is an integral component in the development of transportation systems. Landscaping provides physical (erosion control, sediment trap, nesting environments) and aesthetic (visual enhancement) value to the motoring public, the natural environment and the neighboring community.

There has, and continues to be, much debate over the use of native plant material or introduced, exotic plant material to revegetate roadsides. There has also been much debate over the care required to protect and nurture planted material on transportation corridors. Much of the available knowledge gained in transportation corridor landscape design and maintenance is informal, undocumented and localized. There is a need to document plant material design, construction and maintenance criteria.

Objectives

The proposed research would create a palette of useful plant material, design considerations and restrictions, construction techniques and maintenance requirements by climatic zone.

Plant material design would focus on the criteria required for the selection of suitable plant types for roadside conditions. The design research would catalog compatible plant species into five major groups; trees, shrubs, flowers, grasses and other (vines, groundcover, etc.). Design considerations such as color, texture, growth rate, ultimate size, massing and offsets from the travelled pavement would be factored. An evaluation of the existing use of plant material would provide insight into the success and development of various plant types.

Construction techniques and requirements would analyze the supply and planting of various materials including stock availability, hardiness compatibility, sourcing, care during shipping, storage and planting.

Maintenance requirements would investigate the long-term effort required to sustain plant material in a

roadside environment and ensure its health and development to the original design intent. This would include an identification of plant material needs in terms of temperature, tolerance to sun/shade, watering, fertilizing, competitive growth characteristics and an overall maintenance rating for various plant types.

This research would be broken up into designated climatic, geographic and accepted hardiness zones across the continent.

Key Words

Plant material classification.

Related Work

- Xeriscape 25, Re-landscaping of the I-25 Corridor Through Denver, Colorado (CDOT, Dist. 6, J. Hughes)
- Aesthetics and Visual Resource Management in the Highway Development Process, Jones and Jones, Seattle, Washington.

Urgency

Moderate to High. Documentation and application of design criteria is needed by the various state transportation agencies. A compendium of plant material relating to design, construction and maintenance specifically related to roadside conditions has been needed for a long time.

Cost

\$450,000

User Community

This research will be of use to state transportation agencies. It will be of particular use to landscape architects, environmental designers, nursery suppliers and landscape contractors as well as state roadside maintenance staff at the supervisory and working levels.

Implementation

The design criteria would be used by state transportation agencies to develop design standards for transportation

corridors. The construction and maintenance findings would be of use in the implementation and care of landscape designs.

Effectiveness

This research effort would be used as constructive, documented design, construction and maintenance guidelines to develop roadside environments that mitigate engineering activities. The use of landscape architecture design principles is an acknowledged mitigative measure when dealing with new construction. Having a compendium of available, hardy plant material is another design, construction and maintenance tool that is vital to plant success and ultimately the success of any construction undertaking.

PROBLEM #31: EFFECTIVE UTILIZATION OF NATURAL FORCES AND ECOLOGICAL PRINCIPLES IN DEVELOPING ROADSIDE VEGETATION MANAGEMENT STRATEGIES AND PROCESSES

Transportation rights-of-ways have traditionally been maintained on an annual basis by mowing and chemical spraying. These methods are often environmentally insensitive, increasingly costly, and sometimes unsafe. Human and financial resource reductions have resulted in a decreased ability to continue with this process. In addition, environmental concern over the management of public lands has created a pressure to explore different methods of controlling vegetated rights-of-ways.

Objectives

The proposed research would identify alternate natural methods and sound ecological principles to use in roadside management. The problem could be potentially alleviated by understanding and assisting re-naturalization processes, stabilizing naturally-occurring plant communities and through the use of ecological management principles and strategies.

Key Words

Naturalization, natural plant communities.

Related Work

RR-243, Review of Existing Vegetation Management Practices and Identification of Future Research Needs, Ministry of Transportation, Province of Ontario, 1990.

Urgency

Moderate to High. Transportation agencies are struggling with reduced resources, both human and financial. Often the first item to be constrained, roadside management needs to develop proactive alternative approaches to traditional maintenance standards.

Cost

\$500,000

User Community

This research will be of use to state transportation agencies. It will be of particular use to state roadside maintenance staff at the supervisory and working levels.

Implementation

A review of natural plant growth communities, ecological principles and strategies along with a detailed economic comparison would give transportation agencies available data and comparisons to make informed management decisions regarding roadside vegetation.

Effectiveness

The economic and societal cost of continuing to maintain roadsides with labor-intensive mowing practices and costly, environmentally-questionable herbicide and pesticide spraying programs is continually being questioned by an informed public as well as efficiency-minded transportation managers. Alternate methods of achieving sustainable, low-maintenance roadsides are very desirable.

PROBLEM #32: ANALYSIS OF VISUAL ASSESSMENTS ON TRANSPORTATION PROJECTS

Transportation projects affect the visual environment. Although several methods have been developed to

determine and identify the significance of visual issues on a project, there are currently no methods to relate the level of effort to produce an adequate visual analysis within the scope of the project. There are also problems of standards (reliability, validity, etc) with visual impact assessment (VIA), various simulation methods and the decision of whether or not the public should be consulted for reaction to projects.

Objectives

This proposed research will provide a review of global VIA methods, analysis and findings, as well as establish standards for reliability, validity and utility. The research will also test VIA methods against the standards and allow input from users and viewers.

Key Words

Visual impact assessment, visual simulation.

Urgency

Moderate to high. This is a well researched area, particularly since the advent of high-technology hardware and software. The problem seems to be that most research in this field is project-specific and done in relative isolation.

Cost

\$300,000

User Community

This research will be of use to state transportation agencies and urban design groups.

Implementation

This proposed research will be used to assemble, compile and evaluate fractured research in this field. Various VIA methodologies will be tested against developed standards, with provision for new visual simulation methodologies and techniques to be researched.

Effectiveness

Completed research on visual impact assessment will evaluate the various methodologies and hopefully derive a standard operating procedure. Incorporation of transportation users and viewers into the evaluation will produce realistic needs and relevancy.

PROBLEM #33: DEVELOPMENT OF STANDARDS OR MEASURES FOR ASSESSING EFFECTIVE WETLAND CREATION AND MITIGATION

Regulatory review of transportation projects and federal policy require projects to contain mitigative measures for wetland areas or a "no net loss" policy which sometimes involves wetland creation. Often these projects are modified—to meet external requirements with no assurances of the quality or success of the end product. In other words, did it work, were the measures successful or what went wrong?

Objectives

Proposed research in the development of standards or measures for assessing the effectiveness of wetland creation or mitigation would provide acceptable standards to measure the effectiveness of projects and give measurable criteria for post-construction disagreements between the proponent and the reviewing agency.

Urgency

Moderate to high. Wetlands are a highly topical issue where most research has focused on the physical parameters of wetlands. A formalized approach to the development of measurable criteria to assess effectiveness is vital to the success of mitigation/creation. Measurable end results are also a valuable tool for designers to use on subsequent projects (ie; what worked well and what did not).

Cost

\$200,000

User Community

This research will be of use to state transportation agencies, AASHTO, FHWA and various regulatory and non-regulatory review agencies.

Implementation

The proposed research could be implemented as a post-construction sign-off or review by construction staff. Measurement standards could be used to assess the effectiveness of the mitigative/creation measures and be documented in the project's construction report.

Effectiveness

Standards and measurable criteria will improve the design, construction and operation of wetland creation and mitigation. There will be a way to objectively assess the measures implemented and determine if they were successful or require remedial action. The feedback to design will improve future projects.

PROBLEM #34: AESTHETIC CONSIDERATIONS IN THE LOCATION OF HIGHWAY CORRIDORS AND ENGINEERING, INCLUDING CORRIDOR ELEVATION, SITE GRADING AND DRAINAGE

The physical location of transportation corridors in the landscape, including their horizontal and vertical alignment, grading and drainage has been a topical subject since the interstate system began and can be traced back to the first parkways. While research has concentrated on visual impact assessment, viewsheds and the aesthetic impact on specific landscapes, very little formal integration of aesthetics into everyday design of transportation projects has been mandated.

Sensitive locations, such as the I-70 Vail Pass in Colorado and the I-90 Seattle Urban Corridor in Washington State, treat aesthetic input as a mandatory requirement. This is due, no doubt, to public pressure over the drastic changes highway construction will create to valued landscapes.

Objectives

A recognition and integration of aesthetic design principles is needed at the technical level of transportation

planning and design. Research of applicable design principles and the development of a method of integration is a first step.

Key Words

Aesthetics, integrated visual design.

Urgency

Moderate to high. The value of aesthetic design has often been underplayed on routine transportation projects. Aesthetic design principles as they are applied to alignment, grading and drainage and if they are integrated into civil engineering design at the appropriate time do not necessarily cost more, do not create more work, but rather offer a different approach to solving the myriad of detail design problems facing Civil Engineering designers.

Cost

\$150,000

User Community

This research will be of use to state transportation agencies, AASHTO, FHWA and the transportation consultant industry at large.

Implementation

The proposed research would be implemented by state transportation agencies as an integral component of their transportation planning and design process on all projects.

Effectiveness

Aesthetic design principles are an influence on the civil engineering component and often offer a different solution to a technical problem with grade, elevation or drainage. Aesthetics can improve the functional harmony of highways, create sculptures out of civil works and integrate civil works quietly into the landscape. The result is an improved end-product at little-or-no additional cost.

PROBLEM #35: AESTHETIC CONSIDERATIONS IN THE DESIGN, LOCATION AND LANDSCAPING OF NOISE WALLS

Noise walls satisfy a need, that being to reduce corridor noise adjacent to sensitive receiver areas. Noise walls also create a visual design statement and can become integrated highway fabric, sculptural works of art or visual eyesores and vertical walls that prohibit lateral viewing and contribute to the sense of transportation corridors as tunnels. Often the physical location and integration of noise walls is not considered and grading, drainage and landscaping are not effectively utilized to create an integrated product.

Objectives

Research into the identification, recognition and integration of aesthetic design principles in noise barrier design is needed at the technical level of transportation planning and design. Research of applicable design principles in noise barrier design and a method of integration into the noise barrier design process is a first step.

Key Words

Aesthetics, integrated visual design.

Urgency

Moderate to High. Aesthetic design principles as they are applied to noise barrier design do not necessarily cost more, do not create more work, but rather offer a visual factor to consider when designing noise walls that will have a significant impact on the landscape for both transportation user and adjacent resident.

Cost

\$100,000

User Community

This research will be of use to state transportation agencies, AASHTO, FHWA and the transportation consultant industry at large.

Implementation

The proposed research would be implemented by state transportation agencies as an integral component of their noise barrier design program and process.

Effectiveness

Noise barriers satisfy a need to reduce noise levels. They are functional and create a visual element of both the transportation corridor and the adjacent landscape. Effective design principles for aesthetic consideration would enable civil designers to create visually pleasing barriers that have a visual sense of fit while performing the function of noise reduction.

PROBLEM #36: EVALUATION OF THE USE, ECONOMIC AND AESTHETIC ASPECTS OF EXISTING HIGHWAY PLANTING

Landscaping of transportation projects has been an ongoing activity in most jurisdictions for many years. With increased need for system upgrading, many of these older plantings will be brought into conflict with highway widening, interchange development and overall system improvements (ie; utilities, freeway traffic management, etc).

Many species of plants have life spans that far exceed that of a highway. There is an opportunity to evaluate older plantings on interstate highways to determine the success and value of the planting. Landscape architects often justify woody plantings for their long-term low maintenance value, is this a fact, do woody plantings self-sustain after initial establishment?

Objectives

A research review of selected, older plantings would establish the initial costs, the long-term benefits, the successes and failures and an indication of the usefulness of highway planting over a long (20-30 year) life span.

There would also be an opportunity to evaluate the end-product to see if the original design intent was maintained and to determine what the maintenance implications were over this period of time.

Key Words

Landscape planting.

Urgency

Moderate. The relevance of this research is the fact that much of the older planting will come into conflict with system expansion over the next few years. There is a window of opportunity to evaluate this older planting, assess its effectiveness and hopefully make the results available in time to aid the next generation of landscape architects in interstate design.

Cost

\$400,000

User Community

The proposed research would be useful to state transportation agencies, AASHTO, FHWA and the landscape architectural consultant industry.

Implementation

Research findings would be used by state agencies to assess the effectiveness of landscaping. An evaluation of older plantings would be a useful design tool to the designers of current roadside development plans.

Effectiveness

A common theme in mitigative work is the desire to satisfy regulatory agencies, local governments, interest groups and the general public. The planting of trees and shrubs has long been a design tool that these interested parties see as mitigative of highway construction. There has, however, been very little follow-up on the post-construction effectiveness of this mitigation, particularly over an extended period of time. With environmental concern high on most agendas, it is imperative to know what works and what does not in terms of mitigation.

PROBLEM #37: RELATIONSHIP OF PLANT VARIETIES, THEIR PLACEMENT, AND MAINTENANCE PRACTICES RELATING TO SAFETY, VISUAL QUALITY, SURVIVAL, AND REMOVAL OF POLLUTANTS

Plant material is an acknowledged mitigative measure in highway construction. Plant material is used to provide

intangible benefits to users and adjacent residents in terms of safety (glare control, visual separation, snow control, reduction of monotony and impact absorption), visual quality (improvement of viewsheds, screening, vertical/natural form relief and enhancement of structures) and environmental improvement (increased biomass, pollutant intake, cleaner air). All of these benefits are intangible, qualitative and unmeasurable. Most are based on limited research or scientific data, some, such as pollutant intake, are extremely questionable.

Objectives

An evaluation of plant material in highway environments to determine the quantitative value of the plantings for the above benefit factors will result in more tangible reasons for planting. The objective is to review the subjective opinion and unmeasurable criteria and put some scientific fact into the benefits of planting and decisions affecting plant material.

Key Words

Plant material effectiveness.

Urgency

Moderate. Plant material has been used as a general panacea in highway construction for many years. The benefits are intangible and subjective. Tight economic times result in increased scrutiny for expenditures.

Landscaping of transportation projects needs some quantitative and objective criteria to prove its worth.

Cost

\$250,000

User Community

The proposed research would be useful to state transportation agencies, AASHTO, FHWA and the landscape architectural consultant industry.

Implementation

Derived research findings would be used by state agencies to assess the effectiveness of landscaping and to provide additional rationale for the use of plant material on highway projects.

Effectiveness

Research in this area will alleviate soft rationale and supposition for the use of plant material to create safety, visual quality and environmental improvement benefits. The use of plant material to provide dramatic benefits such as increasing overall bio-mass, improving air quality by the uptake of pollutants and reducing roadside monotony should be based on fact and hard research rather than good feeling and hearsay.

A2B02 COMMITTEE ON RIGID PAVEMENT DESIGN

The research problem statements appear in the order of priority established by the committee.

PROBLEM #38: DETERMINATION OF THE EFFECTS OF CURLING AND WARPING STRESSES ON THE DESIGN OF CONCRETE PAVEMENTS

There are some design procedures for concrete pavement which use curling stresses in addition to load stresses. To accurately reflect field conditions, these analyses also should incorporate warping stresses. Warping is the upward concave deformation of a concrete slab due to variations in moisture content with depth of the slab. Warping results in loss of support along slab edges and also results in increased compressive stresses at the bottom of the slab because the weight of the slab restrains the upward movement of the slab. Curling refers to slab behavior due to variations in temperature. During the day, when the top of the pavement is warmer than the bottom, tensile restraint stresses develop at the bottom of the slab. Conversely, during the night, the temperature distribution is reversed and tensile-restraint stresses develop at the slab surface. Temperature distribution is usually nonlinear and constantly changing. Also, maximum daytime and nighttime temperature differentials exist for short durations.

Usually, the combined effects of curling and warping stresses are subtractive from load stresses because the moisture content and temperature at the bottom of the slab exceed that at the top. The differential conditions at a slab's top and bottom plus the uncertainty of the zero-stress position make it difficult to compute and/or measure the restraint stresses with any degree of confidence or verification.

Objectives

The objective of the proposed research is to develop a data base of the temperature and moisture distributions in concrete pavements and associated effects on flexural stresses. The data base would be used to more accurately model the temperature and moisture distributions through the slab and the associated flexural stresses.

Key Words

PCC pavement, curling warping, flexural stresses.

Related Work

There has been some work done in this area but the bulk of research has concentrated on the effects of curling stresses. This work should focus on the combined effects of curling and warping.

Urgency

The results of this work would be incorporated into concrete pavement design procedures to more accurately reflect the thicknesses required to account for the combined effects of curling and warping on the flexural stresses in concrete pavements.

Cost

\$500,000

User Community

FHWA, AASHTO, NCHRP, state Departments of Transportation, universities, pavement consultants.

Implementation

The results of this research could be implemented through the distribution of refined pavement design manuals and computer software to state Departments of Transportation, universities, and others.

Effectiveness

The results of this research would benefit society by providing for more refined designs of concrete pavements which in turn should lead to more effective usage of available funds for pavements.

PROBLEM #39: DEVELOPMENT OF DESIGN PARAMETERS FOR PCC OVERLAYS OF EXISTING AC PAVEMENTS

In recent years various agencies have been using a procedure called "White Topping" for rehabilitation of

existing bituminous pavements. This practice has generally involved placement of five (5) to six (6) inches of PCC overlay over an existing bituminous pavement. one test section has included placement of a PCC overlay as thin as two (2) inches. Current design procedures generally are empirical and are based on limited data. Research is needed to define the design parameters of this pavement systems and to incorporate this into a rational design procedure.

Objectives

The objective of this research is to define the design parameters of a composite pavement system consisting of a PCC overlay constructed over an existing bituminous pavement over an aggregate base and/or subbase and compacted subgrade. This would include development of a procedure to determine slab thickness, the minimum practical thickness, for the PCC overlay, joint spacing requirements, the strength and extent of bonding between the existing bituminous pavement and the concrete overlay, the method of evaluating the support capacity of the existing pavement, the need for load transfer, and performance prediction models. The proposed research should include an evaluation of in-service pavements for verification and calibration of models and procedures.

Key Words

PCC overlays, AC pavements, white topping, rigid pavements.

Related Work

There have been some PCC Overlays of existing bituminous pavements built in several states including Kansas, Missouri, and Kentucky. These projects would form the basis for developing a performance data base

but would best be supplemented with the construction and monitoring of additional test sections.

Urgency

The results of this work may be developed into a design methodology which could be compiled into design manuals and/or computer models and programs which would provide the pavement designer with a more effective methodology to design for this pavement rehabilitation technique with some degree of confidence. This would ultimately improve the potential for utilization of available funds by providing the designer with additional alternatives for rehabilitation.

Cost

\$500,000

User Community

FHWA, AASHTO, state Departments of Transportation, pavement consultants, and universities.

Implementation

The results of this research could be implemented through the distribution of design manuals and computer programs distributed to state Departments of Transportation, universities, and others.

Effectiveness

The results of this research would benefit society by providing the pavement designer with a refined method for designing for this type of composite pavement structure. This should provide for improved utilization of available funding.

A2B03 COMMITTEE ON FLEXIBLE PAVEMENT DESIGN

The research problem statements appear in the order of priority established by the committee.

PROBLEM #40: UNBOUND PAVEMENT LAYER PERFORMANCE CHARACTERIZATION

Current mechanistic pavement design procedures, except in isolated instances, only consider failure (or performance) criteria for bound layers (AC, PCC or other stabilized materials) at or near the pavement surface, and at the top of the subgrade. Typical criteria are based on horizontal tensile stress or strain at the bottom of the bound layer, and vertical compressive strain at the top of the subgrade material. The former is considered to be related to cracking of the bound layer while the latter is thought to be an indicator of surface rutting. Other unbound layers in the pavement structure such as base, subbase and sometimes selected (improved) subgrade layers are typically ignored in the design process since little or no data is available on the performance of these layers in terms of repeated traffic loads. Research needs to be directed at developing usable performance relationships for unbound layers in flexible (and rigid) pavement structures, so that the entire pavement structure can be analyzed as a system.

Objectives

The research should produce performance relationships for unbound layer materials that relate distress to number of load cycles. A stress or strain based equation (or both) could be developed. These relationships may be similar to those currently used for cracking of bound materials or subgrade rutting, or they could be quite different. The relationship should be a function of the complete state of stress or strain in the material. Such relationships would allow a more balanced overall pavement system design approach when applying mechanistic techniques, i.e. all pavement components could be included in the analysis rather than the typical approach of considering bound (surfacing) layers and subgrade only. The research may involve development of improved constitutive relationships for unbound materials under repeated loads in order to more reliably evaluate the state of stress or strain in the pavement system.

Key Words

Base performance, distress, failure, aggregates, soils, stress, strain.

Related Work

- SHRP;
- Barksdale et al (stress);
- Maree et al (stress);
- Ullidtz et al (stress);
- Raad et al (shakedown);
- Thompson; and
- Witczak.

Urgency

It seems that there is generally consensus that the state-of-the-art in terms of ability to perform pavement structural analyses is significantly ahead of the understanding of material response characteristics in these applications. If this is indeed the case, then the proposed research should have a relatively high significance and priority.

Cost

\$500,000

User Community

State DOTs, AASHTO, FHWA, Forestry Service, Corps of Engineers, FAA, SHRP, NAPA, universities, etc.

Implementation

If these performance relationships are developed, they would be immediately implementable in any mechanistic pavement design application.

Effectiveness

The project has a high probability of developing useful relationships for pavement system design applications for pavements involving unbound materials as surfacing or support layers.

PROBLEM #41: GENERALIZED FATIGUE CRITERION FOR ASPHALT CONCRETE PAVEMENTS

Current mechanistic pavement design procedures consider fatigue cracking of asphalt concrete (AC) pavements in terms of maximum horizontal tensile strain at the bottom of the AC layer. In certain instances, tension may not develop in the AC (e.g. thin surfacings or AC overlays on PCC), yet cracking still occurs. Based on this, it appears that a more general distress indicator than the single strain component is desirable. Research needs to be performed that relates AC performance to number of load cycles through a distress indicator that considers the overall state of stress or strain in the AC caused by each load cycle. Some aspects of current research by SHRP using strain energy considerations is consistent with this idea, and the proposed research should be coordinated with the relevant SHRP contractors.

Objectives

A performance relationship for AC would be developed that relates distress (cracking) to number of load cycles using an indicator based on the three-dimensional stress/strain state generated in the material by each load cycle. Relationships such as those used for metals, based on "effective stress" concepts, may serve as a beginning point. Strain energy approaches also appear to have significant potential. Understanding the general failure mechanisms of asphalt concrete in pavement applications is an essential facet of the proposed research. Relationships that are developed should be sufficiently general to relate to actual loading conditions as well as "equivalent" loads (such as ESAL's).

Key Words

Asphalt concrete, fatigue, distress, failure, aggregates, soils, stress, strain.

Related Work

- SHRP;
- Little et al. (Octahedral shear stress);
- Monismith et al. (Octahedral shear stress; effective stress);

- Lytton et al. (Fracture mechanics); and
- Raad et al. (Fracture mechanics).

Urgency

It seems that there is a general consensus that the state-of-the-art in terms of ability to perform pavement structural analyses is significantly ahead of the understanding of material response characteristics in these applications. If this is indeed the case, then the proposed research should have a relatively high priority. The current status of Related Work may provide a better indication of priority requirements.

Cost

\$500,000

User Community

State DOTs, AASHTO, FHWA, FAA, SHRP, AAPT, NAPA, Corps of Engineers, Forestry Service, universities, etc.

Implementation

If these performance relationships are developed, they would be immediately implementable in any mechanistic pavement design application. Typical mechanistic analyses already produce all components of the three-dimensional stress state in the pavement so that the generalized distress indicator would be easily calculated. These components could also be used for energy approaches, if these are developed.

Effectiveness

Based on existing laboratory evidence for asphalt concrete performance in terms of strain energy concepts, the proposed research is likely to produce fairly sophisticated and usable general performance relationships for asphalt concrete pavements. This would be particularly timely, and may be applicable, with some modification to other bound pavement materials.

A2B04 COMMITTEE ON PAVEMENT REHABILITATION

The research problem statements appear in the order of priority established by the committee.

PROBLEM #42: STRUCTURE/PAVEMENT INTERFACE IMPROVEMENTS

The approach and departure slabs at the end of bridges, some box culverts, and other highway structures have a tendency for differential settlement thus attaining an elevation different than the bridge deck riding surface. This result may be from the incompatibility of materials, design of the joint between the two structure types, improper compaction practices or a combination of these. The resultant faulting at the interface joint or expansion device provides a bump or sag in the roadway that is unsafe, an inconvenience to the motoring public as well as a source of future roadway/structure failure and subsequent maintenance. Examples of this problem can be characterized by:

1. Bulging/subsiding of asphalt or concrete pavements at bridges or structures with differing construction between the roadway and structure;
2. The vehicular approach and departure from asphalt to concrete or concrete to asphalt that are noticeably distorted and in need of repair or reconstruction; and
3. New transitions between concrete bridges and asphalt or concrete pavements, initially ground to assure a smooth transition but, over time, are in need of repair or have been repaired due to pavement subsidence.

Objectives

The objective of this study is to verify the existence, magnitude and severity of the problem as well as determine the probable cause(s) of the problem whether it be due to design, materials or construction practice.

The objective can be accomplished by contacting researchers and highway agencies to determine the state of the art and identify treatments used successfully. The investigation should be stratified by geographic region, highway facility type, traffic, and other factors, including environment, that may affect performance. The ultimate objective of the study will be a synthesis report identifying successful treatments given the above parameter along with copies of plans and specifications for the recommended treatments.

Urgency

Research is urgently needed to improve safety, minimize roadway associated damage to vehicles, conserve resources, and minimize both pavement maintenance/repair efforts and associated costs.

Related Work

Several highway agencies have introduced new and innovative methods to reduce the bump at the end of the bridge. These innovations along with their associated performance should be investigated and reported in a well coordinated study.

Cost

\$200,000

PROBLEM #43: MECHANISTIC ANALYSIS FOR PAVEMENT REHABILITATION

Structural rehabilitation of highway pavements is being accomplished by various design approaches. The mechanistic approach to analyzing the load carrying capacity of existing pavements has been developed to a point but not in a format for practical application. Schemes for simulating existing pavements are over simplified in some cases and may cause errors in the stress/strain prediction of rehabilitated pavements. A modified procedure with sufficient documentation is required that satisfies a need for simplicity.

Objectives

The objective is to develop a catalogue based analysis procedure for use in highway pavement rehabilitation design. This procedure (catalog) would be based on mechanistic analysis and would encompass all types of existing pavement. The hand/cookbook type procedure should be complete and require no need for computers so that it could be easily used in small design offices.

Key Words

Pavement rehabilitation design, mechanistic analysis, pavement analysis, catalog based.

Related Activities

AASHTO will be providing the rehabilitation design chapter sometime in 1993 which will provide the designer with the ability to perform pavement rehabilitation designs.

Both NCHRP and FHWA have conducted some research towards the development of this technology. Work is underway in the LTPP program to provide the basic data needed as input to mechanistic analysis procedures.

Urgency

This study is important as the now outdated and rapidly deteriorating highway system must be rehabilitated and the finest technological innovations are warranted.

Cost

\$350,000

PROBLEM #44: MATERIALS REQUIREMENTS FOR PAVEMENT REHABILITATION

Structural rehabilitation of pavements is being accomplished by numerous techniques. Rehabilitation now includes asphalt concrete overlays and combinations of materials. These strategies may include removal and replacement, various forms of recycling, grouting and undersealing, concrete additives/asphalt binder modifiers and the use of fabrics and membranes. Materials performance criteria and strength requirements and other physical properties are not well established for many non-traditional rehabilitation concepts.

Objectives

The objective is to synthesize the expected performance criteria of materials used for pavement rehabilitation. Specific objectives will include the evaluation and reporting of existing experimental and limited use applications of new materials in pavement rehabilitation.

The resulting synthesis should contain a performance based data base along with the associated structural coefficients of the materials addressed.

Key Words

Pavement materials, rehabilitation, recycling, fabrics, additives, binder modifiers.

Related Work

Many agencies are using various new materials in pavement rehabilitation either to reduce reflection and/or fatigue cracking, to reduce the required thickness of asphalt, or to reduce the use of virgin asphalt mixtures. Recycling and the use of new materials with recycled materials is becoming commonplace. Applied research is being conducted by many states on new materials used in pavement rehabilitation. However, the required engineering properties of these new materials and their performance are not well-defined.

A significant step toward more effective and rapid transfer of innovative technology into actual practice on the nation's highways will be accomplished with the proposed Highway Innovative Technology Evaluation Center. Work identified in this proposed research study will complement the direction to be taken and information developed by the center.

Urgency

This study is considered of value and importance because of widespread interest in new materials and the increased emphasis on pavement rehabilitation. The asphalt and portland cement materials will probably be treated in SHRP but other materials will not.

Cost

\$200,000

PROBLEM #45: FAST TRACK REHABILITATION OF CONCRETE PAVEMENTS FOR HIGH VOLUME TRAFFIC

Many of the pavements on the completed portion of the urban interstate and primary system are rigid pavements. Many of these pavements are either past their original

design life or the traffic that they have carried is well in excess of what they were expected to carry. For large traffic volumes, pavement rehabilitation strategies for concrete pavements are needed. Evaluation techniques and design criteria for enhancement and prolonged pavement life are necessary. It is imperative that all techniques be considered and that life-cycle costing and pavement management techniques be applied to the rehabilitation of concrete pavements for the large volume of heavy traffic that is expected.

Objectives

The objective is to develop rehabilitation criteria for concrete pavement under heavy traffic conditions such as urban highways. Design criteria simply do not exist for the effective rehabilitation of concrete pavements for heavy traffic. The objectives might include the selection of some specific sites on the existing road network to evaluate what types of rehabilitation are cost-effective and what are not. The ongoing Strategic Highway Research Program long-term pavement performance (LTPP) monitoring should provide input to this. The rehabilitation should consider not only the increased strengthening but maintenance of the integrity, strength, and supporting characteristics of the existing concrete pavement. Existing "fast track" construction techniques need further development and the long term performance characteristics of these concrete projects need to be evaluated.

Key Words

Concrete pavement, rehabilitation, heavy traffic, concrete pavement design, life-cycle cost, concrete pavement evaluation.

Related Work

NCHRP has research in progress on the rehabilitation of concrete pavements. Likewise, there are programs underway in the FHWA administrative contract program and probably numerous projects in the S P&R program being carried out by state departments of transportation. Of particular importance is the FHWA training course on pavement rehabilitation.

Efforts currently underway in the long-term pavement performance (LTPP) program on highway pavements

should provide information on pavement performance, pavement design and pavement rehabilitation requirements which should enhance the entire pavement management and design process.

Urgency

This study is considered to be of urgent need relative to the state of the condition of many of the concrete pavements on the urban interstate and primary systems. Rehabilitation technology is necessary to provide state highway design engineers with criteria for the selection of the proper forms of rehabilitation for concrete pavements in heavy traffic areas. Because of the increased funding for rehabilitation, it is necessary that the best and most current criteria be used rather than to continue programs that may not provide the best long-term service or be the best investment of funds available.

Cost

\$250,000

PROBLEM #46: REHABILITATION OF PAVEMENTS CONTAINING GROUND RUBBER TIRES

The Intermodal Surface Transportation Efficiency Act (ISTEA) requires highway agencies to use an increasing amount of ground up rubber tires in asphalt pavements. As these pavements continue to be placed on the nation's highways, their rehabilitation will be necessitated as they deteriorate. The recycling and other rehabilitation treatments of these pavements, containing ground rubber tires, will create a problem for design and construction engineers. These problems will be magnified by the lack of knowledge and experience in evaluating the physical properties of the in-place rubber modified materials and their compatibility with existing rehabilitation strategies. Standard construction practices associated with items such as milling, hot recycling and others may have to be modified to successfully accommodate the presence of the ground rubber tires. In addition, the maintenance of asphalt pavement containing ground rubber tires may also require unique and different repair procedures and materials.

Objectives

The objective is to develop procedures to be used by design, materials, and maintenance personnel when rehabilitating pavements containing ground rubber tires. These procedures should include methods to evaluate the in-place material as well as design, construction, and rehabilitation strategies. Maintenance strategies such as pothole repair and crack sealing may also differ from standard procedures used on conventional asphalt pavements. These modified maintenance strategies should also be addressed.

Related Work

Research and new technology currently underway that deals with other asphalt binders may be applicable to

ground rubber tires. This includes information associated with the use of polymers, fabrics and other technical advices in asphalt binders.

Urgency

This study is important since the ISTEA legislation will introduce a product whose properties are not well known to the asphalt paving industry. It is therefore important for highway engineers and maintenance personnel to be aware of potential problems in order to avoid costly and misdirected rehabilitation strategies.

Cost

\$500,000

A2B05 COMMITTEE ON STRENGTH AND DEFORMATION CHARACTERISTICS OF PAVEMENT SECTIONS

The research problem statements appear in the order of priority established by the committee.

PROBLEM #47: ANALYTICAL AND EXPERIMENTAL ANALYSES OF PAVEMENT/FWD INTERACTION

The structural adequacy of pavements is routinely evaluated by utilizing testing devices such as Falling Weight Deflectometers. The response of the pavement, in terms of surface deflections due to the imparted load, are input in many backcalculated algorithms developed to determine the pavement material stiffness parameters. In the algorithms that are most widely used by the highway agencies, several assumptions are made. These are:

1. A uniform pressure distribution for the applied load;
2. Defect and crack-free pavement;
3. Static load; and
4. Linear material properties.

The loading system of any FWD should be designed so that the load transferred to the pavement is uniform. This is typically done by utilizing a composite loading plate. However, the pressure distribution is also affected by the pavement profile being impacted on. Generally, the less stiff is the pavement structure, the more nonuniform the load distribution will be. Surface imperfections such as in rutted pavements further aggravates this problem. The dynamic nature of the load in terms of the resonant frequency of the pavement structure (location of bedrock) and the duration of the impulse also interact to affect the deflection basin. Load-induced material nonlinearity is another factor of significance, especially with granular subgrades.

A survey of literature reveals that the highway agencies and researchers are concerned with the effects of these parameters on the backcalculated stiffnesses. In the research community, extremely sophisticated finite element analyses are routinely performed to demonstrate the theoretical effects of these parameters. However, as these programs are extremely time-consuming, the number of cases studied are limited. In addition, very few of these theoretical cases are validated through field tests. On the other hand, approximate solutions to these problems are often suggested. As most of these approximate solutions are not based upon a theoretical foundation, very few of them can be universally applied with success.

Objectives

The primary objectives of this study are:

1. To conduct an extensive analytical study to determine the combined effects that the parameters mentioned above may have on the measured deflection basins;
2. To design and conduct a field experiment to validate and calibrate the results of the analytical study mentioned above;
3. To determine the significance of these parameters on the mechanistic design of pavements; and
4. To develop recommendations and guidelines in terms of the operation of the FWD under different pavement conditions considering the pavement structure, levels of load, duration of impulse, etc.

Key Words

Nondestructive testing, layer moduli evaluation, dynamic loads, nonlinear behavior.

Related Work

Several theoretical studies dealing with the dynamic nature of loads and load-induced nonlinearity have been carried out. One study considering the combine effects of nonlinearity and dynamic nature of loads is available. Very recently, a feasibility study has been carried out to determine the combined effects of load-induced nonlinearity, dynamic nature of load, and load distribution under the plate. Most of these studies have been theoretical in nature and have not been field validated.

Urgency

Given the importance of data collected with FWD devices, this topic should be pursued with extreme urgency. The reasons for such an urgency can be found in the implementation statement below.

Due to the urgency and need for such an study, this can be considered as the research statement with top priority for Committee A2B05.

Cost

\$475,000

User Community

The FWD device is extensively used by practically all federal and state agencies. Therefore, this problem statement should be distributed as widely as possible. Certainly the AASHTO and the FHWA should receive this problem statement.

Implementation

The evaluation of pavements for structural adequacy and for assessment of future rehabilitation needs is highly dependent upon the adequacy of the nondestructive testing procedures and analytical methods for layer moduli backcalculation. The development of improved and more reliable techniques would provide highway engineers with means of determining the rehabilitation design of pavement structures prior to the development of excessive distress or deterioration. This problem statement is particularly timely in implementing some of the objectives of the ISTEA.

Effectiveness

This problem statement impacts the society significantly in terms of best use of the pavement maintenance and rehabilitation funds. Better understanding and more effectively utilizing the FWD device data in the design and rehabilitation strategies would permit that highway agencies to optimize their funds.

PROBLEM #48: EVALUATION OF PAVING LAYERS WITH NON-DEFLECTION BASED METHODS

The most widely-used devices for evaluating paving layers are deflection-based devices such as the Falling Weight Deflectometers. The FWD's are usually utilized to characterize the effective stiffness of different paving layers under simulated loads of up to 25 kips. However, it is typically known that the deflection basins are more sensitive to the stiffness of lower paving layers (especially subgrade) than the upper paving layers. As the paving layers become thinner, the determination of their stiffness becomes more difficult. Therefore, even though

the FWD device may be a reasonable tool for pavement design, it may not be as desirable as a diagnostic tool for paving layers.

Several emerging technologies have been under development in the past few years. The ground penetrating radar (as a network level qualitative tool) and wave propagation methods (as a project level quantitative tool) are two examples of these technologies. These two tools have been under development and automation by SHRP. Based upon preliminary field tests, both devices are feasible tools for pavement evaluation. However, the limitations and usefulness of them have not been fully studied.

Objectives

The main objective of this study is to determine the limitations and usefulness of these two technologies through well-designed and systematic field and laboratory studies.

In particular the goals of this study would be:

1. To theoretically assess the ranges of flexible and rigid pavements where these tools would be effective;
2. To design a field experiment to test these ranges; and
3. To develop protocols and recommendations detailing when these technologies will be most effective to the highway agencies.

Key Words

Nondestructive testing, radar, wave propagation techniques, pavement evaluation.

Related Work

These two technologies have been under intense development under SHRP. The near-commercial prototypes of both devices are available. Several field studies have been carried out under SHRP direction.

Urgency

The evaluation of pavements for assessment of future maintenance needs is highly dependent upon the adequacy of the nondestructive testing procedures. More accurate methodologies are needed to ensure effective maintenance. Therefore this problem statement is

considered as urgent and assigned a Priority 2 by Committee A2B05.

Cost

\$525,000

User Community

At a minimum the AASHTO and FHWA should receive this problem statement.

Implementation

The development of improved and more reliable techniques would provide highway engineers with means

of determining the maintenance needs of the pavement structures prior to the development of excessive distress or deterioration. As preliminary results from SHRP studies indicate, both these devices can provide accurate results with respect to the state of the paving layers. The monetary rewards associated with timely maintenance as opposed to major rehabilitation or reconstruction are obvious.

Effectiveness

This problem statement impacts society significantly in terms of affecting the best use of pavement maintenance and rehabilitation funds. Better characterization and representation of the onset of deterioration would lead directly to cost-effective preventive maintenance solutions.

A2B07 COMMITTEE ON SURFACE PROPERTIES-VEHICLE INTERACTION

The research problem statements appear in the order of priority established by the committee.

PROBLEM #49: SETTING PROFILE MEASUREMENT STANDARDS FOR ACCURACY AND REPEATABILITY OF PROFILE MEASURING EQUIPMENT AND ESTABLISHING THE ACCURACY NEEDED FOR VARIOUS SUMMARY INDEXES

In the generation of roughness data using profile equipment there are at least four interdependent variables the equipment, the human operator, the road being profiled, and the index being generated. ASTM, FHWA, TRB, etc. appear to be setting standards based only on the equipment without considering the other variables involved. Failure to consider the other variables may cause accuracy and repeatability standards to be arbitrary if not outright meaningless.

The human operator has a limited ability to concentrate on the job of profiling. The ability to concentrate is time dependant, i.e., an operator will probably do a better job testing short (tenth of a mile) control sections than longer (100+ miles) inventory sections. The very fact that a human is required to operate the equipment limits the accuracy and repeatability.

Roads can and do change profile characteristics due to moisture, temperature, season, etc. During the daily cycle of heating and cooling, the seasonal cycle of heating and cooling, wetting and drying; a road's profile goes through changes. If a road's profile changes from day to day, it limits the value of acquiring highly accurate and repeatable data. As an example (using arbitrary numbers), what is the significance of using equipment good to .01% if the road being measured varies by 1% during the year and the operator's ability varies by 2%; and then the profile is used to determine a summary statistic that is only 5% accurate? Should an organization obtain equipment that is more accurate or repeatable than the other variables involved? Also, the spacing (sampling distance) needs to be included in this study.

It is recommended that a project be sponsored to determine the variability of profiles measured due to the human operator and the actual changes of the roadway profile with time. Recommendations need to be made about any future performance standards. With these factors established, further work is required to evaluate the effect of profile accuracy on summary indexes. The

class of profile equipment needs to be established based on the accuracy needed to compute these summary indexes. In particular the NCHRP Ride Number and the International Roughness Index (IRI) are two summary indexes that need to be evaluated.

Objectives

- To develop the accuracy and repeatability of roadway profiling equipment;
- To develop profiling equipment classes and standards; and
- To develop the accuracy needed by the various summary indexes.

Related Work

FHWA is currently requiring states to report IRI and no one knows what accuracy is required, and as a result there are all types of equipment being used with all levels of accuracy. Several studies have included time effect on roadway profile, but all of them have only included but a few sites or tests; however, they all show that there is an effect. Several user groups are starting to look at accuracy, but no overall study is being done because of the cost.

Urgency

Very urgent. FHWA is collecting IRI data and it is not clear at this time if these data are meaningful or not. Similarly, many states are purchasing profiling equipment and do not know if their equipment will provide meaningful data.

Cost

\$300,000

User Community

FHWA, AASHTO and other transportation agencies at all levels.

PROBLEM #50: MEASUREMENT OF SN AT T INTERSECTIONS, BRIDGE DECKS, AND APPROACHES

Many highway segments such as on-off ramps, non-tangent sections having small radii of curvature, street intersections ("T" intersections) are difficult or impossible to measure with the current locked wheel testers. Other measurements need to be investigated such as fixed-slip or a low speed locked wheel test with a macro-texture measurement are but 2 possibilities.

At high accident sites, peak braking friction may be more useful in accident analysis than skid number since vehicles lose directional control after passing the peak friction and before reaching locked wheel. Limited tests show that fixed slip testers near the peak correlate with the transient tests obtained with locked wheel testers.

Presently about 10% of the new vehicles have ABS brakes. This number is expected to increase and perhaps be required in the near future. The study should include the impact of ABS operation and if E274 locked wheel testing should be modified. as in the case above, transient tests with the locked wheel testers can be used to measure peak values which may be all that is needed to insure a good surface for ABS users.

Objectives

A research project needs to be established to determine whether modified locked wheel tests or tests with additional measures (such as macro-texture) or other testers like fixed slip are more useful to the highway engineer than the present E274 locked wheel tests or if relations can be obtained to meet the requirements of peak braking, cornering, and ABS systems.

Related Work

The PIARC international experiment will provide the data to establish the relationships if they do exist; however, further field testing will be needed to complete this study.

Urgency

At present there are no methods to measure skid number at 40 mph at intersection, on-off ramps and many other locations where the lateral forces are high or where reduced speed is required. These locations are potentially high accident sites and need a method to insure they are safe.

A2B08 COMMITTEE ON VEHICLE COUNTING, CLASSIFICATION, AND WEIGH-IN-MOTION SYSTEMS

The research problem statements appear in the order of priority established by the committee.

PROBLEM #51: DEVELOPMENT OF AN ADVANCED HIGHWAY VEHICLE CLASSIFICATION SCHEME

The existing Federal Highway Administration (FHWA) highway vehicle classification scheme [1] has been well accepted by the State highway agencies, and other groups, including the Strategic Highway Research Program (SHRP). It meets the basic highway vehicle classification needs, but there are several reasons why the existing classification scheme should be supplemented by one which is far more advanced or detailed.

Objectives

Better Utilization of Traffic Monitoring Technology - The existing scheme provides only a basic truck classification by using 9 truck categories. It would be beneficial to have an additional, more detailed classification scheme. Many existing Automatic Vehicle Classifiers (AVC) can accommodate more than the 13 FHWA vehicle categories. The number often encountered is 24. Some agencies are already using more than the standard 13 categories. The Availability of a more detailed, standardized classification scheme would promote a better utilization of the existing technology, both hardware and software, and would provide guidance for those agencies already using more than the 13 categories.

The existing 13-class scheme cannot provide a unique identification of important truck types, such as:

- The 3S2 truck (a 3-axle tractor with a tandem driving axle connected to a semi-trailer with a tandem axle); and
- Trucks with triple axles.

Additional concerns which should be addressed during the course of the proposed research project are:

1. The advanced classification scheme should be compatible with the existing scheme to enable direct conversion (aggregation) of the advanced classification data into the basic classification data.
2. The advanced classification scheme must take into account the limitation of the existing AVC hardware which is unable to distinguish between single-unit and multiple-unit vehicles.
3. Any classification scheme should be supported by a corresponding classification (sorting) algorithm. Any such algorithm should be verified by field testing.

Related Work

The FHWA Traffic Monitoring Guide, Section 4, 1985.

Cost

\$100,000

A2C01 COMMITTEE ON GENERAL STRUCTURES

PROBLEM #52: ONGOING LRFD BRIDGE DESIGN SPECIFICATION SUPPORT

A new Load and Resistance Factor Design (LRFD) specification for bridges is being completed and will be considered for adoption by the AASHTO Subcommittee on Bridges. Historically, AASHTO has maintained bridge design specifications through the activity of committee volunteers, and over the years those specifications became inconsistent and disjointed due to piecemeal updating, giving non-uniform safety and reliability among the various bridge types and materials. The new code has been prepared by a highly qualified group of professionals contracted by NCHRP. It is a very comprehensive document and will be difficult to properly maintain using committee volunteer effort only. As new information comes from research or practice, it needs to be considered in a manner consistent with the philosophy and calibration of the entire code, otherwise the new code will eventually have the same problems as the previous design code. The AASHTO Subcommittee on Bridges will need expert outside assistance available to them when needed.

Objective

Provide a professional resource group to be available on call to assist AASHTO and its technical committees in implementing the new LRFD Bridge Specifications, or in preparing revisions or new provisions consistent with the philosophy and format of the initial document. Perform calibration studies as needed, and special studies on issues or problems needing resolution for design specifications purposes, through a contract with and under the administration of NCHRP. The contract should be renewable on an annual basis.

Related Work

The NCHRP Project 12-33, which prepared the LRFD Specification, ends June 30, 1993.

Cost

\$100,000 per year, and the estimated time for this support activity is indefinite.

User Community

All transportation agencies that use AASHTO Bridge Design Specifications.

PROBLEM #53: DEVELOPMENT OF DESIGN CRITERIA AND AASHTO SPECIFICATIONS FOR FLEXIBLE AND RIGID LONG-SPAN AND THREE SIDED BOX CULVERTS

The NCHRP 12-33 study investigated the performance of a large variety of conventional bridge types and developed new design practice based on these findings. However, with the exception of a editorial review, the culvert specifications were excluded from this development effort. Design procedures for long-span culverts have been based in proprietary data which has not been reevaluated for some time. The long-span culverts and 3-sided box culverts are seeing increased use for small bridges, replacement structures and specifications based on simplified methodology are needed to appropriately analyze these structures. The need exists for an independent in-depth evaluation in a national level to correlate all sources available data and develop generalized design methodology.

Objectives

Target structures include long span pre-cast concrete arches, corrugated metal long-span culverts, and 3-sided box culverts of both concrete and metal. The research would include soliciting and compiling results of all available research reports and data on the design of target structures; performing comparative analysis of all available data to verify the design on a non-proprietary basis; calibrating computer models for lower bound trends and verifying results with full scale field testing; and developing simplified equation based methodology for application of results. It should also include draft specifications that could be incorporated into the AASHTO Bridge Specifications.

Key Words

Culverts, design procedures, long-span culverts, three sided box culverts and arches.

Related Work

No recent related work except that done by industry to serve its interests.

PROBLEM #54: BRIDGE DESIGN CRITERIA FOR TEMPERATURE DIFFERENTIAL

A recent study using field measurements has shown that current AASHTO Segmental Bridge Design Specifications prescribe certain temperature differentials through the depth of bridge superstructures that may be overly conservative and thereby unduly raise the construction cost of these bridges. The present design provisions were based on NCHRP Report 276 which used limited field information for verification.

Objective

Using the latest data available, conducting additional field or analytical studies if necessary, prepare new or revised criteria for bridge design which reflects the actual behavior of the structure due to temperature differential.

Key Words

Bridge design, temperature differential.

Related Work

Ongoing data collection from San Antonio "Y" Bridges by the University of Texas. Other recent work includes data collection and analysis by Louisiana State University from the Red River Bridge at Boyce, Louisiana.

PROBLEM #55: EFFECT OF COMPUTERS ON QUALITY OF BRIDGE DESIGN

Modern automated bridge design and detailing practice takes advantage of computer software for accuracy and efficiency in calculations and drawings and the ability to carry out very complex types of analyses. However highly computer oriented designer may fail to develop the intuitive design skills which come from working more deliberately through each step of a bridge design and gaining a feel for reasonable design results. Also there is a tendency to use more sophisticated analyses that is

justified by the type of structure or assumptions made. These issues may lead to either unsafe or inefficient designs through misapplication of software or to constructability problems through lack of feel for practical structural proportions and details. Also, bridge type selection and other design decisions may be based solely on software availability or limitations, tending to discourage consideration of alternatives or innovation.

Objectives

Review the current state of Bridge design practice and evaluate the effect of extensive computer use on the overall quality of design. Recommend design guidelines and design management procedures to assure that overall quality of design is not compromised by excessive reliance on computer technology.

Key Words

Bridge design, computers, design quality.

PROBLEM #56: AESTHETIC CLASSIFICATION, EVALUATION AND RANKING PROCEDURES FOR PROPOSED BRIDGE SITES

Many bridges are designed without a formal evaluation or consideration of the aesthetic, cultural or social implications of the completed structure on the site environs. The need exists for an objective method of quantifying and integrating the aesthetic, cultural, social and historical elements of the bridge site into the design process.

Objectives

To develop a procedure identifying, quantifying and classifying the contextual elements of proposed bridges sites (historical, social, political, architectural, cultural, geographical, etc.) which should be considered when establishing the required level of aesthetic emphasis of proposed bridges.

Based on an aesthetic ranking of proposed bridge sites, (i.e., critical, significant, sensitive, trivial, impoverished), develop a method for quantifiably evaluating the various contextual elements of a bridge site so that a bridge site's ranking can be determined.

Based on such classifications, evaluations and rankings, bridge designers will then know in advance the

level of aesthetic effort that may be necessary to achieve a bridge design that will properly reflect and enhance the context of the site at a level commensurate with its aesthetic ranking.

Key Words

Bridges, aesthetics, ranking.

Related Work

Numerous publications including the recent TRB publication, "Bridge Aesthetics Around the World."

PROBLEM #57: DEVELOPMENT OF COMPUTER SOFTWARE FOR BRIDGE SAFETY INSPECTION

Artificial intelligence methods have not been applied to develop applications for personal computers which will provide useful information to bridge safety inspection personnel. Programs are needed to facilitate planning and accurate reporting of inspections of existing bridges.

Objectives

Develop a computer software system for personal computers which will be capable of aiding bridge inspectors in identifying critical components and in coding and reporting results of bridge safety inspections. Work with several State transportation agencies will be necessary.

Key Words

Bridge inspection, bridge safety, inspection, computers, software, artificial intelligence.

Related Work

Bridge management system work in the States of California, North Carolina, Pennsylvania and New York. The PONTIS bridge management system and the ongoing NCHRP bridge management system work.

PROBLEM #58: DISPOSAL METHODS FOR SANDBLAST SAND CONTAINING LEAD

Current methods for disposing of residue from lead based paint removal projects are expensive, environmental difficult and may be subject to additional restrictions in the near future.

Objectives

Develop a method of disposal for mixture of sandblast sand paint chips resulting from public works projects for repainting of steel structures. The method must be environmentally acceptable and meet all applicable requirements of the Environmental Protection Agency.

Key Words

Lead based paint removal, bridge painting, hazardous waste disposal.

Related Work

Research at University of North Carolina, FHWA and the Steel Structures Painting Council. The recent NCHRP Synthesis 176, "Bridge Paint: Removal, Containment and disposal."

PROBLEM #59: DEVELOPMENT OF SITE-SPECIFIC LIVE LOAD MODEL FOR BRIDGES

A previous NCHRP study attempted to develop a model for the static portion of live load. However, this was never completed. The major problem was the availability of reliable data. The weigh in motion (WIM) results used in the project were incorrect. Therefore, the only contribution made was the development of an approach. In the meantime, new data was collected by various research agencies, including the University of Michigan (Michigan DOT Study) and at the University of Colorado (FHWA Project). The proposed project would provide a very needed verification for the live load model used in the development of the LRFD bridge design code now under consideration by AASHTO.

Objectives

To develop a site-specific model for live load on highway bridges, the work should include the review and processing of the available data (WIM and other measurements), calculation of load effects (moments and shears), extrapolations for longer time periods, simulations for multiple presence and calculations of other site-specific parameters. Static and dynamic load effects should be considered. Major tasks include:

- Literature review.
- Review of the available data (WIM, truck surveys).
- Processing of available data, calculation of load effects (moments and shears).
- Development of simulation procedures for static and dynamic load effects.
- Calculation of live load effects for multilane bridges (by simulation).
- Simulation of live load effects.
- Development of site-specific statistical parameters for live load.
- Verification of the current live load models.

PROBLEM #60: DEFLECTION OF STEEL GIRDERS AND BEAMS UNDER SUPERIMPOSED DEAD LOAD.

Currently, deflection tables in construction plans as prepared by designers reflect the deflection of each

beam assuming that it acts independently of other beams even though the beams are connected together. The framework of beams, crossframes and diaphragms behaves in a three dimensional manner. As a result dead load camber and final concrete deck grades are miscalculated.

Objectives

Conduct a three dimensional parameter study of typical steel beam and girder arrangements to determine predicted deflections and provide designers with a more accurate method of predicting deflections of beams and girders under superimposed dead loads. Under actual construction conditions, measure the deflection of each beam in the respective spans to determine the relationship between actual and plan deflections. Develop guidance for designers and construction personnel.

Key Words

Bridge construction, analysis, deflection, dead load camber.

A2C02 COMMITTEE ON STEEL BRIDGES

The research problem statements appear in the order of priority established by the committee.

PROBLEM #61: EFFECT OF LIVE LOAD DEFLECTION ON STEEL BRIDGE ELEMENTS

Deflection limits are commonly applied to steel bridges but are seldom used for other materials. These deflection limits sometimes control the design of the bridge. It is not clear how these limits were developed and that they are really needed for the safety and serviceability of the bridge. Research is needed to determine how these limits affect the performance of the bridge and whether they are needed.

Objectives

The present requirements may be unnecessarily restrictive to slab-and-girder type bridges, and they may adversely affect the economy of bridge design. On the other hand, the deflection limits may have some beneficial effect on controlling the overall performance of some bridges, which is not directly apparent when examining the deflections only. Thus, this must be a broad based study to not only examine the deflections, deflection limits, and bridge serviceability, but to examine the deflections and the deflection limit on the overall bridge performance. The research should define when deflection limits are needed, when they control the design, and how these controlling limits affect the bridge performance.

Related Work

Research was performed approximately 10 years ago, but it was of limited scope and did not receive wide acceptance.

Urgency

This is rated as a urgent project. It is urgent, because it may affect many bridges, and considerable saving could be achieved if the requirement is not needed.

Cost

\$150,000 for an 18 month period.

PROBLEM #62: EFFECT OF SKEWED SUPPORTS ON BRIDGE DESIGN AND BEHAVIOR

Skewed bridges are often required due to alignment of streets and highways with rivers and other obstacles. It is well known that skewed bridges respond differently to applied loads and environmental conditions than do right bridges. Unfortunately there are no good design models for accounting for bridge skew. Instead design rules for right bridges are arbitrarily applied to skewed bridges, and this frequently leads to uneconomical design and occasional problems in that the bridge does not perform as expected. The development of models to predict this behavior could lead to greater economy and reliability in design. Research is needed to better define and understand this response. As a minimum, the following issues should be addressed:

- It is known that the load distribution between girders is different for skewed bridges than for right bridges, and rules are needed to account for this.
- Temperature effects and movements affect skewed bridges differently than right bridges, and integral construction is typically not used on severely skewed bridges. Models are needed to better account for this and to determine if and when integral construction can be employed.
- Bracing and restraint requirements are different for skewed bridges. Guidelines are needed for diaphragm arrangement.
- Determination of when skew must be considered, when it can be neglected, and how it affects the economy and performance of the bridge.

Objectives

To develop simple, accurate, and reliable design rules for dealing with the wide range of problems caused by skewed bridge geometry.

Urgency

This is an urgent topic, because skew is required on many bridges. There are no consistent design procedures for dealing with the geometric effect, and occasional problems have been noted.

Cost

\$350,000 for a 3 year period.

PROBLEM #63: EFFECT OF SHRINKAGE OF THE CONCRETE SLAB ON THE DEFLECTIONS OF STEEL PLATE GIRDER BRIDGES

Concrete slabs shrink during the drying and curing process. At present there are no reliable ways to prevent the concrete shrinkage. This shrinkage may induce forces and deflections in the bridge and cause deck cracking. The deflections affect the camber that is required during the design as well as the deflection (and camber loss) expected during the construction process. Some designers account for this effect while others do not. Several different methods have been used to predict this effect. Research is needed to determine the importance of the shrinkage effect, to find the parameters which cause it to be important or unimportant, and to develop reliable methods for predicting the behavior. Effects of shrinkage compensated cements to reduce such deflections and reduce cracking, also should be considered.

Objectives

Research could proceed in two directions. Research which provided methods for controlling or preventing time dependent concrete shrinkage and deformation could eliminate the problem. However, this does not appear plausible at present, and so research is needed to assess the importance of the issue to bridge performance and develop strategies for controlling it.

Urgency

Urgent topic, since it could have immediate effect on bridge performance.

Cost

\$250,000 for 2 years.

PROBLEM #64: DEVELOP METHODS TO CONTINUOUSLY MONITOR BRIDGES AND PREDICT WHERE FAILURE WILL OCCUR

Theoretical models for predicting bridge behavior have advanced a great deal in recent years, but there are very

little experimental data to indicate how bridges actually behave under loading or environmental conditions. Deterioration of the bridge also occurs with time, and non-destructive evaluation and monitoring techniques could be used to monitor these conditions and to help determine when repair or replacement is required. These issues are increasingly important in light of recent developments such as the LRFD design specification, where more refined statistical models of bridge behavior have been proposed even though there are few data available to verify some of these models. The results would also be beneficial in developing strategies for evaluating the condition of existing bridges and economically repairing and rehabilitating older bridges. Limited experimental data that are available often suggest that bridges behave differently than is often suggested in design models and simplified analysis. These variations are probably greater on some types of bridges than in others. A long term research program is needed to move forward in this area.

Objectives

This is a broad based research topic with very broad long term objectives of determining exactly how bridges behave, how they deteriorate, and the methods of monitoring and determining this behavior.

Related Work

A few isolated bridge tests are being performed, but there is no integrated research in this area.

Urgency

This is a very long term research effort, as a result it is rated as moderate urgency. Successful completion of the research will result in a great impact on bridge design.

Cost

\$450,000 per year for 5 to 7 years.

PROBLEM #65: BEHAVIOR AND DESIGN OF STEEL BOX SECTIONS FOR COMBINED BENDING AND AXIAL LOADING

AASHTO specifications are not clear regarding design of non-I Shapes for combined bending and axial force.

Width to thickness ratios are not defined for some conditions and must be inferred from other parts of the specification which address composite box girders, trusses and solid rib arches. Allowable fabrication processes, quality control requirements, and special considerations for fracture critical members should be considered as well, and specific recommendations should be made for use of electrosag or electrogas welds in tension members especially when the member is nonredundant.

Objectives

The initial portion of this research requires a comprehensive state of the art evaluation, and the incorporation of these results into present design practice. The initial study will isolate issues which require further study, and additional research probably will be required to address these topics.

Urgency

This is an important issue for some classes of bridge, and is very important in their design, but it is of moderate priority overall.

Cost

\$125,000 during a 2 year period for the initial state study.

PROBLEM #66: CORROSION CONTROL

Research is needed to develop design details (particularly at joints and bearings) which enhance the corrosion life of the bridge. These details should permit periodic inspection, cleaning, repainting, and replacement, during the service life of the bridge. Past research has been performed on corrosion of A588 Weathering steel, and this project should make full and practical usage of the past research.

Objectives

To provide the definitive study which will resolve past conflicts and inconsistencies and help the bridge engineer deal with the control and prevention of corrosion.

Related Work

Field study information has already been achieved with industry support, from which two reports were prepared:

- Performance of Weathering Steel in Highway Bridges, AISI, August 1982.
- Remedial Painting of Weathering Steel - A State-of-the-Art Survey, AISI, February, 1984.

The first of these reports reviews the performance of weathering steel bridges in 49 bridges in 7 states. This report suggests that corrosion problems are largely a problem caused by deicing salts and leakage, concentration of corrosive material at joints and other critical locations, and traffic induced spray. Drainage, duration of wetness, and moisture retaining debris also affect the corrosion potential. The second report proposes that painting systems combined with the use of A588 steel may improve the performance of some of these critical locations.

Urgency

The problem is important. Results of the research will have an immediate impact on bridge design.

Cost

\$250,000 for 2 years.

PROBLEM #67: DESIGN ISSUES FOR BRIDGE BEARINGS FOR STEEL BRIDGES

Many issues regarding the design and placement of bridge bearings are unique to steel bridges. Steel bridges often deflect and move more than other bridge types. Steel bridges are often larger bridges with more complex geometry, and these place greater demands upon the bearing or special orientation of placement. Some construction specifications require placement of bearings on steel shim stacks, erection of the superstructure, and then grouting under the base plates. Modern multi-rotational bearing systems are often damaged by this sequence because the base plate or masonry plates are too flexible to support the applied load without continuous support. Voids in the grout have also occurred with this sequence, and this has also contributed to damage to pot bearings. Research is

needed to define construction methods which allow adjustments during the construction process while assuring the adequacy and acceptability of the finished product. Requirements for bearing inspection, access for inspection, design to support construction load without physical damage or plastic deformation, and capability for bearing replacement should also be included.

Objectives

Research is needed to address the wide range of specific issues related to bearings in steel bridges. It is well known that a large portion of the problems associated

with bridges in service are caused by or related to improper performance of the bearings, and this could lead to potential savings in the first cost and maintenance of the bridge.

Urgency

Moderate

Cost

\$125,000 for a 2 year study.

A2C03 COMMITTEE ON CONCRETE BRIDGES

PROBLEM #68: DESIGN AND EVALUATION OF PRESTRESSED CONCRETE BRIDGES FOR FATIGUE

First applications of prestressed concrete to highway bridges in the U.S. were started in 1950. By the late 1980's, about 50% of bridges being built annually were made of prestressed concrete. Although the performance of these bridges has been very satisfactory, concerns have been expressed about the remaining fatigue life of these bridges.

Current AASHTO Specifications for Highway Bridges do not offer guidance for fatigue of strands. Although these specifications permit nominal tension of $6\sqrt{f_c}$ in the concrete under service loads, some states allow half that amount, while others do not allow any tension, because of concerns about fatigue.

Tests conducted in the late 70's and early 80's on full-size prestressed girders resulted in some fatigue fracture of strands. Most of these tests were performed on precracked girders. Amplitude of fatigue test loads was severe compared to design truck loads. Further, effects of cyclic creep of concrete were not accounted for during design of test specimens or analysis of test results.

Because of the growing population of prestressed concrete bridges in the U.S., there is a need for provisions to design against fatigue of strands. Further, guidance is needed to evaluate existing prestressed concrete bridges.

Objectives

The objective of this study is to develop provisions for design against fatigue of strands, and for evaluation of existing bridges and assessment of their remaining fatigue life.

Key Words

Analysis, design, evaluation, prestressed concrete, fatigue life, strands.

Related Work

● Overman, T.R., Breen, J.E., and Frank, K.H., "Fatigue Behavior of Pretensioned Concrete Girders," Research Report 300-2F, Center for Transportation Research, The University of Texas at Austin, November 1984, 382 pp.

● Paulson, C., Frank, K.H., and Breen, J.E., "A Fatigue Study of Prestressing Strand," Research Report 300-1, Center for Highway Research, The University of Texas at Austin, April 1983, 124 pp.

● Rabbat, B.G., Kaar, P.H., Russell, H.G., and Bruce, R.N., Jr., "Fatigue Tests of Full-Size Prestressed Girders," Report to Louisiana Department of Transportation and Development, submitted by Portland Cement Association, Skokie, Illinois, June 1978.

Urgency

Because of the rapid growth in construction of prestressed concrete bridges, the lack of current design and the concern about the safety of existing ones, this project deserves high priority for research.

Cost

Approximately \$500,000

User Community

FHWA, AASHTO and other transportation agencies

Implementation

Conclusions and recommendations of this research should be directly implementable in the AASHTO Specifications for Highway Bridges and the appropriate documents for Evaluation of Existing Highway Bridges.

Effectiveness

Results of the research can be effectively implemented through the AASHTO Specifications and will avoid problems encountered in the steel industry.

PROBLEM #69: BUCKLING OF LONG AND SLENDER HIGH-STRENGTH CONCRETE GIRDERS

Concrete with strengths in excess of 10,000 psi (69 MPa) are now commercially available in many parts of the United States. The use of high-strength concrete in

structural elements offers many benefits and advantages. From a structural viewpoint, span lengths can be increased or dead loads of bridges reduced. When high-strength concrete is combined with the use of deeper and more slender cross-sectional girders, it becomes necessary to consider the lateral stability of the structural members.

Stability of prestressed concrete girders with usual span lengths is not a problem. However, for very large spans with slender girders, the safety against buckling, particularly local buckling of the web and compression flanges, can become a dominant design consideration (Refs. 1 through 3). Lateral buckling of a full-scale bulb tee girder of high-strength concrete has been reported in Ref. 4. With complex geometric shapes and complex materials having stress/strain relationships exhibiting different behaviors in tension and compression, effective and useful predictions of buckling response using current design approaches are generally very approximate.

Objectives

The first objective of this investigation is to use a computer-based, nonlinear, finite element numerical technique involving large deflection theory, nonlinear material characteristics, and realistic steel and concrete properties to predict the instability of structural plate elements and actual girders.

The second objective is to compare the calculated buckling and post-buckling results with experimental results.

Using the developed analytical tool, the third objective is to develop a simplified approach that can be used by designers. If appropriate, provisions for including in the AASHTO Specifications will be developed.

Key Words

Buckling, finite element, flow hardening, high-strength concrete, post-buckling, slenderness, yield.

Related Work

● S. C. Das, T. D. Huang, and X. Zhang, "Numerical Buckling Analysis of Concrete Plate Elements and Comparison with that of Experimental Results," Report No. ST-91-1, submitted to the NSF, part of the NSF Project MSM-8919385, March 15, 1991.

● S. C. Das, T. D. Huang, and X. Zhang, "Nonlinear Finite Element Buckling Analysis of a Long-Span R.C. Folded Plate Model," Report No. ST-91-2, submitted to the NSF, part of the NSF Project MSM-8919385, April 17, 1991.

● T. D. Huang and S. C. Das, "Nonlinear Finite Element Buckling Analysis of Full-Scale Prestressed Concrete Folded Plate Structure," Report No. ST-91-3, Department of Civil and Environmental Engineering, Tulane University, submitted to the National Science Foundation, Washington, D.C., under Grant No. MSS-8919385, December 15, 1991.

● R. N. Bruce, H. G. Russell, J.J. Roller, and B. T. Martin, "Feasibility Evaluation of Utilizing High-Strength Concrete In Design and Construction of Highway Bridge Structures," Interim Report No. FEWA/LA-92/264 for the LTRC and the FHWA, December 1992, 228 pp.

● R. F. Mast, "Lateral Stability of Long Prestressed Concrete Beams - Part I," PCI Journal, Vol. 34, No. 1, January/February 1989, pp. 34-53.

Urgency

The growing interest in using high-strength concrete in longer span girders has resulted in the necessity to consider stability of the girders prior to placement of the concrete decks. The issue applies to girders during handling, transporting, and erection. Current procedures are complex because the problem is complex. A simplified approach is needed before a catastrophic failure occurs.

Cost

\$250,000 over 30 months.

User Community

AASHTO Subcommittee on Highway Bridges and bridge design engineers.

Implementation

Conclusions and recommendations of this research will result in a simplified design procedure that can be readily applied to verify the stability of long-span slender girders. Suitable provisions for use in the AASHTO Specifications for Highway Bridges will be developed.

Effectiveness

The results of this investigation will enhance the existing knowledge on the subject and through proper implementation will prevent a major failure from lateral buckling.

A2C04 COMMITTEE ON TUNNELS AND UNDERGROUND STRUCTURES

PROBLEM #70: APPLICATION OF EXPERIENCE TO DESIGN

Tunnels continue to be designed and constructed without full knowledge of the on-going experience of existing tunnels. In general, people who operate and maintain tunnels are not the ones that are in charge of designing the new facilities. The link of experience to current work is weak and fragmented.

Objectives

Provide a current summary of the performance experience of existing tunnels as timely input to design of new tunnel facilities, or the planning and design of rehabilitation of existing facilities.

Key Words

Tunnels, operations, maintenance, rehabilitation, design, lessons learned, infrastructure.

Urgency

Very high in recognition of the broadness of the topic and the timeliness of this work in this time of infrastructure renewal.

Cost

\$150,000 for one-year.

User Community

All broad-based agencies and organizations having any tunnel facilities.

Implementation

This proposed research project is primarily a data gathering activity. It would involve detailed contacts with tunnel owners and operators, which would involve travel and extensive correspondence. A data base per se would not be the goal, but rather a summary and synthesis of the current experience and practices for the varying

facilities in North America. The goal would be to expediently identify both general and specific issues that can be readily used by owners in the planning of new facilities, and designers when the detailed designs actually take place. It would have a secondary use of providing information to existing tunnel owners that still have rehabilitation or other operational changes needed for their facilities.

PROBLEM #71: ROLE OF NATM

Despite the historic achievements of the NATM in the U.S. over the last decade, considerable confusion remains within the tunneling industry about the attributes and capabilities of NATM to provide cost-effective and technically superior solutions to the transportation-tunneling challenges. The lack of a comprehensive and authoritative experience-statement is hampering the full realization of the many benefits that NATM has to offer in the field of transportation-infrastructure development.

Objectives

To disseminate the state-of-the-art NATM experience in the U.S., in "user-friendly" terms. Owners, constructors, design professionals, transportation policy makers and researchers would all be able to derive benefits from the publication. The proposed reference would serve as a benchmark publication in the field of transportation tunneling, under the TRB's auspices.

Urgency

Very high priority in view of the expected infrastructure renewal program.

User Community

Planners and owners of tunnels.

PROBLEM #72: MODEL CONSTRUCTION SPECIFICATIONS

Despite the ever increasing use of NATM in transportation construction projects, no model

specifications exist to optimally promote future developments in this field.

Objectives

Based on the recent NATM experience in the U.S., and the ongoing developments in Europe, develop model construction specifications. The specifications would be sufficiently detailed to include provisions on ground classification, excavation procedures, initial and final support systems, instrumentation requirements and interpretations, and the observational decision-making process inherent in the NATM construction practice.

Urgency

High, in so far as NATM is concerned, second highest priority after the related work as item 71, mentioned above.

User Community

Owners and designers of tunnels

PROBLEM #73: MANAGING UNCERTAINTY IN TUNNELING

Some Owners are now removing "changed condition" clauses when Federal funds are not involved. Some Contractors have decided not to bid because of this restriction. Others are placing high contingencies or anticipating the filing of lawsuits. These Owners feel that the "clause" has been abused by Contractors and they (the Owners) claim that they will get sufficient bids at the "right" price regardless.

Some Owners are reluctant to become involved with the Contractor's problems and are concerned about getting sued. Years ago, the Engineer often adjudicated disputes and interpreted contract requirements and specifications. Nowadays, Contractors are suing Engineers for "overzealous inspection", "interference", "conspiracy to bankrupt the Contractor", etc. Some Contractors say they cannot account properly for all the "risks" in their bid. Some of the more frequent types of disputes center around:

- Changed physical site conditions and delays;
- Unknown physical site conditions and delays; and
- Unforeseen delays.

Some Contractors say that Owners are unwilling to entertain extras for subsurface changes or unknown conditions because they (the Owners) claim that the Geotechnical Report covered the disputed item(s), and of those Owners who will consider these item(s), most do not resolve them quickly and/or adequately.

Objectives

Develop a standard of practice for Contract Language acceptable to all parties to manage uncertainties associated with construction risk.

Related Work

The ASCE Technical Committee on Contracting Practices of the Underground Technology Research Council has prepared a document on "Avoiding and Resolving Disputes in Underground Construction." This report includes a specification for implementation that could accomplish the objective of this research. As excellent as this document is, the problem is implementation. It is suggested that the best way to accomplish this is to develop a Standard of Practice on this subject that is subjected to the full consensus process and accordingly having received the prerequisite support of all parties involved in tunnel construction.

Urgency

Very Important. In order for a Standard of Practice to go through the consensus process, 2 to 3 years are required. It is urgent that this Standard development be implemented as soon as possible.

User Community

Owners planning to construct new tunnels.

PROBLEM #74: GEOTECHNICAL INSTRUMENTATION FOR TUNNEL CONSTRUCTION

Tunnel design and construction have progressed in some current projects using instrumentation as an integral part of the tunnel design and construction process. In prior years, a great deal of attention has been given to instrumentation and monitoring for protection of structures adjacent to tunnels. Less

attention has been given to the instrumentation associated with the tunnel lining, particularly tunnels built in soil or weak rock using observational methods.

Objectives

Provide a guideline for procedures, equipment, and construction management requirements for instrumentation and the use of instrumentation findings to create a "back analysis" allowing modification of design during construction based on actual loadings encountered.

Related Work

No research is known to be in progress on this topic. NCHRP Synthesis No. 89 (Geotechnical Instrumentation for Monitoring Field Performance) has no specific information on this topic, and there are no plans to implement an update.

User Community

Owners, designers, and construction managers.

PROBLEM #75: NEW TECHNOLOGY FOR TUNNEL CONSTRUCTION

Tunnels are high capital facilities which cannot produce revenue until they are completed. Speeding up construction is important both for the owner and contractor.

Objectives

Develop new excavation and material technology to speed up construction. This may also involve aspects of remote sensing ahead of the tunnel. High performance materials may also lead to an absolute cost reduction.

Related Work

None is known in U.S. Most is in Japan and Europe. Research need #76, herein, is related.

Urgency

High considering expected future tunnel work.

User Community

Owners of tunnels, contractors.

Implementation

This broad-based statement of research need reflects the situation in the U.S. where little technological leadership is exhibited today. It is unrealistic to propose a major government-funded research project to address what has become strictly a construction industry market-driven issue. Implementation is practical by accelerating transfer of technology from other countries, identifying potential demonstration projects, and providing policy input to enable innovation and lower cost.

PROBLEM #76: TUNNELING ECONOMY

Tunnels are increasingly being used for temporary storage of storm water runoff. They are also components of super colliders and programs addressing the storage of hazardous wastes.

Development of high speed rail systems can result in extensive tunnel construction needs, even in fairly flat terrain. The German high speed rail experience indicates that the cost of tunneling can be a very significant proportion of the overall cost of the project. Future high speed rail developments in the U.S. will no doubt find a need for indigenous technical know-how in this area. Thus, ideal tunnel design and construction techniques are needed to ensure the economy of the overall project.

Objectives

To re-evaluate the state-of-the-art of tunneling around the world and document those technologies that promise more economical solutions.

Related Work

There is no present reassessment underway of our present knowledge as related to increasing economy. Research need 75, herein, is related.

Urgency

Important. The subject relates directly to more economical tunnel construction.

User Community

Owners of major tunnel facilities.

Implementation

A study of the state-of-the-art in this field is needed. German, French, Japanese and other experiences should be reviewed. Several tunnel design and construction alternatives should be researched for possible future use. Tangible recommendations for research needs should be developed. Excavation methods, lining systems, dynamic response of tunnel structure, ground-structure interaction and pressure-transient problems are some of the areas that would need attention.

PROBLEM #77: RESOURCE CENTER

There have been many studies and reports developed by various agencies, consultants and other groups regarding many components used in tunnels. For instance, there have been at least two studies in the last several years on the interior finishes of roadway tunnels. Some of these studies may be redundant and an unnecessary cost to the agency that authorizes the study. There are literally hundreds of reports developed by individual properties and authorities that would be donated to a resource center if the request were made. It would be very beneficial to the industry for TRB, or some other entity, to form a library that would actively collect and record these reports, and make their existence known to all parties in the industry.

Objectives

Establish a resource center to collect and disseminate research and studies on tunneling problems.

Urgency

Important. The subject relates directly to more economical tunnel design and construction as well as addressing safety issues.

Implementation

The best approach could be to interest a university in establishing an Institute of Tunneling Technology to

accomplish this objective. Considerations should be given to cooperation with the American Underground Association (AUA).

PROBLEM #78: TUNNELS WITH MULTIPLE PURPOSES

All too often a tunnel is planned and designed for a single function; for example, highway or rail transportation. The effort to design and construct a tunnel is typically great, but the full benefit of such a facility is not always realized. Co-existing uses, such as for utilities, are not adequately considered. An example is a tunnel where an exploratory tunnel is built outside the limits of the future permanent tunnels. The exploratory tunnel can be a utility corridor for electrical and communications lines. If it were planned with such intentions, part of the initial cost might be shared with the tunnel owner.

Objectives

Provide a rationale for multiple use of tunnels for general benefit of the public.

Related Work

Some past work has been done on the use of exploratory facilities for permanent use in research at MIT.

Cost

Moderate, as this would be a paper study of policies and possibilities.

User Community

All agencies responsible for planning, designing, constructing and operating tunnels.

Implementation

This is envisioned as a data gathering activity to summarize existing practices followed by development of policy recommendations. In order to make the study and disseminate the information as it is being assembled, a series of workshops could be held in conjunction with

TRB's Annual Meeting, as a mid-year meeting, or as an add-on to professional meetings on tunneling.

PROBLEM #79: EMERGENCY EVACUATION

In long tunnels, how do we get people up to the surface in emergencies--especially tunnels under water? Some European tunnels have longitudinal escape tunnels with safety escape rooms that have separate services for air and lighting. This problem should be addressed and a practical policy developed for guidance of those parties interested in long tunnels.

Objectives

Develop a guideline for tunnel design that addresses emergency evacuation of personnel in long tunnels.

Related Work

None in U.S.A. This problem has been addressed individually in other countries. There is no consensus on what is a satisfactory approach.

Urgency

Modestly important in U.S., since most long tunnels are not for vehicles carrying people, are not underwater or are close to the surface as with the case of transportation tunnels. However, it is a problem that should not be neglected, and should be a part of planning for future tunnels, which are reported to be larger.

PROBLEM #80: TUNNEL CLEANING

Tunnel cleaning is normally accomplished by contracting for this service. The degree of cleanness is directly related to visibility and safety. There are three basic related problems that should be addressed in standards for cleaning contracts with definitive guidance provided for the contractor. These are:

1. Establish a criterion for what is clean for tunnel walls and ceilings. At present this is a subjective term. Some easily performed test should be established to measure an acceptable norm.
2. Establish criteria for environmentally acceptable cleaning compounds. Obviously certain chemicals are

wonderful for cleaning but the waste water runoff is contaminated and environmentally unacceptable for discharge into sewerage systems. What is needed is a listing of environmentally acceptable cleaners that have been pre-qualified by appropriate testing. Associated with this is the method and rate of applications since this may influence the acceptability.

3. Establish criteria for cleaning tunnel pavements. There have been a number of several-car pile-ups recently on tunnels with asphalt pavements. Skid tests show the asphalt has a skid resistance of 11-14. The problem may be associated with washing and sweeping the roadways. Tunnel pavements do not get naturally cleaned by rain. Oil and grease can build up, leading to slick surfaces.

Objectives

Develop a standard specification that can be used in contract cleaning contracts that contains appropriate criteria and test methods.

Related Work

Experiments are being made with use of a high-pressure spray for cleaning. Also, consideration is being given to slowing the speed of traffic.

Urgency

Very important.

PROBLEM #81: ALTERNATE FUELS

Many vehicles today operate using alternate fuels rather than diesel oil and gasoline. These include gasohol and natural gas. A safety analysis for vehicles operating with alternative fuels in a tunnel environment has never been made. Some fuels could be disastrous while others would be much safer when compared to conventional fuels. As the problem with the shortage of oil and its related fuels accelerates in the future, this issue grows in importance.

Objectives

Develop a program for testing the safety of alternate fuels and conduct tests.

Urgency

Future Importance.

PROBLEM #82: TUNNEL CEILINGS

Safety aspects of a reflective ceiling in roadway tunnels. Recent trends in the use of ceiling-mounted counter beam lighting, and the theory used to justify same, indicate that it may be possible to stop using a reflective-type ceiling. Considerable cost, both construction and

maintenance, could be saved if the ceiling does not have to be reflective.

Objectives

Determine if reflective tunnel ceilings are required for safety.

Urgency

Important. The problem relates directly to economy of construction as well as economy of maintenance.

A2D03 COMMITTEE ON CHARACTERISTICS OF BITUMINOUS-AGGREGATE COMBINATIONS TO MEET SURFACE REQUIREMENTS

The research problem statements appear in the order of priority established by the committee.

PROBLEM #83: UTILITY OF MODIFIED ASPHALTS AS CHIP SEAL BINDERS

Additives of all types are being used to modify asphalt cements and emulsions used as binders for chip seals. The cost associated with these modified asphalts is often significantly higher than conventional binders. On some projects where vehicular damage or motorist inconvenience is considered high, this added cost is considered justifiable since the perceived benefit of increased chip retention may lead to less complaints. However, it has not been demonstrated objectively that modified asphalts provide a commensurate benefit in keeping with the added cost. Also, it has been observed that in some cases modified asphalts are being used in lieu of proper construction practices, ie, dirty chips, cold weather, etc., when it is believed the modified binder can 'make up for' these deficiencies.

Objectives

Determine whether modified asphalt binders are cost effective for use as chip seal binders. Describe circumstances where modified asphalts should be used as a cost effective alternative to conventional asphalts.

Urgency

High, due to the significantly higher cost of modified asphalts.

PROBLEM #84: EFFECT OF OPEN-GRADED FRICTION COURSES ON POTENTIAL STRIPPING OF UNDERLYING ASPHALT CONCRETE LAYERS

In the recent past several states experienced stripping in the asphalt concrete layers underlying open-graded friction courses (OGFC). This led to a moratorium on the use of OGFC. Some of these states have now started to use OGFC again, but an antistripping (AS) agent is usually specified in the underlying layer. This phenomenon is now being experienced in some western states leading to a moratorium on the use of OGFC. It

is not clearly understood as to what factors are contributing to this phenomenon. These factors could be associated with:

- Gradation of OGFC (different states use different gradations);
- Construction techniques;
- Characteristics of the underlying layers especially permeability; and
- Climate, especially rainfall.

There is a need to determine the cause(s) of this stripping phenomenon so that proper remedial measures can be taken by all state Departments of Transportation using OGFC.

Objectives

Identify the states which have experienced or are experiencing stripping of asphalt concrete layers underlying OGFC; document the measures (including their effectiveness) taken by these states; evaluate the characteristics of OGFC and underlying layers, construction practices, and prevailing climatic conditions to determine common denominators possibly causing the stripping; and make recommendations to eliminate this problem.

Related Work

It is quite possible that some in-house research may have been conducted by the affected states. No known published report exists. Three NCHRP syntheses, Nos. 49 (1978), 104 (1983) and 180 (1992), can provide some general background information for this problem statement.

Urgency

There is an urgent need to study and remedy this phenomenon so that states can continue to use OGFC without experiencing pavement distress which necessitates the premature removal of OGFC and underlying layer(s).

PROBLEM #85: MATERIAL CHARACTERISTICS AND STRUCTURAL BEHAVIOR OF GAP-GRADED ASPHALT CONCRETE AND MODIFIED-ASPHALT CONCRETE SURFACE PAVEMENTS AND OVERLAYS

The three main classifications of aggregate gradation used in hot-mix asphalt concrete are dense, open, and gap. Many agencies are using increasingly dense-graded asphalt concrete mixes to minimize prevalent rutting problems. The resulting reduction in asphalt content and flexibility makes thin overlays less resistant to fatigue, reflective and temperature cracking, requiring costly increases in overlay thickness as a remedy. Gap-graded mixes allow higher binder contents and increased flexibility, and may increase resistance to rutting by improving stone-to-stone contact. In addition, the development of asphalt cement modifier enhances the feasibility of using gap-graded mixes for thinner overlays. However, specific available data regarding the material characteristics and structural behavior of thinner gap-graded overlays with neat asphalt cement and modified-asphalt binders are limited. Additional data are needed to determine the feasibility of using these gap-graded mixes for thin surface pavements and overlays.

Objectives

The objective is to evaluate the feasibility and limitations for use of gap-graded mixes as thin overlays to provide improved resistance to rutting and to reflective, fatigue, and low temperature cracking, with and without asphalt modifiers. Existing specific gap-graded pavement sections (with materials and test data available) should be identified and selected which respectively exhibit excellent, average, and poor performance levels. Material characteristics which may be performance indicators should then be identified by reviewing project data and testing samples from these existing pavement sections. Following modulus and fatigue testing, hypotheses should be developed and tested regarding effects of the identified material characteristics on laboratory mixes. Finally, structural relationships should be developed between gap and dense-graded mixes.

For purposes of this study, gap gradation bands are broadly defined below in terms of weight percent of aggregate passing critical defining sieves.

Sieve Size	For Nominal 3/8" and 1/2" Mixes	For Nominal 3/4" Mix
No. 4 (4.75 mm)	22 - 50	20 - 40
No. 10 (2.0 mm)	12 - 36	10 - 25
No. 30 (600 um)	5 - 20	5 - 15
No. 200 (75 um)	3 - 7	2 - 6

Related Work

Appears to be limited to studying SMA mixes, which comprise only a fraction of this intended scope.

Urgency

There is an urgent need for economy in pavement construction and rehabilitation, and for improving pavement performance.

Cost

\$350,000

User Community

FHWA, AASHTO, and other transportation agencies.

PROBLEM #86: EFFECTS OF MODIFIED ASPHALTS ON CHIP SEAL DESIGN AND CONSTRUCTION

Additives of all types are being used to modify asphalt cements and emulsions used as binders for chip seals. Design and construction techniques developed for conventional asphalt binders are being used to determine binder quantities and describe construction procedures. However, some of these binders do not behave like conventional asphalts with respect to proper spray temperatures, application rates, setting periods, or recommended environmental restrictions. It is likely that some of these more expensive binders are not being applied under optimal conditions. Therefore, performance of some of these special binders may not be as good as expected, not necessarily because of a fault of the material, but because of a lack of understanding about behavior in the field.

Objectives

Identify differences between design quantities of modified asphalts and conventional asphalts. Identify differences in construction techniques for modified asphalts and conventional asphalts.

Urgency

High, due to the significantly higher cost of modified asphalts.

A2D04 COMMITTEE ON CHARACTERISTICS OF BITUMINOUS PAVING MIXTURES TO MEET SURFACE REQUIREMENTS

The research problem statements appear in the order of priority established by the committee.

PROBLEM #87: DEVELOPMENT OF GUIDELINES FOR SELECTING THE CHARACTER OF OVERLAY MATERIALS FOR SMALL AGENCIES

Pavement life is affected by many factors besides the mix characteristics. Possibly the most significant is the interrelationship between loading-support characteristics and mix character. In most geographical areas, the state department of transportation is the only purchaser of asphalt mix with the expertise necessary to prepare a material specification. Smaller agencies then use the same specifications. The existing roadways of the smaller agencies probably have significantly weaker structures which carry fewer loads but deflect more under load than the major highways. Placing a stiff overlay over a flexible facility forces the overlay to carry a greater proportion of each load and resist environmental loads frequently causing early cracking.

Objectives

Develop a simple procedure for the small agency to use to determine the character of overlay mix to specify. The procedure must result in a mix with adequate stiffness to distribute the expected loading to the existing pavement structure while retaining sufficient flexibility of resist cracking from minor deformations and environmental stresses. Procedures must be applicable by a small agency. Factors needed include:

1. Method for determining stiffness of existing roadway.
2. Procedures for estimating frequency and magnitude of loads to be carried.
3. Procedure for determining mix characteristics for maximum performance based on information from 1 and 2.
4. Typical specification for overlay construction that will assure small agency of maximum benefit from expenditures.

Urgency

In many communities, half of the bituminous concrete tonnage produced is applied to small agency pavements.

Literally all pavement research has been oriented to heavily traveled facilities. If the annual work has 75 percent of the possible useful life, the wasted resources annually are well into millions of dollars.

PROBLEM #88: COMPREHENSIVE CONSTITUTIVE MODELING AND LABORATORY VALIDATION FOR ASPHALT-AGGREGATE MIXES

One of the greatest challenges in this field has been the capability of modelling asphalt concrete behavior in situ under traffic and environment. Existing models have some simplified assumptions and do not account for the combined effects of the different modes of distress. The permanent deformation model proposed by SHRP-A003A is the most comprehensive model proposed thus far, as it is capable of capturing dilation, stiffening due to confining stresses, viscous and plastic behavior. The model is not sufficiently general to represent asphalt mix behavior in a number of ways, as it does not account for:

- The change in behavior as the mixture reduces void content due to traffic densification;
- The dramatic change in behavior when air void content drops below 3 percent;
- Changes in fundamental properties due to aging;
- Changes in fundamental properties due to water sensitivity;
- Thermo-mechanical coupling;
- Failure due to fatigue;
- Fatigue due to thermal effects (not thermal cracking); and
- Coupling between cracking (fatigue) and the permanent deformation distress modes.

One of the factors that have limited the development of this comprehensive approach has been the speed of relatively low cost computers that can be made available to highway engineers. This limitation will no longer exist by the time this research effort is expected to end.

Objectives

Develop a comprehensive constitutive model for asphalt concrete capable of incorporating all those aspects of

mix behavior and demonstrate its predictive capabilities in controlled laboratory validation experiments. Efforts should be undertaken in which such a model is developed and implemented in a nonlinear three dimensional finite element program. The development of this research effort should include four stages:

1. Develop a model and adequate test procedures that can accurately predict material behavior. This might require complex and tedious testing which may not be practical for routine use. In this first stage the driving criterion should be the accuracy of the model capabilities to define material response, not ease of implementation.

2. Design and implement laboratory tests using a wheel track device where the predictive capabilities of the model can be demonstrated for a wide range of conditions (traffic loads, contact stress, aging, loading rate, effects of water, etc.).

3. Determine the minimal test procedures and corresponding data reduction program needed to obtain material properties for routine testing. Full advantage should be taken of computer capabilities to minimize user efforts.

4. Incorporate this constitutive model in a commercially available and effectively maintained and supported finite element program that can be obtained by highway engineers for routine use. The code should be sufficiently flexible so that constitutive laws for base, subbase and subgrade materials could be added.

Key Words

3D finite element program, wheel track, fundamental properties, dilation, viscosity, plasticity, non-linearity, damage mechanisms, laboratory testing.

Related Work

SHRP-A003A proposed a three dimensional finite element program to predict permanent deformation behavior. The approach in modelling, determination of fundamental properties and validation should be extended to incorporate other distress mechanisms. The fatigue model developed by Dr. L. Seaman of the Stanford Research Institute has the potential to tie with the 3D constitutive formulation of SHRP A-003A model. The aging and water sensitivity procedures developed at Oregon State University under SHRP A-003A have the potential to provide the basis for an adequate platform providing that the tests executed in the conditioned mixes can yield fundamental properties.

The work developed under thermal cracking in SHRP A-003A and SHRP A-005 can provide a basis for modelling. The SHRP effort has generated data bases of mix properties that can be used.

Urgency

This work should have the highest priority. The SHRP work has provided an excellent start for this innovative and comprehensive approach in modelling asphalt mixes. The facilities, personnel, know-how, and momentum are now in place to provide a basis for this research. The pay-off from a successful implementation of such a model dictate the urgency of this endeavor.

Cost

The estimated level of effort would be \$600,000/year for four years. In this estimate it is assumed that the researchers already have access to adequate testing equipment.

User Community

This statement should be received by NCHRP, FAA, FHWA, AASHTO, USACE-WES

Implementation

The outcome of this research effort should be an easy-to-use 3D finite element program that could be made available to the different agencies involved in the design of asphalt concrete pavements. Training seminars could be held after the research is terminated for key personnel in the different organizations. Furthermore, new sets of test procedures should be made available to the different agencies (that by then will have received the UTM provided under the Pooled Fund Project) so that they can use them to obtain the material properties required by the model. Implementation of such a model and test procedure should not be difficult providing that the research proves fruitful and the expected products are designed having the user in mind.

Effectiveness

A successful project completion and implementation of this project will have a significant impact on pavement

design, pavements material testing and in overall performance on the pavement structures. With such a procedure in place "what if" statements can be effectively addressed and new materials, i.e. with modifiers or recycled components (glass, rubber, etc.), can be accurately evaluated and placed with a high degree of confidence.

PROBLEM #89: INVESTIGATION OF THE EFFECT OF PLANT MIXING AND FIELD COMPACTION METHODS ON THE PERFORMANCE OF ASPHALT CONCRETE PAVEMENTS

SHRP A-003A research has demonstrated that gyratory, rolling wheel and kneading compaction procedures produce specimens with widely varying resistance to permanent deformation. Kneading compacted specimens can exhibit resistance to permanent deformation several orders of magnitude higher than gyratory compacted specimens. It is very likely that the same is true for asphalt concrete layers compacted with steel rollers, pneumatic tire rollers, vibratory rollers and even sheep-foot rollers. Furthermore, a doctoral dissertation by J. Harvey titled, "Mix Design Compaction Procedures for Hot-Mix Asphalt Concrete and Rubber-Modified Asphalt Concrete Mixtures (UCB 1992)" has demonstrated that other factors such as the mixing and compaction temperatures have significant effects on the final performance of the mix. Pavements are usually compacted to initial void contents of 5 to 8 percent. As the mix densifies with traffic its void content decreases, resulting in increased resistance to permanent deformation and fatigue cracking (unless the void level drops below 3 percent with the possibility of the development rutting). In some cases traffic densification prematurely causes the mix to reach void levels below 3 percent.

Objectives

The objective is to identify if there is an "optimal" plant mixing and field compaction procedures that would yield better performing pavements. Several pavement sections should be built using different compaction techniques including a compaction technique that would simulate the aggregate structure created in the laboratory by the kneading compactor. Pavements should be constructed to different void content and their densification and distress mechanisms monitored under traffic. Cores from the pavement should be tested in the laboratory as

densification develops. The test protocols proposed by SHRP A-003A should be used to periodically evaluate permanent deformation and fatigue characteristic of the mixtures with variation of the void content for each of the pavement sections.

Modelling and field validation will demonstrate which are the best mixing plant and field compaction techniques. A screening of several variables should be done by small scale laboratory testing of slabs using a wheel track device prior to building the field pavement section. The slabs could be fabricated in the laboratory or in the field by similar compaction techniques.

Key Words

Traffic densification, aggregate structure, permanent deformation, fatigue, laboratory testing, sheep-foot roller compactor, high pressure pneumatic tire roller compactor, vibratory compactor.

Related Work

Some work has been done in France, in Portugal by C. Azevedo of the National Laboratory of Civil Engineering, and in the U.S by J. Sousa, and J. Harvey at UC Berkeley and at TTI by D. Little.

Urgency

This work should have high priority. The SHRP work has provided an excellent start for this innovative and comprehensive approach in modelling of asphalt mixes. However great pay-offs can be expected from improving mixing plant and compaction techniques. These pay-offs dictate the urgency of this research endeavor.

Cost

The estimated cost of the project would be about \$500,000/year for five years. It is expected that this project would be done in conjunction with the State DOTs and other groups that would provide the pavement section built to the specifications of the research team.

User Community

FHWA, AASHTO, FAA, and USACE-WES.

Implementation

The outcome of this research effort should be detailed plant mixing and field compaction techniques. If improved performance is clearly demonstrated, then cost effective implementation can simply be accomplished by appropriate changes in the project specifications.

Effectiveness

If the research findings are successfully implemented they will have a significant impact on overall pavement performance.

A2E03 COMMITTEE ON MECHANICAL PROPERTIES OF CONCRETE

The research problem statements appear in the order of priority established by the committee.

PROBLEM #90: OPTIMUM PERCENTAGE OF SILICA FUME IN CONCRETE FOR BRIDGE DECKS AND CHLORIDE PERMEABILITY OF CONCRETE CONTAINING SILICA FUME

Silica fume concrete has become a widely accepted material for providing protection to concrete structures from chloride ingress. This widespread use has been based almost exclusively on ASTM C1202, an electrical method which provides an indication of a concrete's ability to resist chloride ion penetration. To determine actual chloride permeability with this method, however, requires correlative data to actual chloride permeability testing. The ASTM method states that the method is "applicable to types of concrete where the correlations have been established between this test procedure and long-term ponding procedures."

This research should examine several levels of silica fume modification, for example, 7 percent, 10 percent, and 15 percent, in concrete with several water-cement ratios and compared to control concretes at the same water-cement ratio. Testing should compare results from ASTM C1202 and AASHTO T259 to determine the relative impact of water-cement ratio and silica fume content on chloride permeability.

In the past several years, a number of cases have been reported where silica fume concrete used for bridge decks has shown extensive cracking. Generally, the percentage of silica fume used in these concretes has been more than 10 percent. Some researchers have attributed the occurrence of cracking to the high percentage of silica fume used in the concrete. Others have disputed this explanation. Thus, it is important that a thorough and systematic study be performed to explain the above cracking problem.

Objectives

The objectives of this research are to determine the influence of silica fume on the chloride permeability properties of concrete and to establish the optimum amount of silica fume that should be used in concrete bridge decks.

Key Words

Silica fume, concrete, bridge decks, optimum percentage, chloride permeability.

Related Work

There are very few reports on the chloride permeability performance of silica fume concrete as measured by a ponding test. Most of the testing has been done by ASTM C1202 test, an electrical method which requires ponding data in order to correlate its results to permeability. No research has been done to show the relation between cracking and silica fume content.

Urgency

Silica fume concrete has been, and is continuing to be widely used as a concrete with superior chloride impermeability properties. The widespread use has been based almost exclusively on the ASTM test method, without any correlative data to actual chloride permeability testing. Owners of bridges, parking garages, and structures that are relying on a certain chloride impermeability performance need to know that they are buying that protection and that cracking will not be a major concern.

Cost

\$500,000 (Actual bridge deck to be constructed and monitored)

User Community

AASHTO/FHWA

Implementation

By effective technology transfer.

Effectiveness

The benefits will be enormous because it will eliminate costly repairs.

PROBLEM #91: MECHANICAL PROPERTIES OF CONCRETE CONTAINING POZZOLANS

Pozzolans and ground slag are being used in concretes prepared with cements with an alkali content greater than 0.4 (ASTM C 114). The replacement of cement with pozzolans and ground slag reduces the early age strength development, particularly when the concretes are cured at low temperatures.

The age at which rehabilitated concrete pavements and bridge decks are opened to traffic, and the length of the season over which repairs can be done, usually are controlled by the compressive strength of concrete cylinders made from the repair materials and cured at ambient temperature. The minimum strengths that are specified are believed to be adequate to withstand the maximum stress that the repair will be subjected to at an early age, but not so high as to require uneconomical mixture proportions, unreasonable lane closure times or restrictions on construction. Unfortunately, there is very little information on the early age mechanical properties of concretes made with pozzolans and ground slag to aid the engineer in making a reasonable decision.

Research should be directed to the collection of data on the early age mechanical properties of concretes containing pozzolans and ground slag and cured at temperatures below 75°F as determined by a number of methods, including, but not limited to nondestructive tests, compressive tests on cores, compressive tests on cylinders cured by temperature matched curing, or at ambient temperature, and flexural, tensile and bond tests on specimens cured under different conditions. The relationship between these methods should be studied.

Objectives

The objective of this research is to develop data on the early age mechanical properties of typical highway concretes containing pozzolans and ground slag and cured at less than 75°F.

Key Words

Cold weather concreting, pozzolans, ground slag, hydraulic cement concrete, mechanical properties,

compressive strength, concrete maturity.

Urgency

The rehabilitation of concrete pavements and bridge decks has increased in recent years and is now a major part of the construction and maintenance expenditures of transportation agencies. The research is urgently needed so that money is not wasted through specifying higher than needed early strength materials and mixture proportions or by damaging repairs by loading them prematurely or not curing them adequately. It is difficult to quantify the benefits from the research. The research should lead to more economical repair mixtures and construction procedures, to more reasonable lane closure time and to a reasonable compromise between early needs and long-term performance of concretes containing pozzolans and ground slag and cured at temperatures below 75°F.

Cost

\$200,000

User Community

AASHTO/FHWA

Implementation

Technology Transfer

Effectiveness

Transportation officials can plan construction activities and design mixtures to minimize damage caused by loading concrete that is not properly cured.

PROBLEM #92: REMOTE FIBER OPTIC SENSING OF DEFORMATIONS IN CONCRETE

Usual techniques of strain and deformation measurements in concrete, reinforcement and structural steel elements have inherent difficulties due to losses and inaccuracies once these readings are taken at remote locations such as one to three miles from site.

Objectives

Use of fiber optic sensors can eliminate the strain loss problems while simultaneously enable readings at different locations of the structure.

Key Words

Crack width, deformation, measurements, optic sensors, remote sensing, strain.

Related Work

Related work is in progress at Rutgers University under an NSF Grant. The research is undertaken jointly by the Rutgers Department of Civil/Environmental Engineering and the Rutgers Fiber Optic Center. Results thus far are encouraging and warrant embarking on field ruggedization and testing in bridge decks.

Urgency

The deteriorating infrastructure and the possibilities of unexpected failures demand swift monitoring and remote sensing of deterioration and impending failures.

This should be a top national priority demanding full attention.

Cost

Estimated cost over a three year period is \$675,000

User Community

AASHTO/APTA/FHWA/NHTSA

Implementation

Surface mounting or ruggedized sensing on existing structures and embedment in new construction bridges and other facilities.

Effectiveness

Successful implementation of the proposed high-tech techniques will result in effective control of existing transportation infrastructure, preventive measures to arrest deterioration and, as a result, the elimination of catastrophic failures.

A2E05 COMMITTEE ON CHEMICAL ADDITIONS AND ADMIXTURES FOR CONCRETE

The research problem statements appear in the order of priority established by the committee.

PROBLEM #93: USE OF FLY ASH, SILICA FUME, BLAST FURNACE SLAG, AND OTHER WASTE MATERIALS AND BY-PRODUCTS AS ADMIXTURES TO PREVENT EXCESSIVE EXPANSION OF PORTLAND CEMENT CONCRETE DUE TO ALKALI AGGREGATE REACTION

Alkali reactive sands or coarse aggregates when used in concrete produce severe deterioration. Alkali-silica reactivity (ASR) is responsible for the premature failure of thousands of kilometers (miles) of portland cement concrete pavement. The potential ASR problem has gained a lot of attention from FHWA engineers, product suppliers and state highway departments in nearly every state. The identification and control of reactive aggregates has become important in recent years. The reaction between these aggregates and cement has been the primary focus of existing test methods and specifications. Little or no work has been done to establish what effect, if any, does the composition of concrete admixture have on this problem.

Objectives

Determine the effect of concrete admixtures on the reaction between cement and a reactive aggregate.

Key Words

Alkali silica reactivity, alkali carbonate reactivity, high alkali cement.

Related Work

Test methods and specifications are being developed to identify reactive aggregates and control their use in concrete structures. Specific chemical compounds have been identified as essential in order for the reactive gel to form. This information can be utilized in the proposed study.

Urgency

This project is extremely important if we are to identify and eliminate all sources of reactive aggregate problems.

Cost

\$350,000

User Community

AASHTO, ASTM, FHWA, PCA, ACI, NAS, NRMCA

Implementation

The results could be developed into a specification. Guide lines and recommendations could be developed for the selection of proper type and quantity of admixtures to reduce excessive expansion due to ASR.

Effectiveness

The results of this study could help eliminate premature concrete deterioration when reactive aggregates are used.

PROBLEM #94: EVALUATION OF "ANTI-FREEZE" ADMIXTURES FOR PORTLAND CEMENT CONCRETE HIGHWAY APPLICATIONS

Placement of concrete in northern areas is restricted to temperate seasons of the year because portland cement will not hydrate and gain strength under freezing conditions. While it is often said that there is no "anti-freeze" for concrete, developments have been made in the former U.S.S.R. and eastern European countries and the technology is beginning to be transferred to the U.S. Chemicals used in such formulations include sodium

and calcium nitrates and nitrites, carbonates, and ammonium compounds. Definitive studies on the performance and durability of concretes prepared using these admixtures are virtually nonexistent. The limits of their use need to be better defined.

Objectives

1. To evaluate the effect of anti-freeze admixtures on important properties of concretes made using these materials. These would include rate of compressive and flexural strength gain, drying shrinkage, freeze-thaw durability, permeability, resistance to deicer scaling, creep, modulus of elasticity, and effects on susceptibility to alkali-silica reactivity and sulfate attack.

2. To examine the limits of applicability of these materials with regards to temperature of concrete and ambient conditions of placement.

Key Words

Concrete, admixtures, cold weather, strength, durability, mechanical properties, corrosion.

Related Work

Available information concerning concrete anti-freeze admixtures is summarized in a report prepared by Korhonen for the U.S. Army Corps of Engineers (CRREL Special report 90-32). Almost all documentation regarding these admixtures is contained in Soviet and East European literature. Verification using U.S. materials and conditions is needed.

Urgency

We will most likely soon see the introduction of anti-freeze materials into the U. S. market. User agencies will require guidance on these materials in addition to that supplied by the manufacturers. This unbiased information can then be used to select the materials most appropriate to the planned applications.

Cost

Estimated cost is \$400,000 over 3 years to review existing information, select systems for development, and test long-term properties of concretes prepared with the admixtures at various temperatures.

User Community

AASHTO, NCHRP, FHWA.

Implementation

The findings of the research may be used to provide highway engineers with data on admixture systems which can be used to place concrete under severe winter conditions where it is currently not possible to maintain concrete temperature within acceptable guidelines.

Effectiveness

Successful completion of this problem will allow repairs of pavements and structures that otherwise may have to be postponed until milder weather, resulting in detours or temporary measures being taken which might cause traffic delays or present unsafe situations.

PROBLEM #95: USE OF MUNICIPAL SOLID WASTE FLY ASH IN CONCRETE

Large amounts of solid waste fly ash have accumulated and continues to accumulate as waste-to-energy plants become more common as a method of waste disposal. The problem raised is to what extent can these ashes be usefully applied in concrete and what precautions, if any, must be observed.

Objectives

To establish to what extent and under what circumstances these ashes can be applied usefully as admixtures in concrete.

Key Words

Incinerator ash, municipal solid waste, fly ash, admixture.

Related Work

Considerable work has been done in the area of useful application of incinerator ashes, although not necessarily directed towards the objective of the proposed study. However, the available information could form a solid foundation for further studies.

Urgency

The accumulation of solid waste and fly ash produced in waste-to-energy plants are increasing at a rapid rate and will soon in many areas reach detrimental proportions.

Cost

\$300,000

User Community

AASHTO, ASTM, FHWA, PCA, ACI, NAS, NRMCA

Implementation

The result of the investigation shall be presented in:

1. A material acceptance specification; and
2. A material construction specification.

Effectiveness

The result of this investigation would serve two purposes:

1. The reduction of harmful waste to a reasonable amount; which
2. Can be usefully applied in the building and construction industries.

A2E06 COMMITTEE ON BASIC RESEARCH PERTAINING TO PORTLAND CEMENT AND CONCRETE

The research problem statements appear in the order of priority established by the committee.

PROBLEM #96: ROLE OF FLY ASH, SILICA FUME, BLAST FURNACE SLAG, AND LITHIUM SALTS IN REDUCING EXPANSION DUE TO ALKALI-SILICA REACTION IN CONCRETE

In the early 1940s, the problem of alkali-aggregate reactivity was brought to the attention of the engineering community in the USA. Briefly, the problem was created by the reaction between certain susceptible aggregates and the alkalis from the cement. Subsequently, this problem was solved, to a major extent, by the use of low alkali cements. However, in recent years, the problem has once again become serious in the Eastern seaboard, New Mexico, and parts of California, and elsewhere. The reason for this appears to be due to the use of cements with higher alkali contents, marginal aggregates and the increased use of deicing salts on highways. This problem is more acute in transportation structures as compared to structural concrete.

Objectives

The specific objective of this research is to determine the percentages of fly ashes, slags, silica fumes, and lithium salts, which can be used in concrete, and which will reduce the long-term expansion due to alkali-silica reaction to acceptable levels.

The expected benefits of the proposed research will result in the control or elimination of the distress in concrete structures due to alkali-silica reaction, and thus save millions of dollars in remedial and restoration works.

Key Words

Alkali-aggregate reaction, fly ash, blast-furnace slag, silica fume, lithium salts, concrete, expansion.

Related Works

Some laboratory investigations were carried out on the effectiveness of lithium salt admixtures to minimize expansion due to alkali-aggregate reaction by D. Stark as part of the SHRP program, and these salts have also

been used in a test section of highway, along with fly ash. Prof. Carresquillo, has also investigated the effectiveness of fly ash to counteract expansion due to alkali-silica reaction in laboratory experiments. Currently, long-term field studies are being conducted in Canada by CANMET, EMR, Ottawa, and the Ministry of Transportation of Ontario.

Urgency

The proposed research needs to be carried out on an urgent basis, because the problem of alkali-silica reaction has become serious in a number of areas, especially on the Eastern seaboard, and a number of agencies are using fly ash, or blast furnace slag, or silica fume, with insufficient information as to their long term effectiveness in minimizing expansion.

Cost

On the basis of experience with ongoing projects the estimated cost of the proposed program is \$500,000.

User Community

Principally ASHTO and FHWA.

Implementation

By providing the results of this research to specification writers, and to the standardizing such as bodies, ASTM, ASHTO and ACI so that the developed information can be incorporated into the relevant clauses by these organizations.

Effectiveness

The successful implementation of the results of this research would result in considerable savings on repair and maintenance of highway structures in the future. The funds saved on repair by the state highway authorities could be diverted to other programs.

A2F01 COMMITTEE ON RIGID PAVEMENT CONSTRUCTION AND REHABILITATION

The research problem statements appear in the order of priority established by the committee.

PROBLEM #97: TEXTURING OF PORTLAND CEMENT CONCRETE PAVEMENTS

Achieving a proper texture (transverse or longitudinal) on PCC pavements is a very sensitive art. Surface texture impacts ride quality, noise, and safety. Texturing of PCC pavements over the past 20 years has generally been transverse tining.

The original purpose of transverse tining of concrete pavements was to enhance safety. Tining began in earnest in the late 1970's when the emphasis was on safety. Early skid testing seemed to indicate that transverse tining increased skid resistance. Some states did not agree and continued to this date to longitudinally texture concrete pavements. Recent studies show that tining or burlap drag (or other such texturing) produces the same skid numbers using the standard skid testing equipment. Perhaps tining does not provide the service expected by state agencies.

Deep tining (in some instances as deep as 1/4") has a dramatic impact on ride quality. Tine spacing influences road noise (whirr) and consequently perceived roughness. Surveys indicate that the traveling public on highways judge the pavement quality by the ride quality. This is consistent with the fact that over half of the State DOTs are using ride specifications with incentives for PCC pavements. The news is not all good. There is no nationwide standard for tine depth or spacing, and achieving what is specified varies within a project.

The skid, noise, and ride trade-offs are further compounded by the fact that vehicles and tire designs have improved since the late 1970's. All-season treads, radial tires, and anti-lock brakes are all significant vehicle changes. These improvements have probably done more for vehicle stability and stopping than surface texture, which has undergone no improvements.

Many state officials are concerned with pavement noise. Tine spacing and depth impact noise levels, especially at high speeds. Judging from the lack of uniform tine application, the research in this area seems to be incomplete. For those citizens who live near a highway, noise is a significant factor.

There is obviously support for a safe pavement surface. Pavement texture requirements should be equitable for all types of pavements. The need for tining concrete pavements should be based on quantifiable

data, not a feeling. In view of the heightened sensitivity toward ride, noise, safety, and vehicle changes, pavement texture is a critical issue that needs new research.

Objectives

The research objectives would be specifically designed to evaluate the trade-offs regarding ride, noise, and safety as follows:

1. To assess current details for texturing;
2. To develop design and construction parameters for texturing;
3. To develop alternative methods for texturing;
4. To develop remedial procedures for existing pavements; and
5. To construct a major test section to evaluate various texturing designs.

Related Work

There is no known activity on this problem in the U.S. An exposed aggregate system is being evaluated in Europe.

Urgency

There is urgent need for this research since the issues of ride, noise, and safety are very important to public perception of quality; and since there have been major advances in vehicle designs, new data is needed on a nationwide standard for pavement textures. New standards are needed now.

Cost

\$350,000

User Community

AASHTO, FHWA and other transportation agencies.

PROBLEM #98: CONSTRUCTABILITY OF DRAINAGE SYSTEMS UNDER PCC PAVEMENTS

Many agencies in the past have designed concrete pavements that were essentially surrounded by in-situ materials with low permeabilities. These designs trapped water within the pavement system and were dubbed "bathtub" designs. In an attempt to resolve the "bathtub" effect and reduce or eliminate pumping and faulting, there are several drainage designs being tried. Some are almost impossible to construct with conventional paving equipment and they vary in permeability.

Objectives

Much as been learned about the detrimental effects of water to pavements systems. "D" cracking, loss of support, settlements, and joint deterioration have all been attributed, at least in part, to water. In an effort to halt the design and construction of "bathtub" pavements, specifying agencies have used edge drains and permeable base layers to provide a means to remove water from beneath the pavement. Constructability technology for these drainage systems has lagged behind material technology. As more and more agencies specify permeable base materials, issues concerning the ease of construction of these systems must be addressed.

There is a need to evaluate the various drainable base designs in view of current paving equipment and to determine the best design compatible with construction techniques. This is essential if we are to continue stressing ride quality which can be impacted by the stability of drainable bases.

Related Activities

There exists no known research activity. Many contractors have experimented by trial and error with construction techniques of drainable bases, and some good information may be available.

Urgency

Resolution to this problem would encourage proper drainage designs to be included in new and rehabilitation projects. The goal is cost effective systems. The demand for drainage systems in new and rehabilitation projects is high.

PROBLEM #99: CEMENT STABILIZED OPEN-GRADED BASES UNDER PCC PAVEMENTS

In many drainage designs untreated or asphalt treated open base course materials are used as layers. Cement stabilized open graded base course appears to offer distinct advantages over untreated or asphalt treated base course, especially during the construction phase.

Objectives

Research is needed to determine optimum cement content (or strength) to support construction traffic, optimum gradation for drainage, properties for design of overlying pavement (K, E, etc.) and optimum thickness.

Related Work

There is no known research activities. Some field experience is available, but design parameters have not been established.

Urgency

Resolution to this problem would encourage cost effective drainage designs under PCC pavements that are effective in removing water from the pavement and permit ease of construction.

PROBLEM #100: GUIDES AND SPECIFICATIONS FOR "FAST-TRACK" CONSTRUCTION OF PCC PAVEMENTS

For the last 50 years, portland cement concrete roads have been constructed mostly on new roadway grades closed to everyday traffic conditions. Opening the pavement has typically been based on 14 day or 28 day strengths. Available construction equipment has not allowed placement of lanes adjacent to traffic lanes. Today's reconstruction and rehabilitation needs include overlays and additional travel lanes under traffic. These needs mandate the use of "Fast Track" construction of concrete pavements to improve cost effectiveness and convenience to the traveling public and construction personnel.

The first "Fast Track" experimental project was constructed in 1986 in Iowa. Since that time, many other

projects have been built, and much has been learned. The early results of these projects prompted the FHWA to form Special Project 201 (SP 201) to determine solutions to several items, such as opening to traffic criteria, temperature management, etc. SP 201 was a partnership between the States, FHWA, universities, and industry. This has been a successful venture, but writing guides and specifications were not within the mission of SP 201, and they are needed.

Objectives

Identifying "Fast Track" materials and techniques to allow concrete pavement construction to be performed with the least closure time to traffic is in the public interest.

While some States have used "Fast Track" specifications to construct limited projects within their jurisdiction, questions remain on what is the best procedures available in areas such as design, thickness, mix designs, curing, opening, etc. Even more critical is the concept of "Fast Track" project management. In view of the activities since 1986, the objectives of this research would be as follows:

- A synthesis of past and current activities.
- Develop "Fast Track" project management guides.
- Develop Construction Guide Specifications.
- A report on constructability procedures.

Related Work

Projects have been constructed. A variety of specifications exist; standards do not.

Urgency

This research would result in the more efficient use of PCC pavement under traffic conditions and would result in the least inconvenience to the traveling public. National guidelines would enhance quality, reduce conflicts, and expedite project development.

PROBLEM #101: LONG-TERM DURABILITY OF PCC PAVEMENTS

When applied stress remains below 50 percent of the tensile stress capacity of concrete, damage does not

occur. It is reasonable to be able to design a concrete pavement with sufficient tensile stress capacity that it is not damaged by normal (legal) loadings. The durability of such a pavement can be considerably longer than conventionally design pavements. There are also quality construction parameters that effect durability.

Objectives

Develop design and construction parameter which will allow the construction of concrete pavements which can be maintained for long time periods (say 40 - 50 years).

There is no guide for long-term durability of PCC pavements that include both design and construction issues and their relationship one with the other. Many issues are interrelated. Some trade-offs may be desirable. A report on these issues will provide a more cost-effective long performing PCC pavement.

Related Work

Pennsylvania and Texas have several miles of 15" thick Portland Cement Concrete jointed pavement which likely approximates a theoretical design for longer life. Also, the European Concrete Pavement Study Tour revealed unique designs that have anticipated 40+ year life.

Urgency

This could be used to address heavy hauling corridors including interstate highways to lower life cycle cost and investment. The effect would be to decrease the drain on highway taxes by developing a more cost effective strategy. In addition, there are national leaders suggesting 120,000 pound loads in order to compete on a global basis.

PROBLEM #102: BONDING REQUIREMENTS OF PCC OVERLAYS ON EXISTING PCC PAVEMENTS

The bond strength between a concrete overlay on an existing concrete pavement is critical to their performance. How to achieve this bond and measure it has been debated for several years. Do you use grout, or not? What bond strength is required? How to effectively clean the surface? While some information is available and SHRP SPS-7 may respond in the future to these questions, answers are needed now.

Objectives

To develop a bonding system that is above all else reliable under a variety of climatic conditions. The research would include:

- A review of past and current projects.
- A synthesis of guides available.
- Develop a bonding system.

Related Work

Very little effective research has been done. Experimental projects have established a good database that needs to be studied.

Urgency

A bonded concrete overlay is an effective rehabilitation strategy that would be used much more often if a design engineer was confident it would bond together and last.

PROBLEM #103: PERFORMANCE OF THIN (LESS THAN 7 INCHES) PCC PAVEMENTS

There seems to be a critical minimum thickness of concrete pavements for acceptable performance. However, by reducing this thickness and ensuring proper support, a thinner pavement may be possible, especially if used under mild loading conditions. In this way, concrete pavements may be more cost effective.

Over the past several years, Iowa counties have placed nearly 300 miles of county road pavements in the range of 4" - 7". In September, 1991, an experimental 2" and 3 1/2" thick PCC pavement was placed over asphalt on an access road to a land fill in Louisville, Kentucky. The performance of these pavements have far exceeded

expectations (the 2" at Louisville jointed at 2' x 2' squares has received over 800,000 E-18's and continues to perform well). Bonding of concrete to asphalt and short joint spacings have substantially reduced pavement stresses (measured by strain gages) and many perceived constructability issues have been resolved. This is an emerging technology that warrants more research.

Objectives

To research the possibility of reducing PCC pavement thickness and establish what circumstances govern its use. The research would include both design and construction issues as follows:

- Review past and current projects.
- Develop design criteria for 2" and up thicknesses.
- Develop jointing patterns.
- Evaluate constructability issues, such as mix designs, use of fibers, ride, sawing, etc.
- Develop handbook.

Related Work

Presently engineering judgment and past experience is used. No consideration for risk and cost effectiveness is taken into account for thin overlays of both asphalt and concrete.

Urgency

The best, long-term surface for low-volume roads and city streets is a critical decision under current funding constraints. It is essential that procedures be developed that assist the pavement selection process in obtaining the most cost effective, life-cycle system for low-volume roads and streets.

A2F05 COMMITTEE ON CONSTRUCTION MANAGEMENT

The research problem statements appear in the order of priority established by the committee.

PROBLEM #104: QUANTIFICATION OF QUALITY

Quality in the design and construction of our transportation system has been recognized as an issue of national importance. Consequently much attention is now being focussed on continuous quality improvement initiatives. However, quality remains difficult to define and measure, without quantification quality will continue to be a largely subjective concept. Methodologies need to be developed for quantifying and measuring quality.

Objectives

The objective of this research is to develop guidelines for quantifying and measuring quality in design and construction of transportation projects. The guidelines should identify the various aspects of quality and suggest procedures for quantifying the components making up a total quality product.

Key Words

Quality management, quantification measurement, design and construction.

Related Work

There are many quality improvement initiatives underway. Research in the area of statistical acceptance procedures is relevant to this problem.

Urgency

The national goal of continuous quality improvement is seriously handicapped by the absence of a system for quantifying and measuring quality. With a methodology for measuring quality, performance cannot be monitored. The effectiveness of managerial decisions cannot be determined. The need for quantification is urgent.

Cost

\$150,000 to \$200,000

User Community

AASHTO, FHWA, ASCE, AGC

Implementation

The results of this study should be distributed as a synthesis of current practice.

Effectiveness

Implementation of the guidelines for quantifying and measuring quality will provide managers with the tools required to evaluate quality improvement initiatives. Accurate measurement of project quality is an essential prerequisite to achieving continuous quality improvement.

PROBLEM #105: IMPROVEMENT OF SAFETY ON HIGHWAY CONSTRUCTION PROJECTS

Poor safety on highway construction projects is very detrimental to all parties involved. The results of poor safety are human injury, property losses, project delays, increased costs of insurance for all, and costly legal claims. While many other industries have made great strides in construction safety, the highway industry still lags behind. Although a lot of effort has been devoted to work zone safety, research is needed to identify key safety problems in other construction operations and possible solutions.

Objectives

Data will be collected to identify the major types of safety problems on highway construction projects, possible causes, and associated costs. This data will be obtained via surveys and interviews with highway contractors, transportation agencies, and insurance companies. Details will also be sought on effective contractors safety programs, for both highway contractors and for contractors in other industries with good safety records. Recommendations will be developed to improve the safety of highway construction operations.

Cost

\$200,000 for two years.

Implementation

The results of the research will pinpoint major areas of highway construction needing safety improvement plus programs to implement by contractors or Departments of Transportation to promote better safety in their operations. Transportation agencies may also use the results to develop safety criteria as part of their contractor prequalification process. Special problems needing more research to find safer construction techniques will also be identified.

PROBLEM #106: DISTRIBUTION OF RISK SHARING ON HIGHWAY CONSTRUCTION CONTRACTS

Construction is a high risk business and contractors understand that they must assume this risk if they want to obtain contracts for projects. Owners and designers also have risk, but traditional highway construction contracts assign a large portion of the risk to the contractor. With the high cost of insurance and the difficulty of obtaining either bonds or insurance on high risk projects, contractors and insurance agents feel that DOTs and designers should share more in the risks. This would require a review of existing contract systems, and evaluation of current assigned risks, and the development of possible revisions to balance the risks.

Objectives

An evaluation would be made of the contract systems used by transportation agencies for both design and construction with emphasis on the allocation of risks and the associated costs. Input will also be sought from transportation officials, designers, contractors, and insurance professionals concerning possible revisions to existing contract systems and the expected impact. Recommendations would then be developed for possible contract revisions which would more equitably assign risk to the appropriate parties to help reduce adversity on projects.

Cost

\$225,000 for two years.

Implementation

Transportation agencies could utilize the findings of the research study to evaluate their own construction and design contract systems for possible revisions. If implemented successfully, the potential exists for lower insurance costs, lower project costs, less contract disputes and claims, plus a more cooperative team approach to the building of transportation facilities.

PROBLEM #107: ALTERNATIVES FOR BONDING OF HIGHWAY CONSTRUCTION PROJECTS

Obtaining surety bonds for highway projects remains a problem for several contractors, especially small and/or minority contractors. Obtaining bonds on projects involving hazardous wastes is also difficult, if not impossible, for any size contractor. There are currently several alternatives to traditional surety bonding procedures being proposed or under consideration by several government agencies. Some of these alternatives include: individual surety associations, complete or partial waiver of bond requirements for certain types of projects, raising the Miller Act threshold for bonds on Federal construction contracts, and increased use of collateral in lieu of a surety bond. More in-depth study is needed of all of these proposed alternatives to evaluate the full impact of implementing them into practice on all the parties involved.

Objectives

Alternative methods to traditional surety bonds for highway construction projects will be identified by contacts with government agencies, surety associations, contractor organizations and transportation agencies. An in-depth evaluation of each proposed alternative will be made to assess the impact of its implementation on owners, contractors, suppliers, and sureties. Special emphasis will be given to risk sharing, financial impact, and the difficulties of implementation.

Cost

\$100,000 for one year.

Implementation

The results of the research would serve as a guideline

for transportation agencies who are considering alternatives to traditional surety bonding for their construction projects. It would also allow agencies to consider special programs to enable small and/or minority firms to qualify for their construction projects. Guidelines would also be provided for risk protection on the increasing number of projects involving hazardous wastes.

PROBLEM #108: IMPACT OF TRANSPORTATION AGENCIES ASSUMING MORE LIABILITY ON HIGHWAY CONSTRUCTION PROJECTS INVOLVING HAZARDOUS WASTES

Hazardous wastes are causing serious problems on highway construction projects. When encountered, special and expensive methods must be used for handling and disposal. Contractors virtually cannot obtain bond or insurance coverage for hazardous wastes on their projects since sureties and insurance companies will not assume the risk. They have to raise their bid prices to very high levels to protect themselves or simply ignore this type of work. It appears that one alternative would be for transportation agencies to assume some of this liability on their projects to avoid unreasonable prices.

Objectives

Current practices used to handle hazardous wastes encountered on highway projects will be studied with special emphasis on the assignment of liability to the parties involved. Data will be collected through literature reviews, plus surveys and interviews with transportation agencies, highway contractors, sureties and insurance companies. Alternatives will be studied and the impact assessed for distributing the liability, especially for larger roles by transportation agencies. It would still require that contractors be liable for their own actions on projects.

Cost

\$100,000 for one year.

Implementation

If deemed feasible for transportation agencies to assume more liability for hazardous wastes, then the methods identified could be implemented as special provisions in

construction contracts. The result could be more qualified bidders on highway projects with hazardous wastes, plus the potential for more competitive prices and fewer contract disputes.

PROBLEM #109: AUTOMATED CONSTRUCTION FIELD DATA MANAGEMENT SYSTEMS

A recently completed research project for the Indiana Department of Transportation (INDOT) revealed that the inspector and project engineer on construction projects spend 4-5 hours daily processing paperwork. Based on existing trends of increased construction activity without parallel increases in DOT personnel, data management will continue to expand, consuming more time, and requiring the development of innovative data management systems. Based on a survey performed, thirty-one state DOT organizations are currently involved in some stage of system development. Each state DOT is embarking individually with no cooperative or coordinating efforts currently underway between states. Significant benefits in time, effort, and money can occur if these efforts were coordinated and experiences shared.

Objectives

The following research tasks will be performed to establish a mechanism for coordinating and sharing information in developing these field data management systems:

1. Obtain information from state DOTs on the current stage of system development. This can range from conceptual to operational. Other information needed includes: hardware utilization, development software, development effort, type of data collected, system users expected, and data sharing and transfer options.
2. Based on collected information, develop a database of information that can be shared between the states. This information can significantly enhance these individual efforts and prevent states from having to "create it over and over again."
3. Establish a mechanism to coordinate these efforts. This will consist of disseminating this information and instituting a working session at the TRB annual meeting.

Urgency

This research has a sense of urgency because of the current effort underway. Many states are at various

stages in development and this type of information would be extremely beneficial. Time to perform would be 18 months.

Cost

\$75,000

PROBLEM #110: EFFECTIVE HUMAN RESOURCES PLANNING AND MANAGEMENT

Two major problems facing the Federal and many States in effectively planning and managing human resources are:

1. The need to accurately project human resources requirements for the future; and
2. The need to attract and retain personnel, especially in such key job areas as engineering and automation.

A study is needed to derive better bases upon which to predict human resources and to compete with the private and other public sectors in attracting and maintaining human resources.

Objectives

The following research tasks will be accomplished to determine better techniques to accurately and effectively predict, attract, and retain human resources:

1. Explore and evaluate methods currently being used by FHWA and selected states to predict human resources.
2. Determine factors that generate workloads in designing, constructing, and maintaining highways as well

as managing finances, automation activities, human resources, etc.

3. Explore the statistical relationships of the various workload generators, developed in (2) above.

4. Review and evaluate the selected States' DOT personnel development and hiring practices to determine their effectiveness.

5. Investigate and identify human resource practices of similar public and private sector jobs for comparative analyses of pay, advancement, individual development programs, hiring requirements, career opportunities and other variables affecting retention.

6. Make recommendations for implementation of findings.

Urgency

This is an in depth research study that would require approximately 14 months to conduct. The result of this study would be useful for:

- Forecasting human resources needs by FHWA and the States Divisions, Districts and Residencies;
- Budgeting;
- Coping with shifting demands in construction and maintenance; and
- Forecasting support activity needs.

Also, the results of this study will provide a set of procedures to help acquire and retain desired levels of human resources and improve management control over resource planning and utilization.

Cost

\$200,000

A2H01 COMMITTEE ON APPLICATIONS OF EMERGING TECHNOLOGY

PROBLEM #111: APPLICATION OF BIOTECHNOLOGY TO ROADWAY LANDSCAPING

Landscape maintenance requires excessive resources in terms of water, fertilizer, pesticide, and manual labor when compared to other maintenance categories.

Objectives

Update the design and construction of roadway landscapes by utilizing genetic engineering to develop "designer plants" which would have the following characteristics:

- Incorporate nitrogen-fixing bacteria to lessen or eliminate dependence on chemical fertilizer.
- A xerophytic nature to reduce the need for water.
- A natural resistance to pests.
- A growth habit which would greatly lessen the need for pruning or mowing.

The research would be expensive and would be done in stages with application and benefits at each stage. Implementation of each stage would save millions of dollars in materials and payroll, as well as provide environmental benefits.

Key Words

Genetic engineering, gene manipulation, biogenetics.

Related Work

Most of the work done to date is in the field of agriculture. One of the most publicized products is the tomato that does not spoil.

Urgency

The suggested research has the potential to free up a large portion of landscape maintenance funds for other purposes. In view of the demands on resources, this process should occur as soon as possible.

Cost

The estimated cost of the initial stage of feasibility investigation including laboratory and limited field studies is \$500,000.

User Community

AASHTO, FHWA and other transportation agencies

PROBLEM #112: INTEGRATING REAL TIME CONSTRUCTION SITE DATA WITH MULTIMEDIA DATABASE MANAGERS

In recent years, a variety of nondestructive sensing technologies have been introduced to the construction site. Most of these sensing modes produce either rasterized image (weld x-rays), a time series of rasterized images (pavement images), or a time series of analog values (pavement profile). Many of these sensing technologies are used in isolation of each other and do not employ any structured archiving methodologies. This makes it extremely difficult to integrate (and fuse) diverse data. This lack of archiving organization precludes the on-line storage and use of data during the post construction facility operation and maintenance.

Objectives

In the past, it has been shown that conventional relational database management systems (dbms) can be used to archive data such as bridge sections and member connectivity. However, subjective sensor data such as rasterized images could not be integrated. This research will investigate the feasibility of incorporating this information into an "as built" model using a multimedia database management system. This research will investigate storage requirements, media (magneto optical disk, CD-ROMs, WORMS), economic feasibility, and computing demands. A prototype system modeling an example transportation facility will be constructed.

Urgency

As states demand more and more acceptance testing and as built documentation this technology will become instrumental.

Cost

\$90,000

A2H03 COMMITTEE ON MINERAL AGGREGATES

PROBLEM #113: CHARACTERISTICS AND PROPERTIES OF FINE AGGREGATES AND THEIR INFLUENCE ON PERFORMANCE OF THE END PRODUCTS

It is generally accepted that fine aggregates play an important role in the performance of asphalt concrete, portland cement concrete (PCC) and aggregates in unbound applications, such as base courses. Fine aggregates influence, either directly or indirectly, such properties as strength, durability, workability, finishability, fatigue life and permeability. The exact mechanisms and the extent of the influence of fine aggregates need to be better understood. Particle shape, surface texture, gradation and electrochemical properties are some of the characteristics that need further study. For each of these broad areas of end use several tasks will be required in the investigation. These would include:

- Identify those characteristics of fine aggregate that affect performance;
- Evaluate existing tests and procedures for their ability to measure the characteristics;
- Develop, as necessary, new tests and procedures to measure the characteristics; and
- Develop correlations between measured values and performance of the end product.

Objectives

The objective of this research is to provide a means to evaluate those fine aggregate characteristics identified as significantly influencing the performance of the end product in which the fine aggregate is used.

Key Words

Aggregates, aggregate tests, performance, fine aggregate, asphalt mixtures, portland cement concrete, bases, subbases.

Related Work

A great deal of work has been done in the past in this area. Previous work has shown that fine and "super fine"

aggregate play an important role in determining asphalt mixture asphalt cement content, ability to resist distress, durability, strength and workability. Similarly, in PCC, fine aggregates affect workability and finishability, water demand, strength and skid resistance. For aggregate used in unbound applications, the fines have been linked to compaction, strength and permeability. The proposed work will attempt to bring together all this previous work with the addition of new tests as necessary to adequately correlate and combine all the influencing characteristics of fine aggregate with the performance of the range of end products in which they are used.

Urgency

While a significant amount of research has been conducted in the last few years, the aggregates component of construction materials has often been overlooked as an object of direct investigation. Therefore there exists a lack of sufficient data to adequately address the role of fine aggregates in determining performance. As the Strategic Highway Research Program (SHRP) enters its implementation phase, it will be important to also have the means to characterize a fine aggregate's influence on performance to complement the SHRP findings on asphaltic concrete and portland cement concrete.

There is the potential for a large and rapid payoff if this project is pursued. Specifying agencies will be provided with more complete tools for evaluating the impact on performance of the fine aggregate, thereby obtaining more economical and longer lasting structures. Contractors will be able to more efficiently and economically complete their projects. Aggregate producers will be better able to produce quality products to ensure the desired performance in a specific application, based on the known influence of fine aggregate characteristics and properties in that application.

Cost

\$200,000 for two years

User Community

AASHTO, FHWA

PROBLEM #114: TEST METHODS AND SPECIFICATIONS FOR RECYCLED/BYPRODUCT MATERIAL TO BE USED AS AGGREGATES

Millions of tons of solid waste products and byproducts are produced each year in the United States. There are basically three possible techniques for disposing of this waste—incineration, burial, and recycling. Incineration can be an effective technique for some materials, but environmental concerns about the hazardous or toxic materials that can be released into the atmosphere during the incineration process have limited its use. Burial in landfills has traditionally been the most widely accepted technique for disposal, but landfills all over the country are being filled to capacity and closed with fewer landfills being opened to replace them.

Recycling of the solid waste products has thus become the alternative of choice for the future, although it continues to be a relatively small, but growing, percentage of the total waste disposal picture. In the transportation industry, many waste products are currently being considered for many possible uses. One use that is being investigated is the use of certain waste materials as aggregates in portland cement concrete (PCC), asphaltic concrete, pavement base courses, highway fills, and the like. Some materials, such as reclaimed asphaltic concrete, PCC, blast furnace slag, and steel slag, have been widely used by transportation agencies around the United States. Others, however, have found only limited acceptance because of limited testing or poor performance in laboratory or field test. Still other materials are yet to be discovered.

The research effort for investigating waste products for use as aggregate has, in most instances, been performed with little coordination from agency to agency. These agencies have often found that tests performed on and specifications used for traditional aggregates may not be applicable for the waste product aggregates. Some type of standardization would be extremely helpful to any agency trying to determine how to use a particular waste product as an aggregate. Several general tasks would need to be attempted to begin addressing this problem:

1. Determine the waste products that are currently used or are being considered for use as aggregate and the tests and specifications that are being used. (For an expanded program, researchers could search for promising new waste products.);
2. Determine the product characteristics that should be considered in assessing the suitability of a waste material's use as an aggregate;

3. Evaluate the effectiveness of the tests and specifications currently being used on waste product aggregates;

4. Develop new aggregate tests as necessary for measuring the required properties to assess the potential performance of the waste products as aggregate; and

5. Develop new specifications for use of waste product aggregates as construction materials.

Objectives

The objective of this research is to provide a series of test methods and material specifications for recycled/byproduct materials used as aggregates so that the future performance of the aggregate can be reasonably assured.

Key Words

Aggregates, recycling, reclaimed materials, by-products, waste materials, asphaltic concrete, portland cement concrete, bases, subbases, aggregate tests, material specifications.

Related Work

Recycling of waste materials into the construction of a transportation facility is not new. However, it was not until the late 1960s and early 1970s that recycling began to get increased attention. In the early 1970s, bottom ash from the burning of coal, incinerator residue, and blast furnace and steel slags were investigated for use as aggregate in bituminous mixtures. About that same time coal mine residue was combined with fly ash and used as a roadway base course. Reclaimed pavement materials—asphaltic concrete millings and crushed PCC pavement—began to be used more as recycled materials in pavement structures and have quite naturally become the recycled waste material of choice in many locations.

More recently, waste glass has been used in "glasphalt" and in PCC; shredded rubber tires and building rubble have been placed as aggregate in highway fills; and phosphogypsum has been mixed with portland cement to form a stabilized road base. These materials have shown varying levels of success as road construction materials, and many have only had very narrow usage in limited locations. Engineers specifying these materials have had little guidance in the use of these materials.

Urgency

With the increasing emphasis on recycling in transportation facilities construction, the need for standardized testing methods and specifications becomes necessary so that the design engineer can make intelligent choices in specifying these materials. The ISTEA of 1991 took a first national legislative step when it required the use of waste rubber in asphaltic concrete mixtures on federally funded projects. Although this

material might be considered an asphalt cement modifier instead of a recycled aggregate, it can be speculated that the use of waste product aggregates might be required in the future. Recycling has also been mandated by state governments. For example, in 1988 the State of Florida passed a solid waste management act requiring the use of certain waste materials in road construction. As the landfills continue to reach capacity, similar legislation can reasonably be expected in other jurisdictions in the future.

A2J01 COMMITTEE ON CEMENTITIOUS STABILIZATION

PROBLEM #115: SULFATE INDUCED HEAVE PROBLEMS - IDENTIFICATION AND CONTROL

When the stabilizers most used in clay soils, lime, portland cement and fly ash, are applied to materials with sufficient soluble sulfates in them, a three dimensional heave can occur causing pavement systems to deflect, heave and buckle. Although measurement of soluble sulfates is not new or unusual, the methodology to be used has not been standardized and the result is variations in amounts of sulfates reported. In addition, the frequency of sampling for sulfates testing is often far too small, causing materials containing significant soluble sulfates to be overlooked, or to be the only ones sampled. To deal with the problem of the amount of sulfates present, which is believed to be highly variant, better sampling programs must be investigated and testing be standardized.

Using certain stabilization construction techniques, which include double applications, of lime in particular, and/or the use of additives, sulfate induced heave in clays with low and, in some cases, moderate levels of soluble sulfates has been successfully controlled. Yet, the field measures used to date are largely undocumented in reports. In addition, those clays with high levels of soluble sulfates have not been successfully stabilized or controlled. There is a need to further develop possible construction procedures, agent applications and other stabilizing methodologies to control sulfate induced heave and to test these in full scale field trials.

Objectives

To establish a standard method of measurement of soluble sulfates and a frequency of sampling subgrades to accurately identify the nature of the sulfate heave problem which may occur. To identify stabilizing methodologies, construction techniques and possible agents which can be used to control sulfate induced heave. To verify the applicability of the methods, techniques and agents utilizing full scale field test sections.

Key Words

Sulfates, clays, stabilization, heave, subgrades, lime, portland cement, fly ash.

Related Work

A good deal of work has been done on identifying a standard 1 part soil to 10 parts water extraction method for measurement of soluble sulfates, which is believed to indicate well the potential for a heave problem. Low sulfate amounts are believed to be below 0.5% or 5,000 ppm. Moderate amounts range to 1.0% or 10,000 ppm and high sulfates contents are believed to be over 1.0%. The frequency of testing as indicated by research to date may be at least one test every 50 lineal feet of roadway.

Stabilizing methods, techniques and agents have been researched mainly in the laboratory using a three dimensional swell test to simulate field situations. Some correlations of sulfate test and laboratory swell test results to field behavior have been done. A limited number of alternative methods, techniques and agents have been laboratory tested and applied in limited field trials. The success in the laboratory and field has been mixed.

Urgency

This research is of highest priority because of the relatively large damage which has been done to roadway pavement systems and which will occur. The documented damage, alone, which has caused removal and/or complete rebuilding of pavement systems amounts to several millions of dollars. The amount of damage expected without control of this phenomenon far outweighs the estimated expenditures for research.

Cost

The estimate to conduct the research exclusive of building test sections is approximately \$500,000. The estimated time to complete this research is two to three years.

User Community

AASHTO, FHWA

Implementation

Standardized sampling and testing to identify potential sulfate induced heave and methodologies, techniques and agents to control the problem where it exists.

Effectiveness

If this research is completed it can mean practical control of sulfate induced heave in treated clays.

PROBLEM #116: STABILIZATION APPLICATIONS IN RECYCLING

Highway engineers are turning to recycling existing layers as a viable rehabilitation technique because the Interstate highway system is nearly complete and there is an urgency for maintaining the existing network is given increasing attention. Many miles of existing roads, especially flexible type roads and streets are rapidly wearing out or are inadequate for present day traffic. The cost of upgrading them to current standards/requirements is prohibitive. Often the economical solution to these problems is to salvage the pavement. Stabilization with cementitious agents, for example, cement, lime, fly ash or bituminous products, is the key to salvaging or reconstructing base and/or surface layers that have exhibited serious distress manifestations. The technology of stabilization of recycled material is not new; however, specific data and/or performance of recycled pavement layers are lacking. There is a need for research to fully understand the mechanics, mix design criteria and quality assurance tests for stabilization of recycled materials.

Objectives

1. Develop procedures to determine the technical, practical and economic feasibility of cementitious materials in treating recycled pavement layers.
2. Propose guidelines for selection of appropriate stabilizing agent.
3. Develop criteria and test procedures for mix design of various recycled materials.
4. Examine critically the applicability of existing construction/quality control tests in recycled stabilization construction.

Key Words

Stabilization, cementitious, recycling, base layers, cement, lime, fly ash, bituminous material.

Related Work

Use of cementitious materials has shown promise for recycling old pavement, treating unsurfaced roads to serve as a base for upgraded pavements and other applications relative to resurfacing, reconstruction or rehabilitation of existing roadways. Experience with stabilizing virgin materials is often extrapolated and applied to stabilize recycled materials. Except for sporadic short notes published in the literature, there appears to be no concerted effort to synthesize the problems and challenges facing the engineer. Noted exceptions are the PCA publication titled "Recycling Failed Flexible Pavements with Cement" and summary project reports that appear from time to time in Asphalt Recycling and Reclaiming Association publications.

Urgency

Guidelines and criteria for design and construction of pavement layers using cementitious stabilizing agents are vital to rehabilitation and/or reconstruction of existing "failed" pavements.

Cost

\$220,000

User Community

AASHTO and FHWA

Implementation

With the results of the study documented as guidelines and specifications for design/construction with recycled materials, the publication would be a valuable reference volume for office and field engineers alike.

Effectiveness

As the cost of construction/materials continues to escalate, the economical solution to keep the existing road network in satisfactory condition is to salvage the existing pavement materials. Despite the pavement has shown signs of "failure," it basically contains good material that can be reused and recycled for savings in money and conservation of material.

PROBLEM #117: ASSESSMENT OF LONG TERM DURABILITY OF INDUSTRIAL RESIDUALS STABILIZED FOR CONSTRUCTION PURPOSES

Utilization of industrial residuals for highway construction and maintenance purposes generally requires some form of stabilization. However, the lack of experience as well as a knowledge of the long term stability and performance with these materials under various operating and environmental conditions are a concern. Techniques developed to assess the long term durability of traditional materials and stabilized mixtures are not necessarily applicable to industrial residuals because of basic differences in chemistry, mineralogy and morphology. Also, current EPA leach tests for stabilized wastes may not be applicable to those materials when used for construction purposes. Thus, a methodology is needed to accurately and reliably predict the long term durability, performance and leaching characteristics of stabilized mixtures of industrial residuals when used as construction materials.

Objectives

The basic objective of the research is to develop a laboratory testing and evaluation methodology that will accurately and reliably predict the long term durability performance and leaching characteristics of stabilized mixtures of industrial residuals. If such a methodology can be developed, it will permit an earlier introduction and more reliable use of industrial residuals for highway construction and maintenance purposes. This will make possible the use of industrial residuals in place of traditional materials in situations where such materials are in short supply or costly.

Key Words

Recycling, sustainable development, laboratory testing, performance leaching.

Related Work

A substantial amount of uncoordinated research has been conducted by a variety of research organizations, universities, state highway agencies, and private consultants relative to the utilization of industrial residuals for construction purposes. However, essentially all of the researchers have adopted or adapted methodologies developed for traditional materials to predict the performance of stabilized mixtures. Some attempts, principally

in Europe, have been made to develop rational leaching procedures that are more relevant to the nature of the mixture and the environmental conditions. Little or no fundamental research has been conducted to develop a rational means for the evaluation of long term durability that is consistent with the nature of the materials, operational factors, and environmental conditions.

Urgency

Any large scale utilization of stabilized industrial residual materials for construction purposes will have to be preceded by tests and analyses that will accurately and reliably predict the long term performance (durability and leaching) of the materials. Thus, such research should receive a high priority if we are to be able to effectively utilize all the materials (traditional and residual) that are available to us.

Cost

Between \$500,00 and \$750,000 over a 3 to 5 year period.

User Community

AASHTO, FHWA, ASTM, state DOTs, Highway Construction and Maintenance Industry Research Institutes/Center, universities

Implementation

Research findings should be implemented through the use of demonstration projects with a research agency working in cooperation with a state DOT/DEQ and in coordination with FHWA/EPA.

Effectiveness

If the public perceives that utilization of industrial residuals for highway construction and maintenance poses an acceptable environmental risk, the societal impact will be viewed as a very positive; i.e., converting (recycling) what is now considered a waste materials into a usable product. Rather than stacks of waste materials, secondary products can be generated which will possibly help to reduce the cost of highway construction and maintenance as well as reduce the environmental degradation associated with the mining and production of natural materials.

A2J02 COMMITTEE ON CHEMICAL AND MECHANICAL STABILIZATION

PROBLEM #118: STABILIZATION OF VOLATILE ORGANIC COMPOUNDS WHICH ARE RESIDUALS OF CERTAIN USED SOLVENTS

Millions of asphaltic concrete extraction tests have been conducted using solvents such as carbon tetra-chloride and/or 1, 1, 1-trichloroethane. For years, the residuals of such tests were "thrown out the door" or disposed of in some similar fashion. The by-products from such disposal have leaked into ground water systems and are today evident, in varying degrees. They came to be found in the forms (among others) of 1, 1-dichloroethane; 1, 2-dichloroethane; 1, 1 dichloroethene and 1, 1, 2-trichloroethane. The EPA has placed many of these residuals on the hazardous waste list and declared many of them as carcinogenic. Currently, no economical method exists for stabilizing (or otherwise tying-up) these volatile organic compounds (VOC's). The threat to health can only be guessed as these residuals work their way into the drinking water systems via migration to wells.

Objectives

The objective is to find some way to stabilize or bind-up the loose VOC's and obtain a resultant non hazardous product.

Key Words

Carbon tetrachloride, trichloroethylene, trichloroethane, solvents, dry cleaning fluids, grease solvents, chlorinated solvents, stabilization, volatile organic compounds.

Related Work

Florida State University was reported to have been working on this problem in the recent past with the concept not unlike the process of enzyme stabilization.

Urgency

The State of Florida has already invested more than ten million dollars trying to clean up one small borrow-pit where spent solvent has intruded the surficial ground water table. Other sites are sure to exist. The cost of

clean up by known methods could be exceedingly high. If no action is taken, the effects on environment and health of the general public could be even more costly and disastrous. Therefore, priority of research on this issue is extremely high.

Cost

Estimated cost is \$150,000 over three years.

User Community

Anyone who has run a large number of asphalt extraction tests (most state DOTs) should have a significant interest in this research. This would also impact universities teaching civil engineering, counties and cities and commercial testing laboratories. Auto service stations and dry cleaning establishments also generated large quantities of such used solvents. Finally, the EPA and all state counter- parts to EPA should have a great interest in this project.

Implementation

Place stabilization procedure in the care of EPA and FHWA. Those agencies will distribute the procedures to the states, who in turn can make it available to the counties, cities and testing labs.

Effectiveness

If economical stabilization procedures are developed, the effectiveness will match that of the introduction of Coca-Cola.

PROBLEM #119: UTILIZATION OF BY-PRODUCT GYPSUM FOR HIGHWAY CONSTRUCTION

The sustainable utilization of materials for highway construction purposes requires effective use of both naturally-occurring and industrial residual materials. Whereas naturally-occurring materials such as crushed stone, sand and gravel have been the target of extensive research efforts (largely sponsored with state and federal funds), research directed at the use of industrial residual

materials for construction purposes has been comparatively limited. One of the largest potential sources of industrial residuals is by-product gypsum produced by a variety of industries (e.g., phosphoric acid, hydrofluoric acid and titanium production). In addition, vast amounts of by-product gypsum are being produced by coal-burning power plants from the wet scrubbing of stack gases. There has been some success with ad hoc uses of such materials but traditional methods of evaluation are both unsuitable and unreliable for such by-products because they depend largely on empirical correlations developed for "traditional" materials such as crushed stone. However, crushed stone materials are becoming increasingly costly. Thus, if a proper match can be found between material needs for highway construction and maintenance and the availability of low cost industrial residuals, both the highway construction community and the industrial sector will benefit economically and environmentally.

Objectives

The basic objective of the research is to develop the necessary methodology for the technically acceptable, economically viable, and environmentally acceptable use of by-product gypsum for routine highway construction and maintenance. This will involve investigation of the improvement of engineering properties of residual materials, evaluation of potential environmental problems and assessment of economic values.

Key Words

Industrial residuals, reuse, recycling, sustainable development.

Related Work

Relatively substantial but uncoordinated research efforts related to the utilization of by-product gypsum for a variety of construction applications in the USA have been conducted by:

- Phosphate Research Institute, University of Miami;
- Florida Institute for Phosphate Research (FIPR);
- Florida Department of Transportation;
- Texas A & M University;
- Texas Department of Transportation; and
- Institute for Recyclable Materials (IRM), Louisiana State University.

Presently, the principal ongoing research efforts are taking place at FIPR, Texas A & M, and IRM. These efforts are primarily directed at the utilization of by-product gypsum for highway base construction. For this purpose, the by-product gypsum is generally stabilized with some combination of cement, fly ash and sand.

Urgency

Supplies of naturally occurring construction materials are being depleted and are being subjected to increasingly stringent environmental regulation. Both factors have and will continue to result in increases in cost. Alternative materials, whether low quality natural materials or industrial residuals, need to be investigated to serve as replacements for the higher quality, higher cost materials currently in use. In addition, the disposal of industrial residuals is a major problem and viable, large volume uses of such materials would be of substantial benefit to industry, the highway community, and society in general. Delaying significant research efforts directed at utilization of alternative materials until a crisis exists will be unproductive and not cost effective. Research that will increase the rate of introduction of alternative materials for highway construction will result in a better utilization of scarce resources.

Cost

\$5 million over a 5-10 year period. However, as with traditional materials, a continuing research program must be maintained.

User Community

AASHTO, FHWA, ASTM, state DOTs, Highway Construction and Maintenance Industry Research Institutes/Centers, universities

Implementation

Research findings should be implemented through the use of demonstration projects with a research agency working in cooperation with a state DOT. Tentative design methods, materials specifications, and construction specifications can be developed by research agencies in cooperation with state DOTs and modified on the basis of experience.

Effectiveness

If the public perceives that utilization of by-product gypsum for highway construction poses an acceptable environmental risk, the societal impact will be seen as very positive; i.e., converting (recycling) what is now considered a waste material into a usable product. Rather than stacks of waste materials, secondary products can be generated that may help to reduce the cost of highway construction and maintenance as well as reduce the environmental degradation associated with the mining and production of natural materials.

PROBLEM #120: DETERMINE CHEMICAL AND MECHANICAL PROPERTY ENHANCEMENT OF BASE MATERIALS FROM DETERIORATED SECONDARY ASPHALTIC ROADS THROUGH THE FULL DEPTH RECLAMATION PROCESS

Deterioration of secondary, or "farm to market," roads across the country is a critical problem for most of this Nation's local governmental agencies. In most cases, this deterioration is due to the fact that "today's" roads were built for "yesterdays" traffic volumes and axle loads. As a result of more frequent, heavier traffic loads many of our nation's roads suffer from severe cracking, rutting, and premature break up. Cost to rehabilitate these roads through conventional techniques continues to increase to a point where most local agencies can afford very little, if any, rehabilitation.

Objectives

To quantify the cost reduction of rehabilitation and the increase in density and load bearing capacity of secondary roads through the Full Depth Reclamation process utilizing various chemical stabilization agents.

Key Words

Base stabilization, stabilization, full depth reclamation, asphalt recycling, recycling, chemical stabilization, calcium chloride, chlorides, secondary roads, base, base failure, asphalt.

Related Work

Full Depth Reclamation has been successfully tried and used by a large number of local and state agencies in the

New England area. The process, using a chemical stabilization agent (calcium chloride), is starting to gain acceptance across the Midwest, particularly in Michigan, Minnesota and Iowa.

Massachusetts has specified the use of a chemical stabilization agent (calcium chloride) into all Full Depth Reclamation projects.

Materials such as lime, fly ash, lime/fly ash mixtures, soil cement, sodium chloride, and asphalt emulsions have also been used as stabilization agents during the Full Depth Reclamation process.

Urgency

Moderately high and increasing. Funds for rehabilitation are slowly becoming available through ISTEA and other local funding programs. State and local agencies need to utilize these funds.

User Community

State and local agencies.

Implementation

Agencies, including FHWA, State DOTs, County and Local Engineers, Contractors, etc., in need of rebuilding existing, deteriorated asphaltic pavements, with insufficient bases, will greatly benefit from cost reductions using this recycling process.

Effectiveness

The effectiveness of calcium chloride for base stabilization has been well documented. Several recent reports include the papers "Liquid Calcium Chloride for Dust Control and Base Stabilization of Unpaved Road Systems" by H. Kirchner and J. Gall, Transportation Research Record 1291 and "Full-Depth Reclamation of Asphalt Roads with Liquid Calcium Chloride" by J. Pickett, Transportation Research Record 1291. Also, the paper "Full Depth Reclamation with Calcium Chloride" by J. Pickett (preprint number 910323) was presented at the Transportation Research Board, 70th Annual Meeting.

A2K01 COMMITTEE ON SOILS AND ROCK INSTRUMENTATION

PROBLEM #121: METHODS TO ASSESS COSTS-BENEFITS OF INSTRUMENTATION IN DESIGN AND CONSTRUCTION

Current design methods for roadways and related facilities contain no way to incorporate the benefits of instrumentation into the design process. Although results from instrumentation can considerably reduce the uncertainty in a design and help avoid failures, most codes of practice do not provide a way to incorporate this benefit into the design. Consequently, instrumentation is usually perceived as an unnecessary add-on to the project cost. Unable to quantify the true benefits of instrumentation to the project, many instrumentation programs become severely curtailed, poorly implemented, or entirely eliminated.

Methods exist to quantify the benefits of reduced uncertainty gained from instrumentation programs. However there is not a direct linkage between these methods and the commonly used design procedures that are based on a factor of safety approach.

Objectives

This research will develop a method, or methods, to obtain reduction factors to be applied to design factors of safety that allow for the benefits of using instrumentation. The method, to be based on uncertainty analysis, will allow design engineers to quantify the reduced costs that can result from lower factors of safety permitted when a project utilizes instrumentation. The resulting method must be sufficiently simple in scope that it can easily be applied by design engineers with existing data.

Key Words

Instrumentation, cost-benefit analysis, safety, design, foundations.

Related Work

Much research has been done in civil engineering over the past 20 years to develop ways of using statistics and probability analysis in civil engineering design. Many techniques exist to apply these methods to various aspects of design. Some codes now incorporate the use of load and resistance factors that are based on

probabilistic analyses to better quantify the effects of uncertainty in the design process. No methods exist to directly include the benefits of instrumentation into design and cost evaluations.

There is considerable ongoing effort to include instrumentation into projects to reduce costs related to uncertain elements. Instrumentation technology and methods are being continually refined in various research and implementation projects. This effort seeks a rational mechanism to expand the benefits of instrumentation into all projects.

Urgency

This topic is rated of highest priority by A2K01. The results are urgently needed to provide parameters required by new design methods that are based on limit state design. The results are also needed to have a quantitative mechanism for correctly using instrumentation to lower the overall costs of projects.

Cost

\$200,000 over 3 years

User Community

AASHTO, FHWA, FAA, NCHRP, USACE, DOE, EPA, state transportation agencies, engineering profession

Implementation

Results of this work should be presented to various professional meetings for review and comment.

Proposed revisions to current design methods, codes and Federal design guidelines will be prepared to incorporate results into existing design procedures. A series of workshops, seminars or both should be developed to describe the use of the research results.

Effectiveness

Implementation of this research will result in safer and more cost effective structures. Wider use of

instrumentation on projects would reduce the number of failures that result from design inadequacies, construction deficiencies, or factors unknown during design. Through wider use of instrumentation, greater knowledge will be gained to lower uncertainties in design and allow further reductions in factor of safety used in design procedures to cover our uncertainties. The improved knowledge gained from instrumentation of projects will help produce improved design methods that result in better performing facilities with longer life and reduced costs. While difficult to quantify at this stage, evidence exists to suggest benefit-cost ratios for good instrumentation programs of 10:1 to 100:1 or more.

PROBLEM #122: INSTRUMENTATION FOR LIFE CYCLE EVALUATION OF PAVEMENT SYSTEMS

Long-term performance of pavement systems involves complex interactions of the pavement, base, subbase, foundation, and any synthetic layers between. Unexpected performance or early deterioration of one component may lead to premature loss of the entire pavement system. With knowledge of this adverse performance gained from field monitoring of the pavement system, corrective actions can be taken to minimize the life cycle costs of the facility.

In addition, pavement management systems for evaluating design alternatives rely on much qualitative information for assessing the design alternative that minimizes life cycle costs. The benefits of new materials such as asphalts and geosynthetics for improving roadway support must often be estimated or guessed. In many cases new materials are not even considered in life cycle cost evaluations because of the absence of data on their benefits over the life of the project. As a result, use of new materials is drastically diminished resulting in lost savings and slower response to new technology.

Objectives

This work seeks to develop an instrumentation system that can relatively rapidly give data to evaluate the life cycle performance of a pavement system. The research will seek an instrumentation system which will indicate real-time changes in the performance of the components of a pavement system. Changes in measured performance will allow a much more quantitative assessment of life cycle performance and cost.

This instrumentation system may be a combination of existing and new measurement technology. Instrumented

test sections in various pavement systems will be used to test, refine and provide procedures to implement the new system.

Key Words

Life cycle costs, pavement systems, instrumentation, deterioration.

Related Work

Many instrumentation programs have been used to examine the performance of specific elements of a pavement system. These include efforts to look at strains in the pavement, stresses in the subbase, movements of the foundation, and relative deflections of the pavement system from a surface load. Generally these efforts have not focused at the overall performance of the pavement system.

Recent developments in electronic technology, sensors and remote real-time monitoring equipment make an integrated real-time monitoring approach possible.

An ongoing effort within SHRP has produced several instrumented roadway sections that could be used to develop and evaluate a new instrumentation system produced by this work.

Urgency

This topic is rated of highest priority by A2K01.

Many miles of pavement are failing years before reaching their design life. In many cases the deterioration proceeds too far to allow relatively low cost preventative actions to restore pavement life. Numerous new materials, like asphalts, geosynthetics, high strength concrete, etc., are being developed to improve pavement performance. With current procedures, it will be many years before sufficient performance data become available to allow their effects on life cycle cost to be evaluated. A faster way to more quantitatively examine these new materials is urgently needed to reduce the time required for society to benefit from the best of new technology.

Cost

\$2,000,000 over 5 years

User Community

AASHTO, FHWA, FAA, NCHRP, state transportation agencies

Effectiveness

Success in this research will lead to substantially lower life cycle costs of pavement systems. By detecting substandard performance of pavement systems early in their life, less costly steps can be taken to correct the pavement system before complete deterioration occurs. Secondly, better technologies for more rapidly assessing the benefits of new materials will result. This will allow promising new materials to be incorporated into pavement systems much quicker than present practice allows. Safer and smoother roadways for less cost will result.

PROBLEM #123: REMOTE LANDSLIDE MONITORING SYSTEM

Most State transportation agencies have hundreds of sites where earth or rock movement is imminent or occurring that pose a high level of risk to the traveling public. There is seldom sufficient resources to eliminate the risk and, therefore, the owners must manage their system to reduce the risk as much as possible. This is often done by closing the facility at critical periods. Maintaining 24 hour patrols and other techniques. Both the cost and the risk associated with these approaches can be greatly reduced if a remote automated landslide monitoring system can be implemented.

Objectives

Develop a reliable, portable, low-cost remote monitoring and warning system to be installed at potentially unsafe sites. The system would consist of a series of selected sensors for the concerns at the specific landslide site. These sensors would be connected to a monitoring unit which would then process the data and with preset guides transmit warning signals to the appropriate sites where action can be taken (the Maintenance Office). The monitoring unit would have a communications link to a response unit through satellite or other communications links for remote sites. The sensing instruments would be designed to measure the key elements of the specific site which might include ground

water elevation, vertical or horizontal movements, freeze-thaw cycles, or others. The heart of the system would be a portable control unit that could be programmed to respond to sensor readings and transmit this information to people that can react.

This type of unit could be moved from site to site as necessary to allow the managers to keep the facility open to use until landslide or other activity is imminent and, therefore, only closing the facility for short times when absolutely necessary. This would result in improved public relations, improved performance of the transportation facility and reduce costs both short-term and long-term for the owner.

Key words

Instrumentation, remote, data processor, landslides, satellite communications, management.

Related work

The concepts of remote warning systems for danger to transportation facilities have existed for years, but have always been expensive and have seldom proved reliable in severe environments where most slides take place. Some recent work in Europe and in California have demonstrated that the instruments and sensors are much more reliable. Some recent work by Loren R. Anderson have demonstrated the effectiveness of satellite communications from remote sites. It appears that all of the technology exists to develop a low-cost easily deployable system that could be attached to a diverse group of sensors meeting the site specific conditions to allow the managers of systems to safely keep the facilities open and to plan corrective measures.

Urgency

The increase in deaths from rock falls and bridge collapses has demonstrated that the rate of deterioration at our transportation facilities is exceeding our ability to rebuild and replace them. A low-cost, site specific monitoring system would allow the owners to maintain the facilities to their highest capacity until disruption is imminent. Therefore, this type of a system is needed in many areas across the county to help the owners manage their limited resources and still provide the safety to the travelling public. There are also direct cost savings resulting from reduced manual observations.

Cost

Approximately \$150,000 to develop a system with a number of prototype units and run field performance tests to verify the effectiveness of the system.

User Community

All owners of transportation facilities would have a potential use including all members of AASHTO, all State highway agencies, all public transportation agencies, and all local governmental agencies.

Implementation

Full implementation of this technology might require the development of appropriate training courses and workshops as well as the necessary manuals and guides for the specific instrumentation packages developed.

Effectiveness

A measure of the effectiveness of this type of a monitoring system would be its acceptance by the user groups and its deployment to critical sites. A second level measure would be how each facility owner uses the information to manage his specific transportation facility. If totally effective, it would reduce costs, improve public service and possibly save lives.

PROBLEM #124: DETERMINING THE PITTING CORROSION OF STEEL ELEMENTS IN SOIL

Steel elements, placed in soil as part of engineering structures, exhibit either uniform corrosion and/or pitting corrosion. Current laboratory and field measurement methods determine corrosion rates of steel in soil as average rates. Since there is no differentiation between pitting corrosion and uniform corrosion, the service life of structures can be seriously over-estimated.

For proposed engineering sites containing steel elements buried in soil, coarse grained soils are usually favored over fine grained soils to achieve higher strength and lower corrosion rates. Corrosion rates of steel in soil, for the most part, came from the work by Romanoff. These rates are based on weight loss and represent average rates for the steel elements studied. Romanoff reported pitting as being one to four times greater than average corrosion.

Laboratory testing can measure the pitting susceptibility of steel manufactured using different processes. Steel subjected to different mechanical manufacturing processes (i.e. cold worked, annealed, hot worked etc.) when tested in aqueous solutions will have varying pitting tendencies.

With present technology and designs based on average corrosion rates, there isn't a reliable method to evaluate the life of steel structures in soil and be certain that pitting corrosion will not occur and cause premature distress to these structures.

Objective

Develop an instrument and method to measure the pitting potential of steel elements buried in soil. Develop the technology to measure the in-place metal loss due to pitting corrosion which can also be used to monitor the life expectancy of steel structural elements in soil.

Key Words

Corrosion, local corrosion cells, pitting corrosion, corrosion rates, disturbed soils, undisturbed soils, steel corrosion, corrosive soils, instrumentation.

Related Work

- "Underground Corrosion", National Bureau of Standards, April 1957, Melvin Romanoff, PB-168 350

- "Durability/ Corrosion of Reinforced Soil Structures", Earth Engineering & Sciences, Inc. March 25, 1986, by Victor Elias, FHWA/RD-89-186, Contract DTFH 61-85-C-00167.

- "The Effect of Thermo-Mechanical Treatment On The Pitting Corrosion Of Reinforcing Carbon Steel Bars", 1992, M. Eslamloo-Grami, J. R. Groza and R. Bandy, Department of Mechanical, Aeronautical and Materials Engineering, University of California, Davis and Department of Mechanical Engineering, California State University, Sacramento. This work completed under separate contracts with the State of California, Department of Transportation, Division of New Technology, Materials and Research, Sacramento.

- "Corrosion of Mechanically Stabilized Embankment Reinforcements", Kevin S. Flora and Douglas M. Parks, California Department of Transportation, Division of New Technology, Materials and Research, FHWA/CA/TL-F91TLO6, final report draft March, 1993.

● "Criteria Related Studies for the Cathodic Protection of Reinforced Concrete Bridge Elements", John Bartholomew, Jack Bennett, William Hartt, David Lankard, Albert Saques, Robert Savinell and Thomas Turk, ELTECH Research corporation, performed under the Strategic Highway Research Program, SHRP-C/UFR-92-XXX, DRAFT Report, 1992.

Urgency

This problem is faced by most owners of structures having steel elements in either disturbed or undisturbed soil. It should have the highest priority.

Cost

The development of this technology/methodology and any related testing equipment to accomplish this task could exceed \$250,000.

User Community

This problem is shared by all owners of transportation facilities and owners of steel foundations, steel

reinforcements in Mechanically Stabilized Embankments, the state DOTs (AASHTO), FHWA, all public work agencies, FAA, DOE, EPA, academia and the engineering community in general. This is a very complex and widespread problem.

Implementation

Initial implementation will probably occur with individual states and municipalities who are trying to determine the life expectancy of their existing structures. If an instrument and/or measurement technique is developed, the engineering community will be able to use the findings to design new structures having lower life cycle costs.

Effectiveness

By providing the ability to detect and measure pitting corrosion, engineers could optimize the use of cost effective materials having low corrosion rates to extend the life cycle of structures containing steel elements buried in soil.

A2K02 COMMITTEE ON TRANSPORTATION EARTHWORKS

The research problem statements appear in the order of priority established by the committee.

PROBLEM #125: PERFORMANCE OF VERTICAL DRAINS

In many deposits, vertical drains do not perform as well as expected. The designer needs a better method of predicting the field rate of consolidation to produce economical use of drains. The horizontal permeability measured in the laboratory is usually significantly greater than the vertical permeability. Field observations, however, indicate that the radial coefficient of consolidation backfigured from the field data is about equal to the vertical and that it decreases as the drain spacing becomes smaller. These reductions are usually attributed to smear. If smear is the problem, no appropriate model of this effect has been presented. All of the models describe a disturbed zone around the drain well but field data indicate an effect that is more far reaching. There is no systematic method available for testing and evaluating the probable effects of smear in a specific soil deposit, and little recognition of the extent of the problem. Not having addressed the fundamental causes of smear, a cure can not be only guessed at. The economics of vertical drains involves comparisons of both the observed and theoretical field rates for vertical drains, and the observed field rates with and without sand drains.

Objectives

To understand the causes of smear so that better testing and design procedures to predict the field behavior of vertical drains can be developed. This will include accounting for the rate of consolidation at various spacings so that projects for which the cost of vertical drains is justified can be more readily determined.

Key Words

Consolidation, settlement, vertical drains.

Related Work

There has been much work reported on field observations from vertical drain areas. Many have noted the reduced coefficients of consolidation below expected

values. None have offered any definitive solution to the problem or its investigation.

Urgency

The properties of many deposits require the use of vertical drains for controlling settlement rate and improvement of shear strength. Installations of vertical drains are expensive and the apparent low efficiency of present methods of design and installation shows that this treatment is not always cost effective. These costs cannot be reduced until the problems are understood and addressed.

Cost

\$200,000

User Community

Departments of Transportation throughout the world

Implementation

TRB publications, FHWA reports, demonstration projects, short courses

Effectiveness

This research should reduce costs for all users.

PROBLEM #126: USE OF INCINERATOR ASH IN CONSTRUCTION

As more communities in the United States adopt the incineration method of reducing the volume of waste materials, it becomes ever more apparent that safe methods of reuse are needed for the ash. At present the resulting ash is being landfilled. There are, however, increasing efforts to eliminate landfills by utilizing the ash. The timing of reuse initiatives tend to be based on political objectives rather than technical feasibility. It is

important for the transportation industry to know the treatments and techniques required to use this material safely.

Prudent use of incinerator ash depends upon two items quality of the particles and quality of the leachate. There are some uses in construction where the particles will be satisfactory but there is some question about the resulting leachate. Techniques of physical and mechanical stabilization that upgrade both the particles and the leachate are available. Most of the present information has been sponsored by the equipment vendors. The incinerator ash question must be addressed before it becomes critical.

Objectives

Develop a realistic approach to use this material in a safe, well engineered manner. This may require chemical or cement stabilization or vitrification of the ash before construction. The user must know the quality of the end product.

Key Words

Waste fills, stabilization, embankments, lightweight fills.

Related Work

Most of the work has been done by manufacturers of the incineration equipment and some has been done by vendors of vitrification and cement stabilization equipment. There has been no comprehensive approach to this problem capable of addressing all of the technical and environmental problems needed for transportation embankment construction.

Urgency

This problem is urgent. The mandated use of incinerator ash in construction will probably occur with little advanced notice. The technical community should be prepared to solve this pressing societal problem.

Cost

\$ 300,000.

User Community

TRB, FHWA, DOTs, society in general

Implementation

FHWA reports, TRB publications, demonstration projects

Effectiveness

Open a new source of material supply, protect the environment, and provide quality construction.

PROBLEM #127: END OF CONSTRUCTION STABILITY OF COMPACTED CLAY EMBANKMENTS

Recently several states have experienced failure or severe bulging of embankments constructed using compacted plastic clay. Factors contributing to these failures include:

- Laboratory compacted samples may not represent the field soil structure.
- Laboratory tests performed on the finer fraction of well graded soils do not represent the behavior of the total sample.
- Shear planes may be induced during the field compaction process.
- Field control using only dry density and water content may not effectively control the soil's shear strength.

Objectives

Evaluate the recent experience involving compacted clay embankments which have failed and determine the acting field shear strength. Perform laboratory shear tests on the soils from these embankments using both undisturbed specimens and recompacted specimens to critically evaluate the suitability of different testing procedures for measuring the design shear strength. Samples including large particle sizes will have to be tested in large scale laboratory equipment. Also examine additional tests that can be used to effectively monitor construction. Finally construct a field scale instrumented embankment designed to fail.

Key Words

Compaction, embankments strength, stability.

Current Activities

The Army Corps of Engineers has been performing laboratory tests on samples having gravel sized particles and has been evaluating their quality control during earth dam construction. The TRRL in England has been investigating the Moisture Condition Value (MCV) test as an effective procedure to control water content of compacted clays. Other investigations of failed dams and compacted fills, both to determine the responsibility and design repair measure, have restricted access because of ongoing litigation.

Urgency

High because much of the reported experience by the USBR and Corps of Engineers involves clays of low plasticity. It is hard to compact plastic clays in the lab and current procedures do not effectively measure the end of construction shear strength. Finally US practice needs to incorporate new construction control procedures that focus on shear strength instead of only on density and water content.

Cost

\$150,000

User Community

FHWA, DOTs

Implementation

FHWA and TRB publications

Effectiveness

Avoidance of failure, more economical construction.

PROBLEM #128: DESIGN METHODS AND PROCEDURES FOR ROCK SLOPE

Weathering and other natural forces can cause rocks the size of a small car to fall on vehicles and pedestrians that pass adjacent to these slopes.

Objectives

Development of guidelines to stabilize rock slopes by utilizing methods and procedures such as but not limited to:

- Scaling (removing small rock that are unstable);
- Rock bolts to retain large rock blocks;
- Containment areas and energy absorbing apparatus to prevent falling rocks from hitting vehicles or pedestrians; and
- Other stabilizing methods such as the utilization of "dental concrete" to fill rock voids;

Key Words

Weathering, erosion, water, rock bolts, nets, energy, shotcrete, geofabrics, geogrids, scaling, rock cuts.

Related Work

Tests performed by the Colorado State Highway Department and the development of a computer program to analyze the energy developed by falling rocks.

Urgency

Rock slopes that were constructed to allow transportation facilities to be constructed adjacent to them are aging. Consequently rocks of variable sizes have fallen causing property damage and injury to individuals. The problem is urgent and requires that research be performed expeditiously to protect the traveling public by developing cost effective designs.

Cost

The cost of the research may range from \$100,000 to \$500,000.

PROBLEM #129: INVESTIGATION OF THE EFFECTIVENESS OF HORIZONTAL DRAINS

As poor drainage is one of the primary causes of slope instability, enhancement of drainage is a common means for increasing slope stability. Many state transportation agencies install horizontal drains for this purpose. However, they are difficult to maintain, and there are serious doubts as to their long-term effectiveness. Improvements in the design of the drain itself or its installation procedure could result in increasing effectiveness and reduced long-term maintenance costs.

Objectives

Investigate alternate horizontal drain designs and installation procedures to see if possible long-term and reduced maintenance costs are possible.

Key Words

Slope stability, horizontal drains, drainage, design, maintenance.

Urgency

According to a recent TRB paper, landslides cause on an annual basis nearly \$100,000,000 in repair and maintenance costs. As poor drainage is considered to be one of the primary causes of landslides and slope instability, improvement of horizontal drains which are relatively inexpensive to install would be a tremendous benefit.

Cost

\$200,000

User Community

NCHRP, AASHTO, FHWA

Implementation

FHWA/NCHRP reports, TRB state-of-the-art reports/circulars.

Effectiveness

Any decline in landslide occurrence and improvement in slope stability will result in tremendous cost savings to user agencies.

PROBLEM #130: SOIL IMPROVEMENT TECHNIQUES FOR FOUNDATION REMEDIATION

Soil improvement techniques are fairly well established in geotechnical practice for new construction. As rehabilitation and retrofitting of existing transportation systems become more important, there is a need for foundation soil improvement techniques which are appropriate for rehabilitation/retrofit situations.

Objectives

Investigate common foundation soil improvement techniques and analyze their suitability/feasibility when used in foundation remediation situations. Applications to embankments, slopes, embankment foundations, bridge foundations, and natural excavated slopes are needed.

Key Words

Slope improvement, foundations, embankments, slopes, retrofit/rehabilitation.

Related Work

Almost none is currently under way on this subject. A workshop sponsored by the National Science Foundation was held at the University of Washington, August 19-21, 1991 which focused on this problem for seismic hazards. The report of this workshop outlines some of the state of practice and specific research needs.

Urgency

High priority; more and more transportation agencies are required to rehabilitate existing facilities.

Cost

\$100,000 for a preliminary feasibility category; more funds to investigate specific improvement techniques.

User Community

NCHRP, AASHTO, FHWA

Implementation

FHWA/NCHRP reports, TRB state-of-the-art reports/circulars.

Effectiveness

If existing facilities can be improved and stabilized without major reconstruction, significant construction cost savings are possible. In some cases, it may be possible to carry out the remediation techniques without closing the facility. Immediate savings in cost and reconstruction time are also possible.

PROBLEM #131: STABILITY OF EMBANKMENTS OF SOFT AND THIN COHESIVE LAYERS

The stability (bearing capacity) of embankments on deep soft deposits can be reliably determined from classical bearing capacity theory. This theory is however, not generally applicable to cases where the width of the foundation is greater than the thickness of the weak layer. Solutions based on idealized model from the theory of plasticity do not agree with each other, and they do not consider very flat side slopes, berms, nor subsurface layers of variable thicknesses. Common slope stability computer programs are not applicable to this problem.

Objectives

Develop a realistic analysis procedure of the problem using both classical mechanics and possibly finite element techniques. Bound the problem for a range of embankment widths, side slopes, thickness of weak layers, and slopes of the underlying firm layers. Develop modified computer programs or simple design charts covering the range of applicable variables.

Key Words

Embankments, foundations, stability analysis, soft soils.

Related Work

Some research has been conducted on this problem as it applies to reinforced embankments, but no easy to use reliable procedures are available.

Urgency

The problem is urgent. An unreinforced bearing capacity analysis must be carried out prior to the design of any foundation treatment alternatives, soil improvement, or reinforcement. Incorrect analysis of this problem could result in unnecessarily expensive foundation soil improvement procedures or even failures.

Cost

\$100,000

Implementation

FHWA reports, TRB circulars or state-of-the-art reports.

Effectiveness

Avoidance of embankment failures; construction cost savings.

PROBLEM #132: PROBLEMS ENCOUNTERED WITH WIDENING EMBANKMENTS

Right-of-way (ROW) in urban areas is often lacking or too costly to develop new roads, with the result that roads (including those on poor soil) are often widened to accommodate added traffic volumes. Whereas the use of embankment is normally the least expensive approach to widening, fills on soft soils may induce additional settlements, slope instability, and asymmetrical "pile drag", which are often avoided by utilizing viaducts or other structures. Strategies must be developed to eliminate faulting of pavements, settlements between old and new fills especially when they rest on compressible foundations. Solutions for stability problems resulting from the additional loads must also be developed.

Objectives

To define and develop design and construction solutions for widening embankments over soft ground.

Urgency

This problem becomes more urgent with time as upgrading of the existing ROW becomes more frequent than new construction.

A2K03 COMMITTEE ON FOUNDATIONS OF BRIDGES AND OTHER STRUCTURES

The research problem statements appear in the order of priority established by the committee.

PROBLEM #133: CAPACITY OF FOUNDATIONS AND MSE RETAINING WALL SYSTEMS DURING EARTHQUAKES

The transportation engineering community is now becoming aware of the need to ensure the stability of bridges and their foundations in all parts of the country against earthquake loading. Experiences from the Mexico City Earthquake of 1985 and the Loma Prieta Earthquake of 1989, among other, have suggested that loss of pile capacity may occur during seismic events in both clay and sand. Such loss of capacity may be the result of buildup of pore water pressures to the point where they influence pile capacity but do not produce liquefaction, to the redistribution of effective stresses in the soil mass and/or to the degradation of soil fabric. Most existing information related to loss of capacity due to vibratory loading is based on experiments that considered loading of the pile through the structure or the pile head, not through the soil, as occurs during earthquakes. Since the degradation characteristics of soils near piles are likely to be very different where loading is applied through the soil, special attention needs to be given to this form of loading before design guidelines can be developed.

Methods of computation for external stability of MSEW structures subject to seismic loading have not been studied to the same degree as have the effects on internal stability and stresses in reinforcement. The effect of surcharges or the type of reinforcement (extensible or inextensible) on developed dynamic earth pressures and inertial forces is largely unknown and inferred from limited analytical studies on structures with no surcharge constructed with relatively stiff reinforcement.

Additional research efforts are therefore warranted, and would be best undertaken at research universities having shaking table and centrifuge capabilities in possible cooperation with NSF, where it is believed matching program funds may be available.

Objectives

The objectives of the research are to:

- Adapt or develop analytical procedures to forecast capacity changes in foundations during seismic events;
- To establish methods of computation for external

stability of MSEW structures;

- To conduct experiments or to access existing data for use in verifying the analytical procedure(s); and
- To use the analytical procedures to develop recommendations for engineers who are producing new designs or evaluating the safety of foundations for existing structures.

Urgency

High.

PROBLEM #134: ARTIFICIAL INTELLIGENCE IN THE DESIGN AND CONSTRUCTION OF DRIVEN PILES AND DRILLED SHAFTS

Perhaps the single most pressing problem affecting the design and construction of deep foundations is the failure of state DOTs to employ knowledge that has been acquired through formal research and through experiences acquired both within the agency and by others. As a result, foundation costs remain excessive, and occasionally designs are inadequate. The problem is especially prevalent in the construction of deep foundations and in the evaluation of existing piles and drilled shafts, in which resident engineers and inspectors are not knowledgeable of proper construction methods and cost-effective remediation of problems that arise during construction or rehabilitation. An effective way of making this knowledge known to practitioners in a way that they will use it is by means of the decision support system, a user-friendly microcomputer program containing a knowledge base and a set of rules developed by experts and verified independently by other experts. This method of mass technology transfer is very effective, especially for younger personnel, who have had considerable experience learning through computers, and should be able to break the barrier of "if it is not done in my state (or district), I don't want to hear about it."

Objectives

The objective of this research would be to:

1. Review existing expert systems and neural network

programs that address design, construction and rehabilitation, both in the USA and elsewhere, and to adapt those feasible for use in DOT technology transfer;

2. To adapt or develop a shell program that would maximize user friendliness while permitting the proper logic to be employed (probably fuzzy logic); and

3. To develop the composite software system and to have it verified by recognized experts in design and construction [A related objective would be to have an arm of the FHWA, perhaps the National Highway Institute, develop a course that could be given in each state to familiarize state personnel with the software].

This will give each state DOT design office access to unbiased expertise in construction methods and problems that it would not otherwise have.

Key Words

Claim avoidance, computers, checklists, error reduction.

Related Work

No formal activities in this subject area are known to exist currently, although some research on expert systems in deep foundations is known to be underway at Clemson University, Auburn University and the University of Houston.

Urgency

It is urgent to develop such methods, as comprehensive expert systems require much time and verification to become reliable.

Cost

The cost of conducting the research described here is expected to be on the order of \$500,000.

User Community

FHWA and State DOTs

Implementation

The most effective implementation would be through a

demonstration project conducted by the FHWA or NHI that would encompass all state DOTs.

Effectiveness

The primary societal impacts would be reduced initial costs of bridge and wall foundations and reduced litigation.

PROBLEM #135: IMPROVED USE OF NONDESTRUCTIVE EVALUATION METHODS TO EVALUATE LOADING BEHAVIOR OF DEEP FOUNDATIONS

At present, the only effective means of evaluating the loading behavior of deep foundations is through high-strain dynamic testing or through static loading tests. These tests are expensive and are time consuming to set up for purposes of evaluating the capacities of piles or drilled shafts that are suspected of having inadequate capacity. Recently developed non-destructive evaluation methods, whose principal purpose is to detect defects, may also be capable of being used to infer stiffness and, either directly or indirectly, capacity. If appropriate enhancements of these techniques and/or modifications to methods for their interpretation can be developed, capacities of piles or drilled shafts suspected of having defects can be assessed, and the importance of the defect on bottom line performance evaluated quickly and economically.

Objectives

The objectives of the research will be:

- To determine which NDE methods can be adapted to capacity evaluation;
- To adapt one or more such methods; and
- To compare the results of static loading tests with results obtained using the adapted method, using piles and drilled shafts that have previously been tested at National Geotechnical Experimentation Sites and elsewhere.

Key Words

Piles, drilled shafts, capacity, settlement.

Related Work

Several firms have attempted to conduct high-strain tests on piles and drilled piers, but the effectiveness of the method has not been demonstrated independently.

Urgency

The urgency of this research is high relative to other problem statements submitted by A2K03. It is quite possible that this statement could be combined with Statement #137.

Cost

The cost for evaluating existing high-strain systems is estimated to be \$150,000. The cost for development of new systems could exceed \$1,000,000.

User Community

FHWA and HPR (state DOTs)

Implementation

This research would best be implemented through a demonstration project managed by the FHWA or contract organization.

Effectiveness

The research could be quite effective in qualifying piles and drilled shafts suspected of having defects during construction. The proposed procedure would essentially be an inexpensive proof test in bearing. It would increase the level of safety for the driving public.

PROBLEM #136: DESIGN METHODS FOR PILE GROUPS TO RESIST DYNAMIC LATERAL LOADS

Heavily loaded bridge foundations often consist of groups of driven piles or drilled shafts. Approximate methods have been developed in the past by several academic researchers to analyze groups of piles subjected to lateral shears and overturning moments due to static loads or to slow cyclic loading. However, design

methods are not generally available to analyze pile groups subjected to dynamic loads, such as impact loads from ships, ice loads and seismic events. In particular, there is a need to develop methods that are as simple as possible for forecasting deflections and rotations at the interface between the piles and superstructure and distributions of shears, moments and axial thrusts among the piles in the group.

Objectives

The objectives of the research are to investigate existing methods for analysis of dynamic loading (both loading through the pile cap and loading through the soil). Using these analytical methods parametrically, and other information, design methodologies are to be developed and reported.

Key Words

Structure-foundation interaction, seismic loading, ship impact, ice loading, soil-structure interaction.

Related Work

An initial effort in establishing a structure for managing the research is apparently being established in the Office of Operations of the FHWA.

Urgency

The urgency of this project is high, since bridges in most areas of the USA will have to be evaluated for response of the foundation to seismic loading and other forms of dynamic loading. The response of the foundations to such loadings is a critical component of the evaluation.

Cost

The cost of a comprehensive research project, which will involve considerable expertise and both analytical and experimental investigations is estimated to be \$800,000.

User community

FHWA

Implementation

Implementation will have to come through the production of design manuals and NHI courses for the bridge divisions in most states.

Effectiveness

The primary impact of the research on the public will be the avoidance of catastrophic failures of the type that occurred at the Cypress interchange during the Loma Prieta earthquake and will also ensure that lifeline paths remain open during catastrophic events that might otherwise destroy bridges.

PROBLEM #137: EXPEDIENT STATIC LOADING TESTS FOR PILES AND DRILLED SHAFTS

While static methods of pile design have advanced considerably during the past years, and while dramatic advances have been made in the high-strain dynamic testing of piles and drilled shafts, there remains a need to conduct static loading tests. However, the costs for such testing are presently in the range of \$50 - \$100 per ton of maximum load, which is often too high to justify static loading tests in the case of smaller construction projects and for conducting fundamental research on pile-soil interaction, especially for prototype-sized drilled shafts, whose capacities can exceed 1000 tons. There is a need to develop or adapt expedient testing methods that are capable of applying high static loads to piles and drilled shafts, that give reliable results and that are inexpensive.

Objectives

The objectives of this research are:

1. To identify and evaluate existing low-cost static testing expedients;
2. To evaluate the reliability of the results obtained from such expedients and develop modifications, if necessary; and
3. To propose new expedient testing methods if existing expedient testing methods, as modified, are not considered feasible and reliable.

The study will result in the capability to test more deep foundations at lower cost and thereby increase the

reliability and reduce resistance factors or factors of safety used in design.

Key Words

Capacity verification, cost-effectiveness, improved reliability, structural integrity.

Related Work

None known by government agencies, but private industry in the USA and elsewhere is known to be developing expedient static testing methods that may be the object of the evaluation.

Urgency

The research is urgent, as it will undoubtedly save wasteful overdesign in foundations for infrastructure rehabilitation, while at the same time helping detect poorly constructed foundations before the public becomes inconvenienced.

Cost

The projected cost is in the vicinity of \$600,000, if an existing system is found to be adequate. If not, an additional \$750,000 may be needed to develop a new system.

User Community

The user community will be the FHWA, State DOTs and highway contractors.

Implementation

Research of this type would best be implemented through the performance of a detailed demonstration project for all State DOTs.

Effectiveness

The research should result in more reliable foundations at lower cost due to reduced factors of safety brought about by more secure knowledge of the actual capacity of foundations.

PROBLEM #138: LOADING TEST DATABASE FOR DEEP FOUNDATIONS

Before methods of analyses and design are accepted for specifying deep foundations, the ability of the method to produce a safe and economical design should be established. A common procedure for assessing these methods is to compare predicted behavior with measured behavior. The types of foundations could include driven piles, drilled shafts, auger-grout piles, mini-piles, and drilled-and-grouted piles.

Uncertainties associated with predictive methods are also illuminated by comparing predicted and measured behavior for a large number of tests. Ideally, a convenient and readily accessible collection of carefully documented axial loading tests on deep foundations would provide the researcher, design engineer, or licensing agency a convenient tool for evaluating new and existing methods.

The results from this collection of axial loading tests represents a unique opportunity to evaluate current methods for predicting axial behavior, to improve the design methods, and to provide for an accessible data base so that design methods can be evaluated rapidly. Use of a database is especially important in the evaluation of resistance factors for the development of new LRFD factors for foundations.

Objectives

The objectives of the research effort are to collect, interpret, and transcribe a large amount of loading test data into an electronic, relational database and use the database to evaluate methods for predicting behavior of deep foundations. The database will be used to evaluate the ability of current methods to predict axial behavior of deep foundations. An additional objective of this research is to make the database available publicly so that researchers outside the DOT, design engineers and licensing agencies can use the database for their purposes. An easily accessible database can potentially enhance and encourage the development of technology and new methods of deep foundation analysis, design and construction by making available the detailed results of past loading tests.

Key Words

Computers, settlement, capacity, universal access, consistent format.

Related Work

Several deep foundation data bases of varying detail have been developed or are currently being developed. These include databases by the FHWA at Turner-Fairbank Research Center, University of Illinois, University of Florida, University of Texas, Cornell University, Texas A and M University, University of Houston, and perhaps others. These databases were developed for differing purposes and are not consistent in detail or format.

Urgency

Since work has already begun at many locations, this statement is less urgent than others suggested by Committee A2K03. However, consistency of format and completeness of data have not been defined. This consideration will probably mean that much of the work that has been done to date will have to be done over in a consistent, complete format.

Cost

The cost of this research is estimated to be approximately \$300,000.

User Community

This is an ideal NCHRP project.

Implementation

The results of the completed project can be implemented through the distribution of reports describing the use of the data base and by NHI instruction courses at the locations of State DOT bridge design offices.

Effectiveness

Bridge designers will be able to develop improved static design methods for deep bridge and wall foundations, thus reducing waste in piling cut off or expensive splicing, leading to lower initial foundation costs, and perhaps fewer claims by contractors.

PROBLEM #139: EVALUATION OF AUGURED PILES FOR LOAD BEARING IN HIGHWAY STRUCTURES

Augered piles (piles that are constructed by drilling a borehole with a continuous flight auger and grouting or concreting the hole as the auger is withdrawn) have been used for decades as bearing piles in the private sector but are almost never used in that manner in highway construction and other segments of the public sector. Lack of usage in the public sector stems from a perceived lack of quality control and a lack of appropriate methods for computing static capacity. There are many instances in which augered piles could be economically superior to either driven piles or conventional drilled shafts, so that further study of augered piles is warranted.

Objectives

The objectives of the research are:

1. To evaluate methods of augered pile construction around the world and to determine which quality controls and quality assurance techniques will be needed to make augered piles acceptable in the bridge engineering community in the USA; and
2. To evaluate or develop design models for predicting the capacity of augered piles in the major soil types. Small-diameter augered piles used for bearing purposes, called "pin piles" or "micro piles," fall into this category.

Key Words

Rapid construction, reduced costs, quality control/assurance, design methods.

Related Work

The Deep Foundations Institute has recently completed an inspector's guide for augered pile construction. Considerable work is underway in France to provide automated procedures for quality control. The French LCPC is embarking on a major research program in pin piles that would provide an excellent opportunity for collaborative work with U.S. researchers.

Urgency

The urgency of this statement is slightly lower than those

that follow only because relatively economical foundation alternates are available. However, considering the timing of the French research and the obvious benefits that could accrue by cooperating with them, the project should be put on an accelerated time schedule.

Cost

Both analytical and experiments work would be involved at an estimated cost of \$750,000.

User Community

FHWA

Implementation

A possible means of implementation would be through NHI workshops conducted for State DOTs.

Effectiveness

If methods to assure reliability of augered piles can be developed, a major change will result in the way in which bridge and wall foundations are constructed -- with smaller and more mobile equipment, which should have an important impact on costs of initial construction and rehabilitated structures.

PROBLEM #140: CORROSION OF DRIVEN STEEL PILES

Many older bridges are supported on driven steel piles. Whether foundation rehabilitation is needed may depend largely on whether such piles are substantially corroded. Some research studies have concluded that corrosion in driven steel piles is not a problem as long as a substantial portion of the pile is below the water table. Yet, there have been a number of instances in which corrosion has been observed when apparently "safe" piles have been exposed. There are no applicable guidelines for investigating a site to determine whether corrosion is likely to have occurred or will occur with new construction. As a result, protection is often recommended by corrosion engineers who are unfamiliar with the corrosive behavior of steel piles, which can result in solutions that are overly conservative and expensive.

Objectives

The primary objective is to develop reliable criteria that will allow the design engineer to determine the likelihood of corrosion in existing piles or in piles to be driven and to quantify the probability that the amount of corrosion will be detrimental to the foundation now or at some time in the future. This objective should include recommendations for in situ and/or laboratory tests that will be appropriate for assessing probable corrosion of steel piles on a specific site.

Key Words

Design life, in-situ testing, corrosive soils, deteriorating foundations.

Urgency

The urgency of this research is not as high as other statements submitted by A2K03, only because the problem has not yet resulted in foundation failures. However, such failures are only a matter of time, so that some level of preliminary research should begin now.

Cost

The cost of a pilot program, which might possibly be conducted at NSF/FHWA National Geotechnical Experimentation Sites, is expected to be \$150,000.

User Community

FHWA or AASHTO. This could also be an effective NCHRP project.

Implementation

A mandate could be issued by the FHWA for all states to inspect steel piling for excessive corrosion, similar to the current program of inspecting bridge foundations for scour. This would be accompanied by a demonstration project to instruct state DOTs in proper methods.

Effectiveness

The effectiveness of this project would be felt over the

long term by providing guidance concerning the proper time for underpinning or replacement of foundations for older bridges, and would thus contribute greatly to present bridge management programs.

PROBLEM #141: FEASIBILITY OF AND DESIGN METHODS FOR LOAD-BEARING SHEET-PILE ABUTMENTS

According to the FHWA statistics, 41 per cent of the nation's 578,000 bridges are either structurally deficient, thereby requiring replacement, or functionally obsolete, requiring either widening or structural replacement. Many of these bridges have short spans, and rehabilitation can benefit from the application of technology that produces cost-effective abutments. Steel sheet piling can carry both lateral and vertical loads, thus affecting considerable economy over separate wall and bearing pile systems. Further economy can be realized by the fact that shoring and cofferdams can be eliminated during construction, thus accelerating the process. Cost savings nationally could potentially exceed \$1,000,000,000.

Objectives

The objectives of this research would be to:

1. Acquire information on the design and performance of load-bearing steel sheet pile abutments both in the USA and elsewhere;
2. Conduct either analytical or experimental studies, or both, to investigate the effects of sheet pile-soil interaction, use of tiebacks, application of combined loading and similar effects, so as to provide a rational basis for design methods; and
3. To develop a straightforward design method that can be confidently applied by bridge design engineers.

Key Words

Composite elements, cost-effectiveness, rehabilitation device.

Related Work

Some load-bearing steel sheet pile abutments are known to have been constructed in New York State and appear to be providing adequate service.

Urgency

Committee A2K03 deems that this research is less urgent than the preceding problem statements but should certainly be pursued, even if on a reduced-funding, extended period basis.

Cost

The cost of a preliminary project, at reduced scale, is expected to be of the order of \$150,000. Such a study would be primarily analytical, with observation (instrumentation) of one or two steel sheet pile abutments that are currently being constructed. Future, more detailed, studies could cost \$500,000.

User Community

FHWA or AASHTO, and HPR programs through interested states.

Implementation

Several implementation strategies could be considered, including NHI workshops on the subject and development of design/construction manuals for the state bridge/foundation engineer.

Effectiveness

As indicted in Objectives, above, steel sheet pile abutments will be very cost effective, especially for short-span bridges and could save up to \$1,000,000 in new construction and rehabilitation costs over the next decade. These funds could obviously be directed to other societal needs.

A2K04 COMMITTEE ON SUBSURFACE SOIL-STRUCTURE INTERACTION

PROBLEM #142: EFFECTS OF SOIL CHARACTERISTICS ON LOADS CONVEYED TO PIPELINES BY MEANS OF TRENCHLESS CONSTRUCTION METHODS

Trenchless construction is the process of installing or replacing underground utility systems without open-cut excavation. In the past several years, the use of trenchless construction methods has significantly increased. This includes the use of pipe jacking, microtunneling, horizontal directional drilling, and guided boring systems.

The increase in use of trenchless construction is driven by the need to replace an aging urban utility infrastructure system and install new facilities, while minimizing construction costs, disruption to the community and environmental impact. A critical area of application for trenchless construction is the crossing of highways, streets, railroads, and other transportation arteries. These crossings need to be implemented without disruption of traffic and with minimal effects on the long term integrity of the overlying facilities.

While the technology has moved forward, there exists limited technical data and knowledge of the relationships among the soil characteristics, cutting mechanisms, soil loads, and conduit materials and dimensions. A quantification of soil loading mechanisms would provide a rational basis for pipe and conduit design. A better understanding of the soil/pipe/machine interrelationship would permit improvements in the design and performance of trenchless equipment and installed pipes.

Objectives

Conduct laboratory and field tests to quantify the interrelationships between the trenchless cutting mechanism, soils to be excavated and loadings on installed conduits. Using this information, develop design guidelines for trenchless installation by pipe jacking, microtunneling, horizontal directional drilling, and guided boring.

Key Words

Trenchless construction, soil loads, pipe jacking, microtunneling, horizontal directional drilling, guided boring.

Related Work

The Army Corps of Engineers in the Trenchless Technology Center at Louisiana Tech University are conducting a field evaluation program on microtunneling equipment and guided boring systems. This program is directed at developing various specifications for trenchless technology. The proposed work would be complementary to the work being conducted by the Army. It would analyze the theory behind the relationships and conduct laboratory experiments to validate the results.

The Gas Research Institute has sponsored research for several years to analyze pipeline loadings at railroad crossings. This work showed that the current design methodology was conservative and new pipeline crossing equations were developed.

Urgency

This project is determined to be of high priority with significant benefit to transportation in our country. Thousands of miles of utility systems are being installed and replaced beneath our highways and roads each year. Trenchless technology offers an economic and less disruptive method to conduct these operations.

Cost

This program is envisioned as a multi-year effort with each year costing \$100,000-\$150,000. The total program will last three years with a cost of \$300,000-\$450,000. It is likely co-funding could be obtained from other interested parties such as utilities, manufacturers, and other government agencies.

User Community

FHWA, AASHTO, NHTSA, local departments of public works, utilities (gas, water, sewer, electric, telephone), contractors, and consulting engineers.

Implementation

All types of design engineers and contractors could use the results on upcoming construction projects using

trenchless technology. Manufacturers could use the results to improve their products.

Effectiveness

Trenchless technology has the potential to significantly reduce construction costs. Some projects have been reduced by upwards of 50 percent or more.

PROBLEM #143: THE DESIGN OF BACKFILL ENVELOPES FOR UNDERGROUND STRUCTURES

Current AASHTO structural design specifications for culverts and other hydraulic structures do not adequately address the design of the select backfill envelopes required to provide adequate structural performance. The revised AASHTO Section 12 LRFD offers no improvement in its current draft form. Most backfill requirements are based on decades-old rules-of-thumb or given lip service such as "should be evaluated." In addition, the number of pipe materials and backfills (e.g., CLSM-CDF, Flash-Fill, etc.) have proliferated without any updating of backfill requirements.

The AASHTO structural design requirements for culverts and hydraulic structures should be revised to provide adequate guidelines for the design and construction of backfill envelopes, foundations, etc.

Current methods of soil-structure interaction analysis (e.g., finite element programs, "Soil-Eval" program, buckling theories, etc.) are now available to aid the designer in providing backfill/foundation requirements based on sound engineering principles. However, work is still needed to evaluate fully the following:

- Influence of installation procedure and bedding conditions on backfill properties affecting structure performance; and
- Influence of the backfill envelope on long term changes in buried structure loads and deflections.

Objectives

Development of guidelines for the design of backfill envelopes for culverts and hydraulic structures.

Key Words

Culverts, soil-structure interaction, finite element analysis, buckling, select backfill.

Related Work

- CANDE update by S. Musser;
- Buckling work by E. Selig and I. Moore; and
- "Soil-Eval" work by Bowser-Morner.

Urgency

Given consideration of the current revisions to the AASHTO design specifications for culvert structures, there is an urgent need for development of guidelines for the design of backfill envelopes for underground structures.

Cost

\$200,000 - \$500,000.

User community

AASHTO, FHWA, local agencies, design consultants

Implementation

Rational design procedures based on the guidelines developed will be implemented by designers of culvert structures.

Effectiveness

More economic and safe culvert designs will result.

PROBLEM #144: PLASTIC PIPE MATERIAL AND STRUCTURAL CHARACTERISTICS AND THEIR EFFECT ON DESIGN

Current ASTM and AASHTO materials specifications for plastic pipe require a minimum ring stiffness (based on flexible pipe theory such as the Iowa Deflection formula) as the only structural requirement beyond material standards for these types of pipes. Section 18 of the AASHTO Standard Specifications for Highway Bridges requires minimum stiffness, wall cross-section area and moment of inertia and utilizes ring compression theory and buckling as limiting design values in a manner similar to corrugated metal pipe procedures. In Section 18, long-term resin properties can be used in design, devalued with time based on tensile

strength values. These standards do not adequately reflect the viscoplastic properties of these materials. They also do not reflect failure modes or forms of localized distress for this type of pipe seen in some field evaluations, which appear to be more closely related to corrugation or profile stability and/or localized longitudinal flexibility.

Objectives

1. Conduct a literature search to collect available data on pipe response to load as well as material properties.
2. Determine material properties applicable to the design or selection of non-pressure plastic pipes.
3. Perform laboratory and field tests to supplement the available data. Explore effects of loading rate, particularly in the compression mode. Tests should be conducted on pipe and resin samples. Profile wall and corrugated pipe samples should be tested to define various parameters to reflect longitudinal flexibility, resistance to bending moment, and corrugation stability.
4. Conduct field tests with varying backfill conditions to determine acceptable limits of the parameters indicated in 1, 2, and 3 above.
5. Develop analytical procedures for predicting performance limits. Relate these performance characteristics to predicted soil reactions.
6. Recommend revisions to the materials and design specifications for profile and corrugated wall plastic pipe types.

Key Words

Ring stiffness, flexibility, flexibility factor, bending moment, soil-structure interaction, corrugation, profile wall, corrugated polyethylene pipe, plastic pipe.

Related Work

Highway research in progress:

- Individual corporate profile and corrugation development;

- Pennsylvania DOT and FHWA funded 104, "Deep Burial Study on Polyethylene Pipe" by Dr. Ernie Selig, University of Massachusetts; and

- Computer simulation using CANDE done by Dr. Mike Katona and funded by the Corrugate Plastic Tubing Association.

Urgency

With transportation agencies using more plastic pipe in critical applications, it is imperative that design limits be accurately defined. This research would greatly improve existing design procedure.

As part of the current national trend to repair the country's deteriorating infrastructure, many states have greatly increased their programs of small culvert replacement. Corrugated polyethylene pipe has shown promise as an easily handled durable product for maintenance culvert replacements. However, structural requirements for this material should reflect the actual distress and/or failure modes encountered in this type of installation.

Cost

\$500,000

User Community

AASHTO, FHWA, local agencies, design consultants

Implementation

Rational design procedures based on the research will be implemented by designers. Manufacturers will be able to produce improved piping and culverts.

Effectiveness

Use of new materials will lead to economic and beneficial choices and promote more cost-effective design and construction.

A2K05 COMMITTEE ON MECHANICS OF EARTH MASSES AND LAYERED SYSTEMS

PROBLEM #145: WATER MOVEMENT IN CLAY EMBANKMENTS

Many clay embankments fail several years after construction. Water, in the form of springs and seeps, was frequently observed in the failure zone. It is widely believed that the water is related to failure. However, the source of such water has rarely been identified. Consequently, it is difficult to identify methods of prevention and repair.

Objectives

To identify source and movement of water in clay embankments; to identify methods for control or removal of such water.

Key Words

Groundwater, embankment, slope stability.

Related Work

Observations of failure in clay slopes and embankments due to loss of negative porepressure following rainstorms have been documented. However, the situation is more complex because water can enter embankments from aquifers in adjacent hillside, via failures in median drains or shoulder drains.

Urgency

This is an urgent problem because failures occur regularly in states such as Ohio and West Virginia. To reconstruct an embankment after a failure is expensive and can equal the cost of the research project.

Cost

\$1,000,000

User Community

state DOTs

PROBLEM #146: DYNAMIC CONSOLIDATION OF FINE-GRAINED SOILS

Methods of dynamic and impact consolidation have been developed and offer potential savings in construction costs. While the processes have been shown to be practicable for loose granular soils, the mechanism is not completely understood and feasibility of application in saturated fine-grained soils has not yet been investigated. Therefore, there is an urgent need to develop a data base to improve our engineering evaluation of soil types that can be cost-effectively improved. Moreover, there is a need to develop a laboratory index test for feasibility assessment.

Objectives

- Develop a mechanistic understanding of the process of consolidation of fine grained soils due to impact loading.
- Understand effect of impact loading on primary consolidation and secondary consolidation.
- Identify soil types that are amenable for cost-effective impact consolidation.
- Understand the factors (e.g. impact time interval, spacing, impact energy) affecting effectiveness of impact consolidation and develop design guidelines.
- Synthesis of case histories to develop a database for study feasibility, cost-effectiveness and develop a fundamental understanding of impact consolidation in fine-grained soils.
- Instrument future project sites to study effectiveness. Collect quality data to study the phenomenon of impact consolidation.
- Study influence of soil type, spacing, impact time interval, impact energy on effectiveness.
- Develop laboratory index test to evaluate soil types that are amenable for impact consolidation.

Key Words

Consolidation, impact loading, secondary consolidation.

Urgency

Several current/future difficult ground (e.g. peat) sites encountered in highway projects can be improved. The

technology proved practical for loose granular soils and could become cost-effective for fine-grained soils provided this feasibility study is conducted.

Cost

\$300,000

User Community

Land developers, ports/airports developers, transportation/highway construction

Implementation

Methodology and technique is available.

Effectiveness

Available case histories indicate very cost-effective for difficult ground conditions where other traditional techniques are ineffective and difficult to implement.

PROBLEM #147: VACUUM CONSOLIDATION OF FINE-GRAINED SOILS

Concept of vacuum consolidation has been developed. Pilot scale studies indicate that this technique is practical and offers potential savings in construction costs. Unique techniques available for ground improvement/settlement mitigation at difficult ground conditions such as soft hydraulic fills, peat, submerged soft ground beneath bridge foundations/port facilities. While the concept is well understood, analytical tools for the design and predicting performance are not well developed.

Objectives

- Understand all the factors governing the design and performance of vacuum consolidation;
- Develop design guidelines to address selection of wick/sand drains, effect of presence of permeable horizontal layers, depth to groundwater and off-shore applications;
- Develop guidelines for selection of site isolation/leakage barrier systems, vacuum pump (power and spacing) and methodology for cost-effective operation;

- Develop laboratory index tests for practical feasibility evaluation;

- Investigate feasibility of vacuum consolidation to improve off-shore hydraulic fills during placement;

- Synthesis of case histories to develop a database and to study feasibility, cost-effectiveness and factors affecting design and performance of vacuum consolidation systems;

- Instrument future project sites to study effectiveness, and collect quality data to study influence factors governing vacuum consolidation;

- Laboratory feasibility studies to simulate vacuum consolidation of hydraulic landfills during construction; and

- Develop design guidelines for design and performance prediction.

Key Words

Consolidation, vacuum, preloading.

Urgency

Several current and future multi-billion off-shore port/air port/bridge development projects can directly benefit from this, provided this feasibility study is conducted and design guidelines are developed.

Cost

\$300,000

User Community

Offshore ports/airport developers, transportation/highway construction.

Implementation

Easy to implement, automated operation and control.

Effectiveness

Available case histories indicate very cost-effective for difficult ground conditions where other traditional techniques are ineffective and difficult to implement. In cases where other conventional techniques can be used,

vacuum consolidation can save about 50% in construction costs alone.

PROBLEM #148: DISCRETE ELEMENT METHODS FOR ANALYSIS OF DISCONTINUOUS MEDIA

While geotechnical engineers routinely apply continuum mechanics to problems in soils and soil-structure-interaction, the fact that granular soils and fractured rock are discontinuous need to be recognized. Solutions that consider the material as discontinuous are needed for a variety of problems.

Objectives

To develop discrete element methods for the practical solution of 2-dimensional and 3-dimensional problems in granular materials and fragmented rock.

Key Words

Discrete element method, discontinuum, granular material, rock, numerical simulation.

Related Works

Discrete element methods have been used to simulate behavior of granular materials and fragmented rock for a number of problems. These include asphaltic cement materials, rock falls and rock slides, tunnel stability, excavation and handling of fragmented rocks, cone-penetration into granular soils, and soil-structure interaction. The material is treated as an assemblage of particles. The voids in the assemblage can be modelled as fluids or visco-elastic materials. The interaction of particles is controlled by the interface properties and void properties.

Urgency

The potential for applications of this method is improving rapidly as the power of computer platforms improves. The recent announcement of the alpha series CPU chips means that engineers will have 150MHz PC's on their desks in the near future. This computer will make discrete element methods, that are computationally intensive, accessible to practicing engineers.

Cost

\$1,000,000

User Community

Designers of rock slopes and tunnels, designers of asphaltic concrete mixes, engineers that need solutions to soil-structure interaction problems.

PROBLEM #149: ENGINEERING BEHAVIOR OF RECYCLED WASTE GEOCOMPOSITES IN PAVEMENT SYSTEMS

The increasing environmental concerns with regard to the engineering needs for dumping and storage of the evergrowing solid wastes have stimulated, during the past few years, the engineering use of recycled wastes in highway construction. Recycled wastes such as used tires, recycled asphalt and PCC pavements, incinerator residues, fly ash and recycled plastics, have been considered and used in pilot projects. However, the implementation of new highway construction materials derived from variety of sources of recycled wastes needs rational methods of characterization for long term engineering performance to be developed. The engineering use of these new construction materials could result in significant savings of project costs and natural materials and appears to provide environmentally acceptable, cost effective engineering solutions. However, it requires a basic understanding of the engineering behavior of geocomposites involving recycled waste materials and natural aggregates to permit reliable performance quality control, environmental impact assessment, and engineering construction guidelines to be developed.

Objectives

- Develop basic understanding of the engineering behavior of geocomposites involving recycled waste materials and natural aggregates for highway construction;

- Environmental impact assessment of the use of recycled waste materials in highway construction; and

- Develop characterization methods, performance quality control and engineering guidelines for the use of geocomposites with recycled waste materials in highway construction.

- Synthesis of available data with regard to engineering use of recycled wastes in highway construction.

- Monitoring engineering performance of test sections using recycled wastes to develop relevant data base for assessment of engineering performance, evaluation of design methods, and on site environmental impact assessment.

- Develop laboratory index tests for feasibility evaluation and environmental impact assessment with regard to the use of waste geocomposites in highway construction.

- Update design methods and specifications for the use of waste geocomposites in pavement systems.

Urgency

Several feasibility studies have been completed demonstrating the various applications for highway

construction. However, there is an urgent need for engineering performance evaluation studies that will permit development of reliable engineering guidelines for mechanical characterization quality control and environmental impact assessment and enhance the implementation of these new construction materials.

Cost

\$360,000 over 30 months

Effectiveness

The proposed research will enhance the present capabilities to manufacture new cost effective highway construction materials (negative costs) while addressing a major environmental concern. It will pave the way for the necessary transformation and advancement of the highway materials and construction practice.

A2K06 COMMITTEE ON SUBSURFACE DRAINAGE

PROBLEM #150: GEOCOMPOSITE EDGE DRAIN INSTALLATION CONCERNS

Installation of prefabricated longitudinal edge drains next to new or old pavements is becoming more popular as the detrimental effects of subsurface water upon pavement systems is becoming more generally recognized. Installation generally calls for the excavation of a trench adjacent to the pavement. No general specifications or construction procedures are available to ensure adequate trench backfill compaction. Field experience indicates that often construction compaction was minimal or ineffective or edge drains were damaged by compaction forces. Lack of compaction of the trench backfill leads to:

- Settlement of the trench backfill; and
- Lack of edge support for the pavement structure.

The settlement presents a maintenance problem. The loss of edge support may result in a substantial loss of pavement fatigue life due to resulting higher strain under loading.

Objectives

The objectives of this research are:

1. Evaluate current construction practices in this area;
2. Evaluate loss of pavement edge support due to drain trenching operations with both good and poor compaction procedures; and
3. Propose and evaluate appropriate construction procedures and backfill materials to achieve high levels of trench backfill compaction and good soil/geotextile contact without destroying the edge drain.

Key Words

Backfill, installation/ construction procedures, compaction, pavement, trench.

Related Work

Past work has been performed on large utility trenches. Work is being performed by the Kentucky Transportation Center to determine the effects of compaction forces on edge drain structure.

Urgency

Prefabricated pavement edge drains are being used to a much greater extent now than in the past. The engineering profession must assure itself that the installation of these drains to remove unwanted subsurface water does not result in magnified pavement strains which will, in turn, lead to shortened fatigue life.

Cost

The estimated cost of this research is \$250,000.

User Community

This research needs statement should be distributed to all state DOT agencies, FHWA, universities currently involved in geosynthetic research, and TRB Committees A2K06 and A2K07.

Implementation

The findings of this research should be distributed to all state DOT agencies and geocomposite edge drain manufacturers for development of improved specifications and installation procedures.

Effectiveness

The implementation of the findings of this research will provide for better and longer term performance of the geocomposite edge drains, resulting in longer pavement serviceability life.

PROBLEM #151: METHODS TO MITIGATE PRECIPITATE POTENTIAL OF SUBBASE AGGREGATES

In the next several years, restoration, rehabilitation and reconstruction of our highways will be our major program effort. To accomplish this program, the use of recycled PC concrete, rubblized or cracked and seated PC concrete pavements and steel slags has proven to be an economical approach to provide granular materials for subbase and porous media backfill. However, it has

been observed that porous media and underdrain pipes become encrusted with CaCO_3 (Tufa) precipitate which is formed by chemical reactions on the free lime inherent in these materials. This leached material has plugged the installation subsurface drainage or blinded geotextile filters or wraps such that the free moisture becomes trapped in the pavement section causing early surface distress.

Objectives

To develop methods to reduce the precipitate potential of recycled PC concrete, rubblized or cracked and sealed PC concrete pavements, and steel slags used as subbases.

Key Words

Rubblized, cracked, sealed, pavement, Tufa precipitate, drainage, slag.

Related Work

At present, some States are investigating the reasons that underdrain systems have failed and have recognized the above problem to exist. The University of Toledo is conducting research for the Ohio DOT to develop methods to identify the precipitate potential of subbase aggregates and offer potential methods to reduce that potential.

Urgency

There is a considerable benefit to be gained by keeping needed subsurface drains functioning throughout the life of a pavement. With the use of recycled (waste) materials being economical, any detrimental effects on other entities of the pavement system should be corrected to obtain the most cost-effective installations.

Cost

The estimated cost of this research project is \$300,000.

User Community

This research needs statement should be distributed to all state DOT agencies, FHWA, AASHTO, universities

with pavement design studies, and members of TRB Committees A2K06, A2E06, A2F01, A2F02 and A2B04.

Implementation

The findings of this research should be distributed to all state DOT agencies, AASHTO, and FHWA.

Effectiveness

The implementation of the findings from this research will result in better design of subsurface drainage systems which will allow for continued use of recycled materials, and provide for longer pavement serviceability.

PROBLEM #152: COST EFFECTIVENESS OF USING FREE DRAINING LAYERS IN THE PAVEMENT SYSTEM

A major factor contributing to the rapid development of pavement distress is excessive moisture in the pavement structural section. In recent years, numerous states have utilized free draining base course layers and subdrainage systems to remove water from the structural pavement section. Although the addition of free draining layer and subdrainage systems to pavement during rehabilitation and new construction increase the total cost, their is considerable feeling that this cost is far outweighed by the increase in performance life of the pavement.

The major problem that exists in this area is that of providing quantitative data which can be used to evaluate the cost effectiveness of using drainage layers in pavement systems and provide a more exact evaluation of the benefits of various types of pavement drainage layers.

Objectives

The general objective of the project is to develop a quantitative base to describe the effectiveness of using free draining pavement layers. The specific objectives of the study are:

1. Define the various types of free draining layers used in pavement systems;
2. Evaluate the total cost of construction of free draining pavement layers to include material costs;
3. Compare the performance of pavements on free draining layers with those on poor draining layers; and

4. Quantitatively compare the cost vs. performance properties of pavements with free draining layers with those pavements without free draining layers.

Key Words

Performance life, distress, moisture base course, subdrainage.

Related Work

Although the benefits of pavements subdrainage are well accepted, little has been done to quantitatively evaluate those benefits. Some of the current activities include

- Studies of subdrainage effectiveness on rigid pavement faulting by California DOT;
- Studies of open graded base course gradation requirements by Pennsylvania, New Jersey, Illinois, and other DOT offices;
- Studies of open graded base course performance in France by the Central Laboratories of the Ponts et Chaussées;
- Numerous FHWA studies on the influence of subdrainage, pumping, and aggregate gradation on pavement performance; and
- The continued interest by highway agencies in water related problems as indicated in SHRP.

Urgency

The influence of water in pavement systems has been widely documented. Various subdrainage systems are being utilized in pavement rehabilitation and construction which need to be evaluated in reference to their cost and benefit. Although there is a qualitative feeling about the practical benefits of good subdrainage systems, an urgent need exists to quantitatively evaluate these systems. A synthesis of practice is urgently needed to provide information for the design of cost effective pavement drainage layers and to establish the value of drainage layers in pavement systems.

Cost

The estimated cost of this research is \$150,000.

User Community

This research needs statement should be distributed to all state DOT agencies, FHWA, AASHTO, and members of TRB Committees A2KO6, A2BO2, A2BO3 and A2BO4.

Implementation

The findings of this research should be distributed to all state DOT agencies, AASHTO, and FHWA.

Effectiveness

This research will provide a quantitative bases on which the cost effectiveness of various base layer systems for pavements can be compared. This will allow the inclusion of the most economical, performance base selection of base layers in pavement design.

PROBLEM #153: DEVELOPMENT OF ANALYTICAL MODELS TO ADEQUATELY ACCOUNT FOR INTERFACE CHARACTERISTICS OF SOILS AND GEOSYNTHETICS

Geosynthetics have been used on an increasing number of projects as an effective means of stabilization. Too often these materials are thought of as cure-alls for a number of problems. Very little effort has been directed towards evaluating the specific effect of the interaction between soil and geosynthetic. Lab modelling of field problems indicate that there are numerous parameters which affect interface properties. It is, therefore, extremely difficult to generalize these properties in a simple analytical model which is useful and yet reliable.

Objectives

The objective of this research is to quantify the actual interface characteristics of geosynthetics in contact with real soil. This would be accomplished by proper modelling of the geosynthetic/soil system and measuring system stress-deformation-volume change characteristics during loading as well as actual stress-deformation characteristics of the geosynthetic material. Upon completion of this phase, development of a realistic analytical model which accounts for these characteristics would be initiated.

Key Words

Geosynthetic, geotextile, geogrid, modelling, laboratory simulation, analytical modelling.

Related Work

Manufacturers typically address and report basic geosynthetic properties in their literature. When results are reported, they are for specific normal stresses, small scale models and "convenient" soil. A more fundamental picture needs to be developed.

Urgency

The use of geosynthetic material for stability has been steadily increasing in recent years. New products are constantly being developed, including some very high strength composites. Very little is known about their interaction. Expensive full-scale test sections are often undertaken to try and fine tune design decisions. An analytical model using measurable fabric and soil properties is needed to economically design fabric soil systems.

Cost

The estimated cost of this research is \$350,000.

User Community

This research needs statement should be distributed to all state DOT agencies, FHWA, universities with geosynthetic programs, and TRB Committees A2KO6 and A2KO7.

Implementation

The results of this research should be distributed to all state DOT agencies, FHWA, geosynthetic manufacturers, and universities with geosynthetic programs of study.

Effectiveness

The results of this research will lead to improved design methods for geosynthetic installations, leading to improved performance and cost savings.

PROBLEM #154: APPLICATION OF AASHTO PAVEMENT DESIGN DRAINAGE COEFFICIENTS TO THE DESIGN OF FULL DEPTH ASPHALT CEMENT PAVEMENTS

The new AASHTO Pavement Design method utilizes a drainage coefficient in the design of concrete and aggregate base bituminous pavements to account for the effects of good, fair or poor subsurface drainage on pavement performance. Unfortunately, the coefficient is not applied to the bituminous layer, thus full depth bituminous pavements may be designed without taking drainage into account. In fact, the new design may encourage the use of non-drained full depth pavements in areas of proper drainage because this one pavement is not penalized by a poor drainage coefficient.

Objectives

To determine the appropriate drainage coefficients to use with full depth bituminous pavements.

Key Words

Subsurface drainage, aggregate, performance, bituminous.

Urgency

The new AASHTO Pavement Design Guide will be in place in all 50 states within three years. It is absolutely necessary that drainage coefficients are in place for all pavement types before full implementation.

Cost

The estimated cost of this research is \$125,000.

User Community

This research needs statement should be distributed to all state DOT agencies, FHWA, AASHTO, and TRB Committees A2KO6, A2BO3, A2BO4 and A2BO6.

Implementation

The results of this research should be incorporated into the AASHTO Pavement Design Guide.

Effectiveness

The results of this research will provide for improved pavement design methods leading to longer service life and reduced maintenance costs.

PROBLEM #155: DEVELOPMENT OF A LABORATORY PROCEDURE TO MEASURE PERFORMANCE OF FREE-DRAINING PAVEMENT LAYERS

Many states and federal agencies are concerned with the removal of subsurface water. There does not appear to be a general specification available that defines the permeability needed for acceptable pavement performance, and a value needed to maintain the free-draining characteristics of the layer by self-cleaning. A standardized test procedure to measure these characteristics is not available.

Objectives

The objectives of this project are to develop a general permeability specification for different types of free-draining layers and a laboratory procedure to measure these characteristics. The specific objectives of the study:

1. Define the various types of free-draining layers used in pavement systems.
2. Determine the effects of gradations and material characteristics on the layer performance.
3. Determine the permeability criteria for each type of free-draining layer to ensure pavement performance.
4. Develop standardized laboratory procedure(s) to measure compliance with permeability criteria.

Key Words

Permeability, self-cleaning, specification, test procedure.

Related Work

Some of the current activities include:

- Studies by the California Department of Transportation;
- Studies of open-graded base course gradation requirements by Pennsylvania, Illinois, New Jersey, West Virginia, North Carolina, and Wisconsin;

- Studies of open-graded base course performance by the Central Laboratories of the Ponts et Chaussées, France; and

- Numerous FHWA studies.

Urgency

While the influence of water in pavement systems has been well documented, the required permeability to ensure the desired level of pavement performance is not well documented and varies with region and specifying agency. Complicating the problem is that there is currently no standardized laboratory tests for measuring the permeability of the different types of materials used in pavement drainage layers.

Cost

The estimated cost of this research is \$225,000.

User Community

This research needs statement should be distributed to all state DOT agencies, FHWA, AASHTO, and members of TRB Committees A2K06, A2B03 and A2B04.

Implementation

The results of this research should be distributed to all state DOT agencies, FHWA, and AASHTO. The laboratory test procedure to measure the permeability should also be submitted to ASTM for incorporation into their Book of Standards.

Effectiveness

The results of this research will lead to improved design methods and criteria, improved performance of the free draining layers, and lead to reduced maintenance costs.

PROBLEM #156: DEVELOPMENT OF A RAPID TEST METHOD TO DETERMINE IN-SITU HORIZONTAL PERMEABILITY OF FREE DRAINING BASES (FDB)

With the promulgation of free drainage bases in pavement design standards around the country, there

arises the need to specify and determine the in-place horizontal permeability of these FDB materials, the desirable performance measure. Currently, the absence of such a test method, specifying agencies are using aggregate gradations, coefficients of uniformity and particle shape indices as pseudo indicators of material permeability. Since most FDB materials have a propensity to segregate during construction, those materials finished on grade are generally non-homogeneous both through the depth of the layer and transversely across the pavement width. In particular, a number of Division Offices of FHWA have been pushing State DOTs to specify a desirable minimum material permeability, and rightfully so. A consensus exists on what these minimum permeabilities should be; however, in the absence of a test method to determine them in the field, this type of performance specification is superfluous.

Objectives

Develop an easy to use, rapid permeameter and test procedure to determine the horizontal permeability of free draining bases insitu. The method should be capable of measuring permeabilities in the range of 100 to 10,000 ft./da., with test accuracy on the order of + 100 ft./da. The evaluated horizontal permeabilities should be for the entire depth of the layer, typically 4 inches or greater.

Key Words

Coefficient of Uniformity, gradations, rapid permeameter, test procedure, specification.

Related Work

Insitu permeability measuring devices and procedures have been developed for dense graded bases.

Urgency

The need for this test method is immediate since State DOTs are already specifying and using FDB's.

Cost

The estimated cost of this research is \$115,000.

User Community

This research needs statement should be distributed to all state DOT agencies, FHWA, AASHTO, universities with geotechnical and pavement design studies, and members of TRB Committee A2K06.

Implementation

The results to be distributed to all state DOT agencies, FHWA, AASHTO, and consultant testing laboratories.

Effectiveness

This research will result in a standard test procedure which will allow uniform, consistent testing of free draining base material. The test results will be incorporated into the pavement design process leading to more effective and improved service pavements.

PROBLEM #157: PREDICTION OF DIFFERENTIAL ICING OR FROSTING DUE TO THERMAL PROPERTIES OF PAVEMENT STRUCTURAL MATERIALS

There is a nationwide push to adopt more permeable base materials to promote subsurface pavement drainage. Limited publications from Scandinavia indicate that such materials may result in differential icing conditions.

Objectives

The study objective is to determine whether the solution to one problem, subsurface drainage, is possibly producing another problem, differential icing. More specifically, the study must produce an analytical method (with real data input and verified by field studies) to predict whether differential icing will occur.

Key Words

Subsurface drainage, permeable base, analytical.

Urgency

The new AASHTO Guide strongly promotes subsurface drainage through the use of highly permeable bases. The

highway engineering profession must assure itself that these measures are not creating a massive, difficult to remedy, safety problem.

Cost

The estimated cost of this research is \$325,000.

User Community

This research needs statement should be distributed to all state DOT agencies, FHWA, AASHTO, universities with geotechnical and pavement design studies, and members of TRB Committee A2K06.

Implementation

The results of this research should be distributed to all users of the AASHTO Pavement Design Guide.

Effectiveness

The results will either verify the validity of the current philosophy of subsurface drainage, or results in changes to the design procedures seeking to maximize drainage, while addressing the safety issues of differential icing.

PROBLEM #158: DEVELOPMENT OF DESIGN PROCEDURES FOR THE SEPARATION LAYER UNDER OPEN GRADED BASE COURSES

For free draining open graded base courses to function effectively throughout the life of the pavement, migration of fines from lower subbase or subgrade layers must be prevented. The open graded base and lower subbase layers must meet filter criteria or a separation layer(s) provided. The separation layer may be either aggregate or fabric.

Criteria exist for the design of aggregate and fabric filter layers for drainage applications. However, the effect of traffic loads on the separation layers under pavements introduces an additional factor that affects the filter layer performance. In addition, stabilization of subbases, base courses, and subgrades will affect the effectiveness of filter media. These factors may influence the applicability of drainage filter criteria to pavement courses.

The applicability of drainage layer filter criteria to open graded base courses and other pavement courses needs to be evaluated. If necessary, new criteria must be established for determining the need for and design of filter layers in pavements with open graded bases.

Objectives

Determine filter requirements for open graded base and subbase or subgrade layers including stabilized subbases or subgrades. Develop design criteria for separation layers.

Key Words

Migration, fines, filter criteria, drainage layer, stabilized.

Related Work

Work is being done by the Kentucky Transportation Center, Pennsylvania State University, and in Ontario to determine the effectiveness of fabrics in pavement systems.

Urgency

The increased emphasis on the use of free draining open graded base courses makes development of filter criteria for pavement systems of critical interest.

Cost

The estimated cost of this research is \$275,000.

User Community

This research needs statement should be distributed to all state DOT agencies, FHWA, AASHTO, universities with geotechnical and/or pavement design programs, and TRB Committee A2K06.

Implementation

The results of this research should be distributed to all state DOT agencies, FHWA, and AASHTO.

Effectiveness

The results of this research should be incorporated into the AASHTO Pavement Design Guide. Doing so should result in improved performance of the entire pavement system leading to reduced maintenance costs.

PROBLEM #159: STABILITY OF OPEN GRADED BASE COURSES

Although the benefits of well drained pavements have been clearly shown, there has been hesitancy on the part of practitioners to use open graded base courses because of concerns regarding stability, especially during construction. The stability of the open graded base course is a major consideration in the design and construction of this course.

Among the factors affecting the stability of open graded bases are aggregate gradation, particle angularity, and whether or not the base is stabilized with bitumen or portland cement. In general, the more stable a base course material is the less free draining it is.

The optimal open graded base design provides both adequate stability and drainability at the least cost. Many different open graded base designs have been used. Information is needed regarding the stability (especially during construction), drainability, and costs of these bases.

Objectives

Compare the stability of various open graded base designs. Compare the drainability of various open graded base designs. Determine comparative costs of various open graded base designs. Develop selection criteria based on stability, drainability, and cost to determine the most economical designs of Open graded base courses.

Key Words

Aggregate, gradation, particle angularity, bitumen, portland cement, drainability.

Related Work

Oregon has conducted research on the stability of stabilized and unstabilized open graded base courses. The cost of various open graded bases should be available from various state DOTs.

Urgency

The increased emphasis on the use of free draining open graded base courses makes development of economically oriented selection criteria of critical interest.

Cost

The estimated cost of this research is \$250,000.

User Community

This research needs statement should be distributed to all state DOT agencies, FHWA, AASHTO, universities with geotechnical and/or pavement design programs, and TRB Committee A2K06.

Implementation

The results of this research should be distributed to all state DOT agencies, FHWA, and AASHTO.

Effectiveness

The results of this research will result in procedures which will optimize both stability and drainage of open graded base courses, while providing the most economical solution.

A2K07 COMMITTEE ON GEOSYNTHETICS

PROBLEM #160: DEVELOP LIFE CYCLE PREDICTION AND COST IMPROVEMENT MODEL FOR THE USE OF GEOSYNTHETICS IN PAVED AND UNPAVED ROADS

The largest potential road construction and maintenance savings for local, state and federal highway agencies is, for the most part, untapped. A primary failure mechanism in roadways is loss of support due to the deterioration of the base. The base course deteriorates over time due to intermixing of the subgrade soil and coarse aggregate, reducing its load bearing capacity. This intermixing is greatly accelerated by the presence of water. This interface intermixing problem is traditionally addressed by adding extra base or by using less than optimum base materials. This adds to the initial cost and only delays the inevitable intermixing and frequent maintenance. The successful use of geotextiles to separate base materials and subgrade soils to maintain the integrity of the base is well established. Recent studies also indicate a potential to use geogrids to reinforce the base, improving its support capacity. Although these concepts are sound, there has been insufficient implementation due to the lack of quantifiable performance and life prediction models, and the lack of effective implementation guidelines.

Objectives

Quantify the performance improvement and the life cycle extension of roads constructed or rehabilitated incorporating geosynthetics. Develop guideline implementation documents, defining life cycle costs and benefits of using geosynthetics in roads for the user community in design and in planning using pavement management systems.

Key Words

Geosynthetics, cost effective road design and construction; road rehabilitation; reduced road maintenance; and extended life of roads.

Related Work

Several states have installed road test sections using geosynthetics. Some studies are well documented and

included control sections. Little work has been done, however, on follow-up monitoring and reporting. FHWA has published a design manual for using geotextiles in paved and unpaved roads, but life cycle models are not included. Caltrans has quantified life cycle cost benefits of rehabilitating roads using geotextiles. Some research on road base deterioration caused by subgrade soil infiltration has been done (Hicks and Washington DOT).

Urgency

Top priority should be given to this issue since there is no other issue with as much historical results to prove the success of the concept nor with as much potential for saving construction and maintenance dollars for highway agencies. A study of this issue will reveal the lack of implementation of this simple, cost effective solution to most road problems. The benefits of geosynthetic use in roads and highways must be quantified and NCHRP is an ideal forum for such a study.

Cost

The total estimated cost is \$300,000. The project should be accomplished in stages as follows:

1. Perform a road improvement assessment, by reviewing existing reports on this concept then by getting agency help in reviewing and documenting additional case studies based on existing road sections which utilized geosynthetics. With a state and industry support, cost should be about \$150,000.

2. a. Summarize how geosynthetics work in roads to improve the road performance. This should be based on existing literature; and

- b. Quantify the extended life cycles of roads and the cost benefits associated with extended life cycles or road utilizing geosynthetics in construction and in rehabilitation. Study cost should be approximately \$150,000.

User Community

The user community is all governmental agencies dealing with the design, construction, and maintenance of roads.

Implementation

Governmental agencies dealing with roads could immediately implement the appropriate use of geosynthetics in the roads they design and construct and in the roads built by others within their jurisdiction (i.e., by mandating the use of geosynthetics in roads built by developers to lower the future maintenance costs to the public agency which inherits the road when the developer pulls out). Quantified life cycle benefits can be immediately input to pavement management systems.

Effectiveness

Unpaved rural road maintenance costs for periodic grading and for replacement of surfacing stone could be significantly reduced or almost eliminated freeing up more funding for other projects. Costs of paved road structures utilizing geosynthetics could be significantly reduced and the life cycle can be greatly increased over traditional designs. Agencies can extend their overlay programs on the same budget by placing more effective and longer lasting pavement overlays which incorporate geosynthetics. By mandating the cost effective use of geosynthetics in roads, agencies can have more control over the quality of roads built by others.

PROBLEM #161: MARGINAL SOIL USED WITH GEOTEXTILE REINFORCEMENT

Geotextile walls are normally used with costly free draining backfill. Non-woven geotextiles, with in-plane permeability, may offer the opportunity to use silty and clay soils as retaining structures. Some laboratory, theoretical, and almost-fullscale testing has been done, but further work is needed.

Objectives

To conduct research into both short term and long term behavior of retaining structures with fine grained backfill subject to static and dynamic loading. Conventional laboratory produced soil geotextile parameters must be related to the behavior of the full scale structures for design purposes, using theoretical, small and large scale tests.

Key Words

Geotextiles, walls, fine grained backfill, in-plane permeability.

Related Work

Some related research is underway in the United States at the Colorado DOT, the University of Colorado at Denver and Boulder, the Ohio State University, and the University of Maryland.

Urgency

High because of the potential cost savings are great.

Cost

\$100,000 (for preliminary studies, centrifuge testing, and monitoring of field installations).

User Community

AASHTO, FHWA, all state and local transportation agencies, and private developers

Implementation

Publications of findings should lead to national and statewide directives on safe applications of fine grained soils reinforced with geotextiles.

Effectiveness

The potential cost savings by using natural site materials as backfill to construct retaining walls are extremely high.

PROBLEM #162: APPROPRIATE GEOTEXTILE STRENGTH TESTS FOR REINFORCING

Wide width geotextile strength tests permits strain to develop over a much greater length than that which develops in reinforcement in-situ as deformation of the soil occurs. This produces incorrect tensile, stress strain relationships for design.

Objectives

Compare existing geotextile strength tests and devise new ones to properly characterize operational strengths of textiles in deforming earth masses both

during initial deformation and ultimately at failure, confirm with monitored field behavior.

Key Words

Geotextiles, strength tests, stress strain, walls.

Related Work

Numerous unsuccessful attempts have been made to devise appropriate test methods to characterize the stress strain performance of geotextiles in reinforcing applications. It is possible that some of the indirect related work might provide a basis for selecting the optimum approach to conduct the research.

Urgency

High priority. If we more closely know the operational geotextile strength, then we can produce better designs with higher safety and lower costs.

Cost

\$50,000 for literature review and model testing.

User Community

AASHTO, FHWA, state and local transportation agencies, private developers.

Implementation

Any improved method of characterizing the design process and the selection of strength parameters would be introduced through national and statewide directives or manuals.

Effectiveness

A clear identification of the stress strain relationships of the soil with geotextile characterization could lead to a reduction of nearly 50% in the amount of geotextile required for the same safety of the wall.

PROBLEM #163: GEOTEXTILE SUBGRADE SEPARATORS FOR OPEN-GRADED BASES

Open graded or "drainable" pavement bases are being increasingly proposed to help mitigate pavement drainage problems and increase pavement longevity. However, there is significant doubt as to how long the drainability of these bases can be maintained because of infiltration of fine soil particles from fractures in the surface and by pumping from the subgrade. It is possible that a properly designed geotextile separator-filter can provide the long-term drainability of these bases.

Objectives

Investigate the suitability of encapsulation of open graded and drainable bases with geotextiles. The effects of initial aggregate placement and long-term performance characteristics of the geotextile should be investigated with emphasis on the permeability and drainage characteristics of drainable bases.

Key Words

Geotextiles, separators, filtration, drainable bases, pavements.

Related Work

Some work is currently underway on pavement edge drains at Purdue University and Drexel University (GRI).

Urgency

As more and more open graded and drainable bases are being used, assurance of their long-term performance characteristics is very important. Premature failure of the pavement system due to contamination of drainable bases is exceedingly costly.

Cost

\$200,000

User Community

FHWA, AASHTO, NCHRP

Implementation

FHWA/NCHRP reports, TRB state-of-the-art reports/circulars.

Effectiveness

If open graded drainable bases can be maintained throughout their normal pavement life, very large cost savings in rehabilitation of pavements are possible.

PROBLEM #164: IDENTIFICATION AND COST BENEFIT OF ALTERNATIVE METHODS FOR REDUCING REFLECTION CRACKING IN ASPHALT OVERLAYS

Premature cracking of asphalt concrete overlays is a serious national problem. A number of different techniques have been employed in an attempt to delay premature cracking of an overlay. Techniques that have been tried include the use of paving fabrics, geogrids, special additives to the asphalt concrete, and the use of selected types of asphalt. The field performance of overlays using these techniques have ranged from clear successes to failures in which the modified overlay appeared to perform worse than non-improved overlay sections.

Objectives

The objective is to identify the most promising existing techniques for delaying reflection cracking, then performing a detailed study of these techniques to determine their cost effectiveness. As a part of the overall study, the important question should be addressed concerning how much money is justified to spend on delaying reflecting cracking compared to other alternatives such as maintenance, sealing of cracks after they develop. Overlay design strategies which show the most promise include infiltration barriers (such as pavement fabrics and heavy duty membranes), special asphalt concrete stress relieving interlayers (either modified or nonmodified) and heater scarification.

Key Words

Asphalt overlays, reflective cracking, stress relieving layers, cost benefit.

Related Work

NCHRP Synthesis of Highway Practice #171 (Fabrics in Asphalt Overlay and Pavement Maintenance) gives a current summary of the current status of delaying reflection cracking.

Urgency

As the serviceability of the highway infrastructure continues to decrease, the construction of overlays will greatly increase in the future years. This project will help to identify:

- Justifiable levels of additional expenditures for delaying reflection of cracking; and
- The best available cost techniques for achieving this goal. Therefore, the urgency is high because of the large amount of overlays are anticipated in the coming years as a result of the ISTEA legislation.

Cost

\$50,000. Initial update of the synthesis is needed with emphasis on the cost effective alternatives. If additional research is necessary, it should be identified and carried on in the second stages. The second stage research would range in the order of \$200, 000 to do laboratory and field tests to verify recommendations found in the initial study.

User Community

AASHTO, FHWA, state and local transportation agencies, private developers.

Implementation

Any improved method of characterizing the design process and the selection of strengthening parameters would be introduced through national and statewide directives or manuals.

Effectiveness

Because of the large amount of overlays being placed on the National Highway System, there is a potential for extremely high costs savings if these techniques are perfected in increasing the life of the pavement. However, if these techniques are not effective, there is a lot of money being wasted on ineffective technology by numerous users around the country that could be used more effectively.

PROBLEM #165: EVALUATE GEOMEMBRANES TO CONTROL EXPANSIVE SOILS ON TRANSPORTATION FACILITIES

Expansive soils occur in over 40 of the 50 states. Their damage to transportation facilities, highways and streets, airports, railroads, buildings, canals, pipe lines, and sidewalks exceeds the \$10 billion a year estimate made a decade ago. Almost 100 projects have been tentatively identified as using geomembranes to control this destructive action. Their effectiveness needs to be assessed.

Objectives

Locate projects which have used geomembranes and secure information on the testing used, the construction practices, the bid price, the fabric chosen and reasons, the rate of placement, problems encountered, and subsequent evaluations. It may be necessary to do additional field evaluations to obtain necessary performance characteristics and, therefore, cost benefit ratios. Once this is done, guidelines can be set up to more effectively apply geomembranes in the control of expansive soil damage to transportation facilities.

Key Words

Geomembranes, expansive soils, performance data.

Related Work

Texas monitors 23 geomembrane sites, other sites are being monitored in Wyoming, Arizona, Bureau of Indian Affairs, Kentucky, Mississippi, Alabama, Georgia, California, Australia, Columbia, South America and China. A paper on Texas experience was presented at the 7th International Conference on Expansive Soils in August 1992.

Urgency

Clay shale and similar soils with destructive expansive capabilities continue to require expensive repairs to transportation facilities. Frequently personnel who worked on older projects are retiring and important information is lost with their departure. As the need to improve our procedures increases (as do financial concerns), gathering of hands on data should not be further neglected.

Cost

\$50,000

User Community

AASHTO, FHWA, state and local transportation agencies, private developers.

Implementation

Any improved method of characterizing the design process and the selection of strength parameters would be introduced through national and statewide directives or manuals.

Effectiveness

Large costs savings are available if the damage from expansive clay can be reduced or eliminated by this technique. Therefore, this information needs to be synthesized and disseminated.

PROBLEM #166: DURABILITY AND LIFETIME PREDICTION OF GEOMEMBRANES

The mechanisms of geomembranes degradation must be clearly understood, particularly to hydrocarbons and various chemicals such as defoliant. A method of estimating the factors at a specific site which might influence the long-time durability is needed along with the appropriate test methods and evaluation techniques to estimate long-term performance under the site environment.

Objectives

• Develop a process that will identify key environmental site conditions that will dictate the necessary studies.

- Develop the requisite test methods.
- Develop the lifetime projection methodology.
- Develop a protocol to see if the above are realistic.

Key Words

Geomembranes, degradation, chemicals, environment.

Related Work

The major effort by FHWA on geosynthetics is related to geotextiles and geogrids. There is little work being carried out on geomembranes.

Urgency

Geomembranes are being used more and more in the transportation industry for controlling or preventing mixing of groundwater, existing contaminants and industrial waste. Therefore, a greater understanding of the applicability of geomembranes for these is very important.

Cost

\$50,000 Stage 1. Synthesis of information - \$100,000; Stage 2 Laboratory testing and field monitoring.

User Community

AASHTO, FHWA, state and local transportation agencies, private developers.

Implementation

Any improved method of characterizing the design process and the selection of parameters would be introduced through national and statewide directives or manuals.

Effectiveness

Since geomembranes are often used to prevent environmental damage, the cost of one failure from environmental cleanup standpoint may be millions of dollars. Therefore a clear understanding must be obtained soon.

PROBLEM #167: DETERMINATION OF THE EFFECTIVENESS OF GEOGRIDS IN STRENGTHENING PAVEMENT SECTIONS

Increasing loads, increasing tire pressures and in the case of multi-lane highway's distribution of traffic patterns may dictate the effective use of geogrids to meet this challenge. The records presently clearly indicate the distortion that takes place in many of the country's pavement without reinforcing.

Objectives

To continue the literature searches and informational searches on existing projects, many have been reported, many are alluded to in general terms that require a clear concise investigation. Many are partially reported and require up to date assessments. New projects need monitoring and careful assessment by practical construction site results that can be correlated with significant laboratory studies that have taken place within the last decade. A comprehensive report should be prepared with hands on construction guidelines for the designers.

Key Words

Geogrids, strengthening, pavement.

Related Work

Summaries and field trials have provided indications of improved performance with geogrids in the pavement sections. The work in this field needs to be coordinated.

Urgency

The urgency is very high in that we are rebuilding a major part of our Interstate and other transportation

systems and the potential is there to increase the life of many of these pavements by introducing reinforcing now.

Cost

\$250,000. This would include updating the known research, conducting the necessary laboratory test models, and planning appropriate field trials to verify conclusions.

User Community

AASHTO, FHWA, state and local transportation agencies, private developers.

Implementation

Any improved method of characterizing the design process and the selection of strength parameters would be introduced through national and statewide directives or manuals.

Effectiveness

Because of the extremely large pavement placement every year, a small increase in pavement life can yield many millions of dollars savings per year in increased life and reduced repairs.

PROBLEM #168: PUNCTURE RESISTANCE OF GEOMEMBRANES

With coarse drainage stone adjacent to geomembranes, puncture is a likely failure mechanism. An adequate geotextile protection layer is often necessary. There is no design method available to evaluate the need and determine if the solution is appropriate.

Objectives

Develop a design methodology for defining a geotextile protection layer for a given geomembrane type and thickness.

Key Words

Geomembranes, puncture, design.

Related Work

Little related work is known at the moment. Some earlier work was done for railroad applications by Gerry Raymond, but little has been done since.

Urgency

As geomembranes gain increasing use in environmental control, a clear understanding of the potential of puncture is essential for consistent use of geomembranes without excessive controls.

Cost

\$75,000. This would include literature search plus laboratory test methods, plus digging up a few selected sites to evaluate field performance.

User Community

AASHTO, FHWA, state and local transportation agencies, private developers.

Implementation

Any improved method of characterizing the design process and the selection of parameters would be introduced through national and statewide directives or manuals.

Effectiveness

Since geomembranes are often used to prevent environmental damage, the cost of one failure from environmental cleanup standpoint may be millions of dollars. Therefore, a clear understanding must be obtained soon.

PROBLEM #169: USE OF GEOTEXTILES AND GEOGRIDS IN BRIDGE ABUTMENTS

Geotextiles and geogrids can potentially reduce the cost of abutments by strengthening the underlying materials and bridging the differential settlements that occur over soft foundations. They also can be used behind higher abutments to reduce the lateral load on the backs of the

abutments and wingwalls. There is a great need to have a design methodology for these applications.

Objectives

Develop a design methodology and construction procedures for the use of geotextiles and geogrids in bridge abutments, especially in rehabilitation and replacement of structures.

Key Words

Geotextiles, geogrids, abutments, settlements, reinforcing.

Related Work

Geogrids have been used in England for the construction of abutments of at least one bridge, more recent work has demonstrated the ability of the reinforced soil mass to reduce the differential settlements and to reduce lateral stresses on the backs of walls. Nothing, however, has brought these together in a unified approach to design methodology.

Urgency

Tens of thousands of bridges on the local and state level are supported on low quality foundation soils requiring high costs of deep foundations. If the use of geosynthetics can be applied effectively, the potential of savings can reach hundreds of millions of dollars a year.

Cost

\$100,000. This would include literature search, centrifuge modeling testing, development of a design methodology and testing in field applications by at least one instrumented design.

User Community

AASHTO, FHWA, state and local transportation agencies, private developers.

Implementation

Any improved method of characterizing the design process and the selection of parameters would be introduced through national and statewide directives or manuals.

Effectiveness

The potential exists to save \$50,000 - \$100,000 per abutment by using geosynthetics in the structure foundation or in the structure backfill.

PROBLEM #170: SOIL GEOSYNTHETIC INTERACTION BEHAVIOR

Although geosynthetics are increasingly being used in the construction of reinforced retaining walls, slopes, and embankments on soft ground, the mechanism of interaction between the soil and geosynthetic reinforcement is not well understood. Preliminary studies indicate that several parameters affect interaction properties, but it is difficult to generalize for design purposes. Both long-term (creep) properties as well as dynamic properties require study.

Objectives

Determine both the short term, including dynamic, and long-term behavior of geosynthetics in realistic soil reinforcing systems and environments. Studies of soil-geosynthetic friction, stress-strain behavior, and creep response are required, the interface characteristics of geosynthetics in contact with soils, rocks, aggregates, waste materials, etc., should be quantified. Develop realistic models of soil-geosynthetic systems and develop procedures for obtaining appropriate stress--deformation-time parameters for design.

Key Words

Geosynthetic, geotextile, reinforcing, analytical modeling, laboratory testing, creep, dynamic behavior, slopes, retaining walls, embankments.

Related Work

Some research is underway on this topic at MIT, LSU, Purdue, Drexel, University of Washington, University of Colorado at Denver, and GeoSyntech consultants, among others.

Urgency

Very high priority. The economical use of geosynthetics in stabilization and reinforcement applications is impeded by this lack of information. New products such as very high strength composites and geogrids are continually being developed. In critical situations, expensive full scale-heavily instrumented test sections are the only way to verify design procedures. While such tests are extremely valuable, the design process could be greatly improved and reinforced soil structures could be made even more economical and reliable if soil-geosynthetic interaction was fully understood.

Cost

\$300,000

User Community

FHWA, AASHTO, NCHRP.

Implementation

FHWA/NCHRP reports, TRB state-of-the-art reports/circulars

Effectiveness

Cost savings for improved designs of reinforced walls and slopes are estimated to be \$100,000,000 per year

PROBLEM #171: IMPROVING THE SEAM STRENGTH OF REINFORCING GEOTEXTILES

Because of large deformations at sites with soft foundation or subgrade soils, simple overlapping of adjacent sheets of a geotextiles is unsatisfactory, and

stabilization or reinforcing of seams is required. Although tests have indicated that sewn seams have significantly (10-50%) less strength than the intact material, designs are often based on intact specimen tensile strengths.

Objectives

Develop procedures for improving the efficiency of geosynthetic seams. Develop new methods for seaming, especially high strength reinforcing geotextiles.

Key Words

Geotextiles, seams, embankments, subgrades, sewing, reinforcing, stabilization, soft foundations.

Urgency

High priority for safe construction of reinforced embankments on very soft foundations.

Cost

\$200,000

User Community

FHWA, AASHTO, NCHRP, geotextile manufacturers

Implementation

FHWA, NCHRP reports

Effectiveness

Increased seam efficiency will result in significant cost savings and reduce the potential for failures.

A2L00 SECTION ON GEOLOGY AND PROPERTIES OF EARTH MATERIALS

PROBLEM #172: APPROPRIATE USE OF WASTE AND RECYCLED MATERIALS IN HIGHWAY CONSTRUCTION

Acceptable disposal of wastes such as coal and municipal combustion ash and flue-gas desulfurization sludge is a growing problem. A related problem is the reutilization of other waste materials such as concrete aggregate, old asphalt pavement, tires, recycled glass and plastics. Due to its high volume consumption of bulk materials, the transportation industry is under increasing pressure to utilize these materials. As these are not our normal construction materials, there are concerns about testing them for design and construction quality control, about their constructibility, and long-term chemical stability and related environmental issues.

New test methods and acceptance procedures are needed to properly utilize waste and recycled materials in a cost effective manner. Their short-term behavior during construction is not well understood, and their physical properties are often unknown. Finally, the long-term chemical stability and any potential environmental problems must be well understood before these materials can be used on a routine basis. Without such information, transportation agencies, consultants, contractors, waste and recycled material suppliers and health officials cannot properly assess the level of the potential hazard nor can they accurately assign levels of liability for potentially hazardous conditions.

Objectives

- Assess the types, quantities and locations in which recycled and waste materials have been used in highway construction. Quantify the constituents of the materials and their service environments.
- Develop appropriate construction guidelines and design and quality control test methods.
- Conduct field and laboratory studies to assess the long-term physical-chemical stability of these materials in realistic environments. Appropriate consideration must be made of potential toxic and hazardous situations for human and wildlife in the area.

Key Words

Waste materials, recycled materials, long-term stability, chemical and environmental compatibility, contaminant

transport, test methods, construction techniques, geoenvironmental engineering, liability.

Related Work

There are a number of small-scale research projects addressing various aspects of this research need. However, these are not coordinated and may not be of an adequate breadth to solve the entire problem, especially for long-term performance and environmental compatibility.

Urgency

Highest priority should be given to this research need. Transportation agencies are under increasing pressure to utilize waste and recycled materials as an alternative to landfilling and other disposal methods. The pressure to use waste materials in highway construction and rehabilitation is likely to increase significantly. In some areas, agencies are mandated to use a certain percentage of recycled materials along with natural materials. The litigation environment concerning environmental and health impacts of these materials will undoubtedly increase, and information from this research is necessary in order to reduce the potential legal costs likely to result from ignorance of the physical-chemical stability and possible hazards.

Cost

\$500,000

User Community

AASHTO, Transportation Research Board, FHWA, and National Institute of Environmental Health and Safety (NIEHS)

Implementation

FHWA/NCHRP Reports; TRB state-of-the-art reports/circulars

Effectiveness

Successful completion of this research will improve our knowledge of the hazard levels associated with utilizing waste and recycled materials in transportation construction and decrease the chance of improper use of these materials. An immediate benefit would be to reduce potential health hazards, environmental damage, and liability resulting from the use of these materials in construction.

A2L01 Committee on Exploration and Classification of Earth Materials

PROBLEM #173: INTEGRATION OF GEOGRAPHIC INFORMATION SYSTEMS (GIS), REMOTE SENSING, AND AUTOMATED MAPPING TECHNOLOGIES FOR SUPPORT OF GEOTECHNICAL EVALUATIONS FOR TRANSPORTATION FACILITIES

The three elements of GIS, remote sensing, and automated mapping make up an overall land information system. Such a combined system is potentially useful for the timely and economical undertaking of many aspects of project assessment, EIS preparation, and overall management of the transportation infrastructure.

Advances in computer technology have made available, on personal computers, affordable and feasible systems for GIS, remote sensing imagery interpretation, and automated mapping. National, regional, and local data are being released in digital formats suitable for use by these systems. Their application for transportation corridors has not as yet been fully defined or described.

Objectives

Although the capability of these various systems have been extensively discussed, their application to the geotechnical needs of the transportation field has not been investigated to the same detail. Some relevant research has been conducted outside the United States, particularly by groups at the University of London and the Transport Research Laboratory. The applicability of such research to North American situations needs to be tested. There should be research to coordinate and integrate these new systems to maximize utilization of data. We have not seen any reports of ongoing research of this nature.

Key Words

GIS, remote sensing, digital soil surveys, landsat.

Current Activities

- The TRIS data base for key words "GIS," "Remote Sensing," and "Landsat" was scanned in preparation of this statement.

- The Soil Conservation Service, U.S. Department of Agriculture, is currently releasing soils data bases in GIS

formats at national, state and local levels. Some data are released, more are planned.

- The U.S. Geological Survey, and some state geological surveys, are releasing geological data in digital formats.

- Several private companies are offering existing digital data, or the production of new digital data sets. A few states (North Carolina, and Illinois) have made some experimental use of these technologies for geotechnical support with transportation applications.

Urgency

Any delay in planning research for integrating these systems and the data will be detrimental to continued state of-the-art use of remote sensing and GIS for geotechnical purposes by the transportation field.

PROBLEM #174: DEFINITION OF LEGAL LIABILITY OF INDIVIDUALS INVOLVED IN EXPLORATION AND CLASSIFICATION OF EARTH MATERIALS FOR TRANSPORTATION PURPOSES

Individual employee engineers and geologists have generally felt immune from professional liability lawsuits. Unfortunately, this has changed in the last few years and individuals themselves are being sued, along with their employer, agency or company. The conditions for this to occur are changing and current trends in professional liability are not clearly defined.

Objectives

The present state of legal (both contractual and tort) liability of individuals involved in exploration and classification of earth materials for transportation purposes should be concisely defined in a brief document.

Key Words

Legal action, legal responsibility, liability.

Current Activities

- The TRIS data base for key words "legal", "exploration", "classification", "earth", and "soil" was scanned in preparation of this statement.

- There does not appear to be any coordinated effort to resolve this problem by the legal profession.

Urgency

The rapid increase of legal threats to professional engineers and geologists in the performance of their duties is having serious impact on their willingness to make detailed judgments.

PROBLEM #175: GEOPHYSICAL EXPLORATION METHODS AND INSTRUMENTS FOR NON-INVASIVE SUBSURFACE EXPLORATION AND CHARACTERIZATION WITHIN TRANSPORTATION CORRIDORS

There have been numerous developments in geophysical instrumentation and interpretation techniques in recent years. Some techniques and instruments have been tested in detail over a variety of geologic conditions. Others have had a minimum of field testing to establish their potential usefulness and/or limitations in subsurface exploration. Traditional applications of geophysical techniques to the petroleum and mineral exploration fields emphasize the coverage of large areas to considerable depths. Geotechnical explorations using geophysics have been more limited. In recent years, however, renewed interest in higher resolution shallow geophysical exploration has occurred, primarily for use in characterizing potential hazardous waste sites.

Transportation-related applications of geophysics have similar needs. Of special interest are the real-time data review in the field in order to reduce remobilization costs, the continuous digital location and recording of the data, and the combined use of data from several methods to complete the characterization, often called "data fusion". This research problem may be subdivided as follows:

- Analysis and comparison of geophysical methods and instruments as applicable to subsurface exploration and characterization at shallow depths and with high resolution; and

- Analysis and comparison of interpretive techniques with special emphasis on transportation applications.

Objectives

1. Determination of those geophysical methods most appropriate for transportation applications.

2. Evaluation of modern geophysical instruments in regard to their applications and limitations.

3. Examination of new interpretive techniques and comparison with established procedures.

Key Words

Geophysics, geophysical exploration, geophysical measurements, soil physical properties, subsurface exploration, subsurface characterization.

Current Activities

- The TRIS data base for key words "geophysical exploration", and "soil physical properties" was scanned in preparation of this statement.

- The Federal Highway Administration Materials Division has sponsored research in two projects dealing with this topic - Project 5-B-2, Tunneling Technology and Project 4-E, Remote sensing and Geophysical Testing. Some reports have been issued.

Urgency

The use of geophysics for subsurface exploration is increasing. Knowledge of appropriate methods, equipment, applications and interpretation will help the practicing engineer select the appropriate geophysical technique for the problem at hand. The problem is considered to be of continuing interest in transportation engineering.

A2L02 COMMITTEE ON SOIL AND ROCK PROPERTIES

The research problem statements appear in the order of priority established by the committee.

PROBLEM #176: SYNTHESIZE QUALITY ASSURANCE TESTS AND INSTALLATION PRACTICES FOR USE OF RECYCLED MATERIALS

Existing test methods and construction control procedures are not adequate to guarantee suitable long-term performance of earthworks constructed using recycled waste products. Some items that are commonly used in earthwork construction are recycled concrete aggregate, recycled asphalt pavements, coal fly ash, rubber tires, recycled glass, and numerous other local recycling products. Many of these recycled products are contaminated by associated materials from their original sources, such as asphalt in the recycled concrete, asbestos in the recycled asphalt, paper and metal in with the recycled glass, and others. New test methods and acceptance procedures are needed to properly use these materials in a cost effective manner in transportation construction. Also, some of the materials do not respond like natural earthwork to compaction energies, vibrations, or seepage.

Objectives

A number of states and private agencies have developed guides and test methods to allow them to make engineering decisions about suitability and long-term performance of these recycled materials in-place. This information needs to be thoroughly investigated and evaluated for suitability nationwide and the information disseminated in a central location for practitioners.

Key Words

Residual materials, reuse, material performance, index properties, design guidelines, health and safety.

Related Work

There is numerous small research projects addressing specific concerns in certain areas of the recycling processes. These are not coordinated and may not be of adequate breadth of investigation to resolve the total spectrum of problems. There is no known coordinated

effort to help judge the long-term performance of any of the recycled materials planned for construction in transportation facilities.

Urgency

As more local agencies are being pressed into recycling as an alternative to landfilling of various municipal wastes, our industry will be called upon to a greater and greater degree to recycle various products presently in the waste stream. This is already becoming very evident in the Northeast where there are governmental mandates of using certain percentages of recycled material in with the natural material presently being sold. It is imperative that we improve our understanding of the items that affect the long-term performance of products containing these recycled materials before their installation, so that they can be adequately addressed.

PROBLEM #177: SOIL-GEOSYNTHETIC INTERACTION BEHAVIOR

Geosynthetics are increasingly being used in the design and construction of transportation facilities. However, in many of these applications, particularly in reinforced retaining walls and embankments of soft ground, the mechanism of interaction between the soil and geosynthetic is not well understood. Preliminary model studies indicate that there are several parameters which affect interface properties, but it is difficult to generalize these properties for design purposes. This makes economical and safe designs difficult and unreliable.

Objectives

Conduct research in both the short term and long term behavior of geosynthetics in realistic soil reinforcing systems and environments. The actual interface characteristics of geosynthetics in contact with real soils, rocks, aggregates, waste materials, etc., should be quantified. This involves studies of soil-geosynthetic friction, stress-strain behavior, and the creep response of geosynthetics. Proper modeling of the soil-geosynthetic system and measurement of stress-deformation-time characteristics during loading is important. Realistic

analytical model or models which account for these characteristics would be developed.

Key Words

Geosynthetic, geotextile, analytical modeling, waste interaction, laboratory simulation.

Related Work

Some research is underway on these topics at a number of universities (Oregon State, Purdue, Georgia Tech, Louisiana State, Drexel, to name a few) and private organizations (STS Consultants, Ltd.) in the U.S. Some research on this has been done in the past by CALTRANS, but few other state agencies are involved.

Urgency

Very high priority. The continued use of geosynthetics in stabilization and reinforcement applications is impeded by this lack of information. New products are continually being developed, including very high strength composites and geogrids. In critical situations, expensive full scale test sections are the only way to verify design procedures. While such tests are extremely valuable, the design process could be greatly improved and be made more economical if soil-geosynthetic interaction was fully understood.

PROBLEM #178: UNIFIED APPROACH TO INTERPRETATION OF IN-SITU TESTING

Current methods for interpreting the results of in-situ tests (cone penetration, standard penetration, vane shear, full-displacement pressuremeter, piezocone, flat dilatometer, stepped blade, spade cells) in soils utilize a different theoretical model for each of the different tests. Common theories invoked for this purpose include limit equilibrium, plasticity, elasto-plastic models, cavity expansion, finite elements, strain path method, and flow field solutions. In addition, an overabundance of empirical approaches have been developed as well. The consequence is that the interpretation of soil properties by practicing engineers often leads to improper usage, inconsistent results, confusion, and uncertainty in assessing the ground.

Objectives

Since each of the aforementioned in-situ tests results in similar high-disturbance effects upon insertion, it should be intuitively expected that one theory could be used to quantitatively describe all of these tests. Possibly, several of the theories are capable of this task. Several series of calibration chamber tests on laboratory soil deposits can be directed at investigating the interrelationships between the in-situ test devices. Numerical and analytical modeling can be applied to the results of the controlled-environment tests. In addition, the models can be calibrated against field and laboratory data already obtained from a number of well-established and well-documented international experimental test sites.

Key Words

Test interpretation, in-situ testing, calibration chambers, soil properties, constitutive modeling, numerical simulation, theoretical soil mechanics.

Related Work

Pursuit of unified-theory approaches have been initiated at Massachusetts Institute of Technology and Georgia Institute of Technology. Calibration chamber tests investigating different in-situ devices are underway at Clarkson University, Louisiana State University, and Virginia Tech. A recent NSF Workshop at University of New Hampshire (1988) has cited at least 77 potential locations for designation as one of the few U.S. National Geotechnical Test Sites for experimentation. Both FHWA and NSF have allocated funding for the latter.

Urgency

High priority. Continued use of mixed bag of correlations and methodologies results in scattered and varied interpretations. Consequence is that geotechnical consultants choose lower bound (or upper bound) of solutions, resulting in unnecessary overconservatism or unsafe underconservatism, depending upon the particular situation (permeability characterization, foundation evaluation, embankment construction, etc.).

PROBLEM #179: EVALUATION OF SOILS AFTER TREATMENT BY GROUND IMPROVEMENT TECHNIQUES

Most of our correlations for soil properties from in-situ techniques such as the SPT, CPT, PMT, etc., have been determined on either laboratory tests on undisturbed samples or in a few cases, full scale field performance. When these devices are used to evaluate sites which have been treated by soil improvement techniques, the old correlations are necessarily used. There is some evidence that these correlations may be inappropriate for treated ground, apparently because of modifications to the soil structure caused by the treatment. There is a need for research to either verify that the present correlations are reasonably correct or to develop new correlations.

Objectives

To verify and/or develop new correlations for important soil properties as determined by various in-situ techniques in ground which has been treated. These devices can either be in common in-situ tests or geophysical tests such as cross-hole dynamic tests.

Key Words

Ground modification, in-situ soil evaluation, geophysical testing, dynamic testing, laboratory testing.

Related Work

Limited research at some universities (Florida and California) and private organizations (GKN, Inc.).

Urgency

Urgent because of the potentially unconservative nature of uneconomical use of existing correlations.

PROBLEM #180: ENGINEERING CHARACTERIZATION AND DESIGN METHODOLOGIES FOR WEAK ROCK AS A TRANSITIONAL MATERIAL BETWEEN SOIL AND STRONG ROCK

Weak rock is present near the ground surface over large areas of the U.S.. Engineering property characterization

methods vary across the country, and most design methods are empirically based and locally applied. Attention has been directed in the past to establishing a unified classification basis for clay-shales, but certain aspects of engineering response are poorly defined even for these studied materials. Other weak rock lithologies have been studied more often on a site-specific basis. Design methodologies are far from consistent.

For a unified engineering design concept, engineering characterization of weak rock should be viewed as defining the gap between accepted procedures for soil and rock materials. A systematic study of property changes will be important for rational design of all civil structures including slopes and cuts, foundations, and underground excavations.

Objectives

1. Conduct a national and international search to identify techniques and tests used for weak rock characterization, and to obtain design methodologies in use;
2. Investigate relationships among weak rock properties in the context of transitional materials, using soil and rock data bases as "end members" in a continuum of geologic material property variations;
3. Critically compare and contrast identified engineering tests and design methodologies. Conduct a testing program for direct comparison of the results of different tests in uniform lithologies;
4. Make recommendations as to rational exploration and design approaches to serve as guidance for state and national agencies; and
5. Identify weaknesses in our current understanding to serve as foci for future research efforts.

Key Words

Weak rock, rock, engineering properties, classification, strength (tensile, compressive, shear), compressibility, stability design methodology, foundations, slopes, tunnels.

Related Work

A number of research projects in the past have been conducted towards the elucidation of the behavior of clay-shales. The use of a continuum approach in data analysis has not been attempted, and should yield immense rewards.

Urgency

Inconsistencies and uncertainties lead to limited understanding and conservative (we hope) design. The development of an integrated set of recommendations for exploration, testing, and design in weak rock will result in increased economy and truly engineered design.

PROBLEM #181: PREDICTION OF AXIAL CAPACITY OF FRICTION PILES BY IN-SITU TECHNIQUES

Present trend of state DOTs in the U.S. is to emphasize in-situ testing and more particularly CPT, as demonstrated by previous or pending purchase of fully equipped CPT vehicles and related equipment by several DOTs, and more particularly, Florida, California and Louisiana.

DOTs and FHWA are aware of the need to also improve analytical capabilities with regard to the ability to predict pile capacity and behavior with more confidence. FHWA funded large pile test programs at the University of Houston in over-consolidated clays and in San Francisco in medium dense sand. As regards the latter, ten experts were invited to predict the load capacity, load distribution and load-settlement behavior of a single axially loaded control pile and an axially loaded group of fifty stiffly capped piles of the same design as the control pile. As demonstrated by the results of these predictions (presented at the June 17-18, 1986, Pile Group Prediction Symposium), none of the predictions adequately predicted the observed behavior.

Objectives

● Demonstrate the use and capabilities of a battery of in-situ tools which can be deployed with a CPT vehicle:

1. Friction cone and piezocone (stratigraphy and engineering properties);
2. Instrumented model piles (pile shear transfer parameters);
3. Dilatometer (in-situ state of stress);
4. Self-boring pressuremeter (in-situ strength and deformation parameters); and
5. High quality sampling (26 and 66 mm samples for confirmation of stratigraphy and cross-correlation with conventional laboratory testing).

● Develop a data bank for DOTs use in designing friction piles. The data bank will be placed on a microcomputer for cross-correlation and will be an

evolving relationship which "self-improves" with the continuous gathering of data.

● Develop improved and designer oriented:

1. Stratigraphy identification;
2. Classification of soils;
3. Soil parameters determination in-situ;
4. Hydraulic conductivity; and
5. Pile capacity methods.

As regards the latter, the present trend, as also realized by FHWA and state DOTs, is to move away from limit equilibrium methods in favor of load-deformation methods which recognize the deformation characteristics of pile foundations.

Key Words

In-situ tests, CPT, DMT, PMT, instrumented model pile, pile capacity, load-deformation, expert system analysis.

Related Work

There has been a number of recent projects (mentioned above) on "pile capacity prediction". However, the extent of involvement with in-situ testing techniques and development of knowledge-based expert systems have been minimal, if not non-existent.

Urgency

Although the ability of the geotechnical community to characterize a site is improving with the use of in-situ tools such as the CPT, and our ability to implement complex analytical methods has made great strides with the use of computers, pile capacity prediction methods, particularly for friction piles, are lagging far behind. This state of affairs is recognized by both state and federal highway design teams which would make this topic a top priority "Research Need".

PROBLEM #182: IN-SITU MEASUREMENT AND INTERPRETATION OF SOIL PROPERTIES -KNOWLEDGE BASED EXPERT SYSTEM DEVELOPMENT

There currently exists a number of in-situ soil tests which are being used to evaluate engineering properties. The numerous advantages of these tests are often offset by the fact that existing test interpretation techniques are

based more on empirical correlation than upon theory. In many cases it is extremely difficult to assess the actual stress strain response of soil and thus not possible to include these characteristics in the interpretation scheme. A review of the available data reveals that cone penetration test (CPT) and dilatometer test (DMT) are the most valuable candidates for extensive use in transportation geotechnology from the viewpoint of practicality, economy and versatility. Vast amounts of local and mostly semi-empirical correlations concerning soil classification, soil strength/stability and compressibility do exist, but have not yet been comprehensively analyzed, cross correlated with theory, conventional testing methods and/or each other.

Objectives

To develop better in-situ estimates of the design parameters required for identification, stability, and settlement analyses of both foundations and earth slopes. This research should involve both natural deposits, and samples prepared in laboratory calibration chambers. A knowledge-based expert system should be developed to cross-correlate and manage the data, self-updating itself with future additional input information.

Key Words

In-situ tests, CPT, DMT, soil strength, compressibility, stability, classification, expert system analysis.

Related Work

A number of independent research projects concerned with experimental and theoretical aspects of a wide variety of in-situ testing methods are active in US (UC, Texas A&M, LSU, UF, Purdue, MIT), UBC and Europe (Oxford, U. NGI, ENEL, Grenoble U). Calibration chamber testing has been more extensively pursued in Europe (UK, France, Italy, Norway), and to a lesser degree in US (UF, VPI). Knowledge based expert system development, although widely used in other fields, is only recently been introduced into soils related work.

Urgency

Reduction or total elimination of disturbed/undisturbed soil sampling and many strength/deformation tests,

utilized in answering geotechnically oriented problems of transportation facilities will result in great savings. To achieve this goal a good number of DOTs are turning to in-situ testing methods. It would thus appear that a better understanding of the geotechnical parameters provided by two of the most promising candidates (i.e., CPT and DMT) of these methods, together with a "smart" data correlating and managing expert system is timely.

PROBLEM #183: IN-SITU DETERMINATION OF GRANULAR SOIL FABRIC

Recent studies have concluded that the concept of "fabric" provides a much more reliable description of the state of granular soils. According to Oda (1978), the fabric for a macroscopically homogeneous sample of granular material should include a measure of the orientation of individual particles (orientation fabric) and a measure that reflects the mutual relationship of individual particles (packing). Previous studies in soil fabrics have concentrated in either numerical analyses or laboratory experiments. Of special interest is that small strain resonant column tests or the shear wave velocity can be used as an indirect but reliable measurement of soil fabric.

It is extremely difficult, if not impossible to obtain undisturbed samples in granular soils. Thus, the above development can not be readily applied in solving geotechnical engineering problems (liquefaction potential, foundation design, etc.) unless a practical in-situ testing method can be implemented. Among the possible in-situ testing methods, the seismic cone appears to be the most promising. The cone tip resistance is known to be influenced by the void ratio and in-situ mean normal stress. Void ratio is strongly related to the average coordination number (one of the fabric parameters) in a granular mass. The added seismic capability provides shear wave velocity measurements in the vertical plane. However, to fully establish the fabric parameters, it is necessary to measure the shear wave velocity in the horizontal plane which has not been reported.

Objectives

The objective of this research is to develop a practical technique to characterize granular soils in terms of fabric parameters. This should include laboratory experiment in a calibration chamber and field verification.

Key Words

In-situ tests, SCPT, granular soils, bearing capacity, liquefaction.

Related Work

Studies that relate shear wave velocity to stress anisotropy in granular soils have been conducted at the University of Texas. Research work on the relationship between shear wave velocity and soil fabric has been done at Cornell University has continued at Old Dominion University.

Urgency

Urgent because of the crude nature of the current practice in characterization of granular soils.

PROBLEM #184: DEVELOPMENT OF A RAPID DEPLOYMENT SCHEME FOR THE SELF-BORING PRESSUREMETER

In-situ soil tests have been gaining in popularity in the recent past. The advantages are numerous. One test, the self-boring pressuremeter test, has long been recognized as having the greatest potential in evaluating with confidence a very wide range of engineering properties. Historically, the disadvantage has been its painfully slow rate of testing because of the self-boring requirement. New development concepts of jetting and full displacement have been conceived and subject to limited advancement, yet these concepts need to be further investigated to evaluate the compromise in test quality that may result.

Objectives

The objective of this research is to develop a companion lab and field testing program to evaluate the effects of property evaluation due to deployment technique. The lab program would be conducted at a scale in which scale modeling could be utilized and actual in-situ response quantified. Equipment development would proceed based on the lab and field trials.

Key Words

Pressuremeter, self-boring pressuremeter, test equipment, deployment, modeling, simulation.

Related Work

Engineering practice has often required the use of self-boring pressuremeter. Due to time constraints, rapid deployment schemes were attempted with mixed success. Little fundamental work has been directed to this area but results have been very encouraging.

Urgency

A fundamental study of deployment techniques has not been initiated. Specific projects have required self-boring pressuremeter utility and certain constraints have required alternate deployment schemes of jetting and/or full-displacements. Results indicate that significant time and cost savings are possible with potentially little effect on the derived engineering parameters.

A2L03 COMMITTEE ON PHYSICO-CHEMICAL PHENOMENA IN SOILS

The research problem statements appear in the order of priority established by the committee.

PROBLEM #185: PHYSICAL-CHEMICAL PROCESSES IN CLOGGING OF PAVEMENT DRAINS

Failure of pavements due to failure of the pavement drainage system is increasing. A common failure mechanism is that of clogging of the drain system. This failure mechanism can occur in both traditional perforated subdrains and geocomposite edge drains. Once a drain has clogged or occasionally even partially clogged, deterioration of the subbase, base and wearing course typically follows.

There are several processes which contribute to drain clogging. Some of these include: fine particle migration and deposition within the drain, dissolution of soil/aggregate materials and precipitation within the drain, and in some instances, clogging due to biological action, i.e., growth and decay of organisms. The processes acting in a given situation are dependent on the geometry of the pavement/drain system, the materials used in construction of the pavement, and the type of drain system. A carefully controlled research program is needed to assess the various processes of clogging for respective drain types.

Objectives

Research will result in quantifying the physical, chemical and biological processes which lead to clogging of pavement drain systems. One task will involve determining the particle migration and subsequent deposition process for various types of pavement materials. The second task is to examine solutioning potential and precipitation processes for different pavement materials and drain systems. The third task involves determining what biological processes act in pavement drainage systems.

Determining how each of these processes occur and the conditions which facilitate their occurrence will ultimately enable designers to reduce and eliminate clogging potential for pavement drain systems.

Key Words

Particle migration, soil, transport, filtration, dissolution, precipitation, blinding, geosynthetic,

edgedrain, subbase, base course, underdrain, biological action.

Related Work

Soon to be completed NCHRP project on "Long-Term Performance of Geosynthetics in Drainage Applications" (Koerner, GRI/Drexel U.) has shown clogging of the geotextile component to be a critical factor in the drain performance. What the proposed research will provide is a definitive evaluation of the mechanisms involved in the clogging process (both for geosynthetics and conventional drain systems). These processes can be physical such as particle transport, chemical such as solutioning/precipitation or biological growth and decay.

Urgency

As new pavements are constructed and, more frequently, old pavements are rehabilitated, it is imperative to take measures to counter clogging of drainage systems. The results of this research can lead to a better understanding of the mechanisms which lead to clogging and will enable designers to secure alternate approaches for the drains.

This effort is given the 1st priority.

Cost

A complete analysis of clogging mechanisms is likely to cost \$400,000 and require approximately 3 years to conduct.

User Community

This research needs statement should be distributed to state DOTs, AASHTO, FHWA and members of TRB committees A2K06 and A2K07.

Implementation

Results of this work should be distributed to subsurface drainage design divisions within each State DOT and

also at the Federal level. In addition, the information should be made available to manufacturers of pavement drainage materials such as drainage pipe, geotextiles and geocomposites.

Effectiveness

Improving lifetimes for pavements impacts society both economically and aesthetically. Less frequent pavement replacement reduces capital expenditures and inconvenience to the public. Success of this research will enable designers to account for conditions which promote pavement drain clogging and potential pavement failure.

PROBLEM #186: ADVANCED TECHNIQUES FOR CHARACTERIZING PHYSICOCHEMICAL PROCESS AT SOIL INTERFACES

Soil additives, contaminant transport and soil-waste interactions result in complex phenomena at the soil-liquid interface. Such reactions can enhance material properties including strength, hydraulic conductivity, and durability. In waste material utilization, these reactions may alter the structure of hazardous constituents or immobilize them in a solid matrix. However, too often little is known regarding the reaction or binding phenomena. This makes performance prediction a tenuous exercise. Such predictions can possibly be misleading.

Knowledge of the structure and behavior of the processes at soil interfaces can aid in the prediction of resulting engineering properties. It can also enable improved prediction of long-term performance. Two methods for examining physicochemical processes at soil interfaces include Image Analysis and Porosimetry. New techniques for performing these analyses permit rapid assessment of the structure of soils, soil materials and more specifically, the soil-fluid interface. Research is needed to utilize these techniques within the scope of activities related to transportation facilities.

There are two specific areas in which these techniques are particularly important to the transportation industry. The first is analysis of the physicochemical processes invoked in stabilized waste materials when used in transportation facilities. Waste materials which are bonded in a matrix, e.g., municipal incinerator ash in pavement applications, must retain any potentially hazardous constituents. This is true throughout the lifetime of the material as a pavement and subsequently should it be removed and used otherwise, e.g., waste fill

material. Image Analysis and Porosimetry information on the material can reveal the nature of the bond or stability of the constituents. The second area is contaminated soils/materials in highway right-of-ways. Image Analysis and Porosimetry can help decipher the structure of the contaminant-soil matrix. Such information is invaluable in decisions on how to remediate the site or indeed even whether the site must be remediated.

Objectives

The objective of this research is to demonstrate the applicability and usefulness of Image Analysis and Porosimetry techniques to the transportation community. This can be accomplished by using these techniques to characterize the physicochemical processes and structure at the soil-liquid interfaces and at soil-soil interfaces.

Key Words

Soil-waste interaction, compatibility, bonding, soil structure, long-term performance, durability, solidification, stabilization, remediation

Related Work

At this time, we are not aware of any related work within the transportation community.

Urgency

Long-term performance of soil, soil-waste liquids and especially stabilized waste materials, are quite subjective. In order to gain confidence in the predictions it is necessary to know what types of reactions and processes are involved at the interfaces of these materials. This needs statement in given high priority and is ranked number 2 in the committee's agenda.

Cost

Approximate cost for the research is \$300,000 over 3 years.

User Community

This research problem statement should be distributed

to the Materials Research Section at all State DOTs. It should also be distributed to AASHTO and the FHWA.

Implementation

The results of this research can be distributed to the Materials Research Sections of all State DOTs. It should also be sent to the any Divisions that are involved with characterization of materials (soil, waste, mixed, or stabilized at any DOT site).

Effectiveness

Use of Image Analysis and Porosimetry techniques can bring more information to bear on the issues of long-term stability and performance of stabilized soils, waste materials or contaminated soils involved in transportation projects.

PROBLEM #187: LONG-TERM STABILITY OF WASTE MATERIALS IN HIGHWAY CONSTRUCTION

Acceptable disposal methods continue to decrease as the quantities of residual waste materials increase. Wastes such as coal combustion ash (70 million tons/year), municipal waste combustor ash (10 million tons/year) and flue-gas desulfurization sludge continue to require increasing areas for disposal. Due to its high volume consumption of bulk materials, the transportation industry is frequently requested, and has in some cases, utilized these and other waste materials in its projects. A principal concern is the stability of these materials under long-term conditions.

There are two "stability" issues which must be addressed. First, is structural stability, i.e., does the material provide the physical properties required in the application? The second issue is that of chemical stability, i.e., what are the elemental constituents of the material, will they become mobile, are they potentially hazardous, can they degrade to other forms? This research need is to address the second of the stability issues.

Objectives

The ultimate objective is to determine whether waste materials when used in highway construction applications pose a significant threat to the environment. Needed is

an assessment of what types, quantities and locations in which waste materials have been used in highway construction or related transportation facilities. The constituents of the materials and the service environments should be quantified. The physicochemical structure of the in-situ materials should be quantitatively assessed. Parallel field and laboratory efforts should address the physicochemical stability of the waste materials. The field studies should consist of long-term monitoring for physical or chemical changes in the materials and analyses of pore fluids for leached constituents. Laboratory investigations of the stability of any potentially detrimental constituents should be conducted under carefully controlled conditions.

The information provided from physicochemical research program should be combined with toxicologic and epidemiologic investigations. This interdisciplinary effort will result in quantification of hazards associated with utilization of waste materials in highway construction. Without such information, transportation agencies, consultants, contractors, waste material suppliers and health officials can not properly assess the level of potential hazard, nor can they accurately assign levels of liability for potentially hazardous conditions.

Key Words

Waste materials, utilization, recycling, reuse, in situ performance, long-term stability, compatibility, contaminant, pollution, hazardous, toxicologic, epidemiologic, liability.

Related Work

There are numerous, small-scale efforts addressing various facets of this research need; however, no concerted effort is being made to combine the results of these efforts or fill in the gaps. A central coordination is needed. Single investigators are examining the leaching characteristics of waste materials; however, such data does not typically get past researchers', designers' or consultants' files. This information must reach toxicologists and epidemiologists to complete the quantification of hazard level.

Urgency

This research need is given third priority. Use of waste materials in highway construction and rehabilitation is most likely to increase. The litigious climate concerning

environmental and health impacts of these materials will increase. Information from this research must be available in order to reduce the potential financial burden resulting from ignorance of the physicochemical stability and resulting hazard levels of using waste materials in highway construction.

Cost

The cost of quantification of laboratory and field physicochemical properties of waste materials in highway construction application is approximated to be \$500,000. This work is expected to require 3 to 5 years. The toxicologic and epidemiologic analyses of level of hazard is expected to require 3 to 5 years and cost \$400,000.

User Community

This research needs statement should be distributed to state DOTs, AASHTO, FHWA, members of TRB committees A2L02 (Soil & Rock Properties), A2K06 (Subsurface Drainage), A1F02 (Environmental Analysis), and the National Institute of Environmental Health and Safety (NIEHS).

Implementation

Physicochemical stability information must be transferred to toxicologic and epidemiologic researchers, Federal, State and local highway agencies and their consultants for use when considering waste material utilization. The results of level of hazard studies must be distributed to the previously noted organizations and to Federal and State Environmental Protection Agencies and environmental concern groups. Only through dissemination of well founded findings will the proper and economic utilization of waste materials increase.

Effectiveness

Information from this research program will increase the knowledge of the physicochemical stability of waste materials and decrease the chances of improper use of these materials. The resulting information will also improve our knowledge of hazard levels associated with using waste materials in highway construction. These steps will result in reducing the potential for litigious actions involving transportation related facilities.

A2L04 COMMITTEE ON FROST ACTION

PROBLEM #188: CHANGES IN PAVEMENT PERFORMANCE INDUCED BY FROST ACTION

Freezing and thawing cause changes in pavement performance. Moisture migrates to the freezing front causing an increase in moisture content and possibly a loosening of the material and/or changes in the soil fabric. Upon thawing all of the changes that occur cause weakening of the pavement system which results in rapid pavement deterioration and the potential need for load restrictions. To date, the technology does not exist to accurately predict how much the pavement system will be weakened, and the only practical method of determining if and when load restrictions should be applied, is to do a pavement system stiffness test at a point at the time in question.

Objectives

The objective of this study is to develop the methodology to predict pavement performance under freeze-thaw conditions and then to determine if, and when, load restrictions are economically justifiable. The result of this research will allow highway owners to manage the roads during the thawing period in a fiscally responsible and fair manner. Specifically, the following are necessary:

- Improve methods of predicting pavement damage from known loading and material properties;
- Improve methods of predicting the effect of frost heave on pavement performance during the heaved condition and its effect on pavement life;
- Improve methods of predicting material properties during freeze-thaw conditions;
- Improve methods for determining the cost of running a vehicle on a thaw-weakened pavement system;
- Develop the use of reinforcement inclusions in the pavement system to stabilize it during thaw-weakened conditions;
- Improve methods of rapidly and accurately determining the pavement system resistance to damage under a wheel load at any point during the thaw-weakened period; and
- Improve methods of posting and enforcing temporary load limits.

Key Words

Frost action, freeze-thaw, thaw weakening, load limits, resilient modulus, soil stiffness, pavement response, pavement performance.

Related Work

A very significant amount of work has been done on some aspects of the problem, but we are not to the point where any portion of the study is routine and/or easily implemented. Most of the work has been funded by FHWA or highway departments and has been performed by highway departments, universities, and CRREL. Specifically:

- Methods have been developed to predict pavement life within an order of magnitude based on measured material properties and calculated pavement strains. Minimal work has been done on predicting the effects of a single load on a temporarily weakened section.
- Very little has been done on determining the effect of frost heave on pavement performance during the heaved condition and its effect on pavement life.
- Many studies have been done on predicting frost heaving in the laboratory. Some of these have included thaw weakening. Some field work has been done on measuring thaw-weakened material properties. Accurate and practical predictive models have not yet been developed.
- Since the methods of predicting pavement damage due to a single wheel load during a thaw-weakened condition are in their infancy, little definitive work has been done on determining the economic implications of running on such a system.
- Virtually nothing has been done on the use of reinforcement inclusions to stabilize the pavement system during thaw-weakened conditions.
- Very little has been done in terms of predicting variations within the thawing period.
- Very little has been done in terms of determining scientifically when and where load limits are to be posted and the posting and enforcing of load limits is manual.

Urgency

Freeze-thaw damage is of grave concern to road owners throughout all areas where freezing temperatures are found. Load restrictions are applied at state, county, and city levels throughout most of the country every year. In general it is done by "intuition" and "experience" with little or no scientific backing. Not applying load restrictions when they are needed costs the owner, and any load restriction costs the trucking industry, and ultimately, the people. The situation is heated every year throughout the country. This should be considered a high priority activity.

Cost

This work will probably be done through many individual research projects over a period of many years. If coordinated, significant progress could be made with ten projects at \$100,000 each over a period of five years.

User Community

AASHTO, FHWA, state & local DOTs

Implementation

New findings should be disseminated immediately to all owners for inclusion into the design, maintenance, and operation arms of all user groups.

Effectiveness

The results would lead to more cost effective road design and maintenance and would allow fair distribution of costs to owners and user groups.

PROBLEM #189: MEASUREMENT OF MOISTURE CONTENT AND/OR MOISTURE SUCTION IN SOILS

The moisture content of soils influences many soil properties including the thermal conductivity, volumetric latent heat, latent heat of fusion, resistant modulus, strength, permanent deformation under repeated loading, compressibility, and hydraulic conductivity. In addition, the behavior of soils under freeze thaw conditions and

dynamic loading is dependant upon the water content and the porewater pressure. All studies of freeze thaw effects require measurement of the moisture content and, at present, there is no reliable method of measuring the moisture content and/or porewater pressures over a period of several years under freezing and thawing conditions.

Objectives

The objective of this study is to develop one or more pieces of equipment which will measure the moisture content and porewater pressure with the following specifications:

- Pressure accurate to ± 10 cm of water.
- Water content accurate to $\pm 2\%$ by volume.
- Applicable in any soil.
- Dynamic response to 10 ms.
- Able to be installed in a borehole.
- Accurate over a period of several years under freezing, thawing, wetting and drying conditions.

Key Words

Moisture content, water content, porewater pressure, soil suction, instrumentation, field instrumentation, freeze-thaw, frost heave.

Related Work

Several devices have been developed as a result of needs in other areas to do some of the things but there is no aggregate of equipment which will satisfy all of the requirements. Unfrozen water content can be measured but not reliably over long periods and ice content cannot be measured. Both positive and negative porewater pressures can be measured but not reliably at below freezing temperatures.

Urgency

Instrumentation is critical to verifying theoretical models in the field. Until such instrumentation is developed, true field verification cannot be performed. SHRP, for one, is planning on installing many more instrumented sites in the next few years and much of the data will be of marginal value without good instrumentation. This should be a high priority activity.

Cost

\$120,000 and two years.

User Community

AASHTO, FHWA, SHRP, anyone with instrumentation in the ground in cold regions.

Implementation

Once the technology has been developed it would be easy to get one or more manufacturers to go into production since there is expected to be a fairly large market, perhaps tens of thousands of dollars per year.

Effectiveness

The technology will lead to improved understanding of road performance under freeze-thaw conditions this is expected to result in improved design, construction and maintenance activities, which will ultimately lead to a reduction in owner costs.

PROBLEM #190: APPLICATION OF CHAOS THEORY TO PAVEMENT PERFORMANCE UNDER FREEZE-THAW CONDITIONS

Progress is being made in the laboratory in being able to determine the performance of some of the materials within a pavement system during freezing and thawing. Unfortunately there is variability in the key parameters within actual pavement systems not to mention the climatic conditions. There is indeed a real possibility that we will never be able to predict pavement performance accurately because of these variabilities. Chaos theory has been used in some applications where the conditions are so complex as to preclude anything but a statistical approach to the outcome. Weather forecasting is one such application leading directly to the possible use of the theory in predicting pavement performance.

Objectives

Determine if the application of Chaos theory to the prediction of pavement performance is viable.

Key Words

Performance prediction, freeze-thaw, frost heave, weather, Chaos, load restrictions.

Urgency

It is unlikely that the performance prediction using these techniques will be significantly more accurate than other technologies being developed however it may prove to be the best technique to use. It is of interest but not urgent interest.

Cost

\$50,000 for one year.

User Community

FHWA, AASHTO, SHRP, all owners in cold regions.

Implementation

This could eventually be the largest design and planning tool in the pavement industry.

Effectiveness

This is a pilot study to see if there is any need to pursue the concept further. It has the potential for revolutionizing planning, designing and managing pavement but it could also lead to nothing.

A2L05 COMMITTEE ON ENGINEERING GEOLOGY

PROBLEM #191: ROCK FALL PROCESSES AND MITIGATION

In mountainous areas, construction of new transportation facilities is encroaching on steep slopes as available land in the valleys is developed for other uses. A major hazard these new routes face is rock falls from the steep upper slopes. These rock falls can block highways and/or damage vehicles and cause risk of loss of life. Newly developed kinematic models permit reasonable prediction of the movement patterns of rocks and total travel distances as they bounce down rock faces and talus slopes. In order to define realistic zones of high risk, it would be necessary to have field measurements of typical rock fall conditions which can be used to develop empirical guidelines for general rock fall behavior predictions. Additional research is needed to determine with improved confidence the areas where rock falls originate, and to demonstrate the need for rock fall mitigation and its effectiveness.

Objectives

The objectives of this research are as follows:

- To provide field measurements of typical combinations of slope geometry, rock type, climate and rock fall records for areas of recurrent rock fall problems.
- To develop improved empirical predictions of rock fall behavior based on records and observations.
- To use these data to delineate hazardous areas and provide guidance for prioritizing hazard areas for rock fall mitigation techniques.
- To use these data to evaluate the effectiveness of alternative rock fall mitigation techniques.

Key Words

Rock fall, roadway hazards, management.

Related Work

Significant recent research activity has occurred within TRB Committee A2L05 and several state's Department of Transportation. Some research results were presented at the TRB Annual Meeting in 1992 and

published in Transportation Research Record No. 1343. Rock fall management is becoming a programmed function at many DOTs; however, no clear national direction or precedent exists to guide these efforts. Committee A2L05 has requested formation of a Subcommittee on Rock Fall Management with a three-fold purpose:

- Share existing technology among DOTs, university researchers, rock fall mitigation manufacturers and consultants;
- Participate in developing new technology; and
- Assist applying technology to rock fall management.

Urgency

A relatively few areas have comprehensive programs to delineate rock fall hazard areas. Those areas with hazard delineations are in need of prioritization so that the most hazardous areas may be mitigated first. Several different rock fall hazard mitigation techniques are available; research is needed to evaluate the effectiveness of these techniques and develop guidelines for selecting the optimum technique.

PROBLEM #192: APPLICATION OF GEOSTATISTICAL METHODS TO IMPROVE THE INTERPRETATION OF SUBSURFACE DATA

Interpreting the characteristics and properties of soil and rock materials between data points represented by borings is becoming more critical as funds available for exploration decrease and liability exposure for such interpretations by engineers increase. The use of statistics and probabilistic methods is becoming more common in geotechnical engineering. Statistical techniques such as kriging and randomization have been applied in the minerals industry to more realistically estimate variations between borings. It appears likely that these techniques or similar ones could provide a more rational basis for interpreting soil layering and/or selective properties between discrete boring points.

Objectives

The objectives of this research are as follows:

- To review existing geostatistical techniques to identify methods with potential applications for subsurface exploration interpretation.

- By use of demonstration projects, to evaluate limitations and suitability of the methods to specific geotechnical data needs, i.e., estimating material quantities and physical properties.

Key Words

Geostatistics, subsurface interpretation.

Related Work

Recent publications that discuss statistical techniques such as kriging and randomization include:

Huijbregts, C.J. "Regionalized Variables and Quantitative Analysis of Spatial Data"; Display and Analysis of Spatial Data, Wiley-Interscience, 1975. Royle, A.G., and Hosgit, E. "Local Estimation of Sand and Gravel Reserves by Geostatistical Methods"; Transactions of Institute of Mining and Metallurgy, Vol. 83, April 1974, p. A53-A62. Olea, R.A. "Measuring Spatial Dependence with Semivariograms"; Kansas Geological Survey Series on Spatial Analysis, Lawrence, Kansas, 1977, 29 p. Green, B.F. "A Practical Interactive Program for Randomization Tests of Location"; American Statistician, Vol. 31, 1977, p. 37-39.

In addition, a series of eight articles published in the Engineering and Mining Journal between May 1979 and February 1980 by various authors provides a good overview of geostatistics as it is applied in the mining field. No current research to demonstrate application of these techniques is known.

Urgency

The need for methods to support engineers interpretation of data between borings is increasing as funds available for exploration decrease and the public's tendency to litigate increases.

PROBLEM #193: APPLICATIONS AND LIMITATIONS OF PROBABILISTIC METHODS IN EVALUATING RISKS ASSOCIATED WITH NATURAL PROCESSES

Natural processes commonly are hazards along transportation routes. Design and maintenance

philosophies for dealing with flood hazards are based on the probability of occurrence of damaging events. Slope movements, particularly earthquake-induced movements, can cause extensive damage, but the probability of occurrence usually is small. The extent to which probabilistic methods may be valuable tools is design and maintenance is unevaluated.

Objectives

The objective of this research is to evaluate applications and limitations of probabilistic methods in evaluating risks associated with natural processes.

Key Words

Probabilistic methods, natural processes, hazards, risks.

Related Work

- The TRIS data base for key words "probabilistic," "natural processes," "engineering geology," "geologic risk," and "geologic hazard" was scanned in preparation of this statement.

- Monte Carlo simulations have been used to assess factors of safety of slopes; however, probabilities of occurrence of various magnitudes or intensities of natural processes (other than floods and earthquakes) remain largely unevaluated.

- Significant recent research activity has occurred among members of TRB Committee A2L05. Some research results were presented at the TRB Annual Meeting in 1990 and published in Transportation Research Record No. 1288.

Urgency

The current need to maintain and upgrade transportation infrastructure is extensive. Prioritizing activities is desirable because of limited availability of funds. Probabilistic methods may be a valuable tool to assist in this prioritization.

PROBLEM #194: EARTHQUAKE-INDUCED GROUND FAILURE AND DAMAGE POTENTIAL

The Loma Prieta earthquake and many other earthquakes have demonstrated that it is very difficult to

estimate the magnitude of vertical and horizontal displacements, or even predict with confidence where liquefaction-induced ground failure effects will occur. Nearby sites seemingly having similar soil properties can have great differences in settlement or lateral spread movement. Factors such as stratum thickness, lateral variations in sediment properties, grain size characteristics, and layering details are all doubtlessly relevant, but of unknown influence. A need also exists for development of relatively straightforward criteria that can be used by the practicing engineer to assess whether liquefaction-induced ground displacements at a site might be sufficiently large to warrant a much more costly, detailed analysis.

A need also exists for post-earthquake examination of landslides (non-liquefaction related), in order to confirm existing models or develop new models for predicting distance of movement. Few case history studies are available which address the validity of currently used models for estimating landslide displacements. Numerous landslides triggered by the Loma Prieta earthquake provide a large data set for analysis.

Objectives

The objectives of this research are as follows:

- To develop more realistic models for estimating settlements caused by liquefaction;
- To develop more realistic models for estimating lateral displacements caused by liquefaction;
- To develop simple techniques for evaluating if liquefaction-induced damage potential exists; and
- To evaluate the validity of currently used landslide displacement techniques.

Key Words

Earthquake, ground failure, damage, prediction.

Related Work

● Geotechnical engineers at a number of universities collected many liquefaction-related data after the Loma Prieta earthquake, and some of these data are still being analyzed. The role of some variables on lateral spread displacements is being reassessed for historical earthquakes. Federally funded research is focused on the role of geologic factors in determining where lateral spread movements took place in response to the 1811-1812 New Madrid earthquakes.

● Many landslide data have been collected for the Loma Prieta earthquake, especially by U.S. Geological Survey personnel. Analysis of these data continues.

● Significant recent research activity has occurred among members of TRB Committee A2L05. Some research results were presented at the TRB Annual Meeting in 1993 and have been accepted for publication in a future Transportation Research Record.

Urgency

The potential for earthquake hazards is only now beginning to be known for many parts of the country. Many engineers are having to make decisions for situations using analysis procedures that are unproven.

A2M01 COMMITTEE ON RAILROAD TRACK STRUCTURE SYSTEM DESIGN

PROBLEM #195: DETECTION AND CONTROL OF THERMAL EXPANSION IN CONTINUOUS WELDED RAIL (CWR)

Numerous derailments occur each year on railroads because of the inability to detect, far enough in advance, excessive internal stresses in CWR caused by abrupt temperature changes.

Objectives

To develop a nondestructive practical method to detect the occurrence of excessive stress and take corrective action to release and adjust prior to the track buckling ahead or under a train to avoid a derailment.

Related Work

At present, during periods when drastic temperature variations are imminent, railroads dispatch trained track inspectors to travel over their lines to visually detect alignment irregularities that often precede buckled track. Also, arbitrary train orders are issued alerting train crews to the possibility of track buckling when conditions that cause buckling are predicted. Both actions depend entirely on visual observations. Many times, the buckle occurs under the train as it is passing over the point of high stress. When this happens, it is normally too late for the train crew to take corrective action, as applying the brakes only aggravates the situation.

To date, nothing of a technical solution has been perfected. Strain gauges, x-ray, etc. will measure such stresses, but such units are impractical to cover the trackage involved. Most non-destructive residual stress measurement techniques only measure residual stress at the surface of the rail whereas a bulk stress measurement is required in this application. The Volpe National Transportation Systems Center (VNTSC) and AAR have developed a rail uplift technique that, although it measures longitudinal stress accurately, is impractical for production track inspection.

What the railroad industry needs is an economical, mobile, portable device that can be transported using a hi-rail vehicle or some other light rail-mounted equipment. Such equipment would be run over the railroad particularly during periods of suspect temperature variations and alert all concerned to take

corrective action prior to the passage of a train, such as placing a slow order or adjusting the rail to relieve the stresses.

Urgency

The research is urgently needed. The economic and safety factors are constantly facing all railroads using CWR and the present methods are not very timely, reliable, or accurate.

PROBLEM #196: ARE EQUIPMENT AND TERMINAL SAVINGS FROM USE OF 125-TON CARS LESS THAN THE INCREMENTAL INCREASE IN TRACK MAINTENANCE COSTS FOR MOVEMENT OF THESE CARS?

The efficiencies of carrying containers two-high on railroad cars has transformed rail movement of intermodal containers. These double-stack economies do not apply to containers too heavy to stack two-high on existing 100-ton cars, so 125-ton capacity cars have been constructed. Whether the cost of increased wear on track components is offset by the economies from greater car capacity is unknown.

Objectives

Correlate wear rates from ongoing research for track and equipment deterioration with equipment and terminal investment and operating costs to evaluate the net gain or loss by use of 125-ton equipment.

Related Work

The AAR Transportation Test Center, FAST, is conducting equipment and track wear testing.

Urgency

Most of the railroad intermodal fleet is obsolete and will be replaced within ten years. An evaluation of the economies is urgently needed to guide both investment and research towards the most efficient car type.

PROBLEM #197: WHY, WHERE, AND WHEN TO USE THE VARIOUS TYPES OF RAIL PRESENTLY AVAILABLE (SUCH AS STANDARD, HEAT-TREATED, AND ALLOY RAIL)

At the present time, there is a multitude of conflicting and confusing information available regarding rail and rail usage. The AAR, AREA, independent researchers, rail manufacturers, and railroads themselves all have studied the subject extensively, with each producing their respective views. There is no collective data that incorporates all the findings into a useable form to simplify the decision-making process.

Objectives

Develop a simple useable matrix to assist railroads in selecting the most economical type and section of rail to be laid that will give the maximum service life, have the greatest return on investment, and provide the maximum degree of safety for the property and type of traffic involved.

Related Work

The AAR, at the FAST facilities, are conducting tests regarding the various types of rail available. Many railroads have done likewise and with the assistance of the AAR have constructed computer financial models to assist in selection. However, not much progress has been made toward a common set of standards.

Urgency

Standardization is extremely desirable. A matrix incorporating the appropriate research findings to express the most economical and practical selection of rail section, type, and laying sites would result in significant benefits for most railroads. Benefits would include lower overall capital expenditures, greater rail service life, and simplified rail and rail-related products inventories.

PROBLEM #198: THE PRESENT COST OF RECLAIMING RAILROAD TRACK ACCESSORIES IS EXCESSIVE, AND THE QUALITY AND UNIFORMITY OF THE ITEMS RECLAIMED NEEDS TO BE IMPROVED

As a result of mechanized track maintenance operations such as rail laying, tie installations, switch renewals, etc.

many good useable track accessories are released and loaded into cars indiscriminately with a magnet and transported to centralized facilities for classification and reuse or scrapping. Economic studies have indicated that some type of sorting and classifying is justifiable. One of the most costly elements of a reclamation process is the labor involved in accomplishing the task.

Objectives

To design and develop a system to sort, classify, and reclaim metal rail track accessories. The purpose is to determine whether the materials being evaluated should be reused or scrapped. The object would be to accomplish the task utilizing modern technological concepts that would produce a more economical, efficient, and accurate sort of the items involved. It would eliminate individual opinions, and selection would be based on preestablished specifications and standards.

Related Work

To date, a number of Class I and short-line/regional railroads reclaim rail accessories either utilizing their own labor and facilities, or they contract the work to outside companies. The operation entails transferring the material from railroad cars onto a conveyor belt and then passing it slowly past laborers stationed along the belt who visually scrutinize it and decide whether to save it or scrap it. If it is scrapped, the item goes to the scrap bin. If it appears to be reusable, then it must be classified, sorted, and separated accordingly. This process is extremely subjective and depends upon the judgment and experience of the individual reviewing the materials.

Urgency

This is an economic problem. Solving it would result in a better grade of reusable track material at a lower cost. The quality of the resultant materials would be superior and produce a longer service-life for reused items.

PROBLEM #199: WHAT FATIGUE LEVEL JUSTIFIES REPLACEMENT OF LIGHT RAIL (LESS THAN 100 POUNDS PER YARD)?

The abandonment of over 40 percent of the U.S. railroad network since 1916 resolved many inadequate rail conditions. In the past decade, another alternative to

branch-line abandonment emerged, creation of short-line and regional railroads. However, problems with light rail are actually intensified by increased traffic volumes hauled by many of these new carriers. Old rail sections, rolled when 18-ton axle loadings were standard, now carry 33-ton loadings and they are expected to remain serviceable for decades. Current criteria for renewal, when maintenance expenses and derailment costs become excessive, is an inefficient evaluation process. A procedure to predict future life can provide valuable input to guide public and private rail planning and avoid the excessive expenses now incurred before rail renewal.

Objectives

To develop guidelines for predicting useful rail life on light rail sections.

Related Work

As of January 1989, CN was reported to be studying fatigue life. The Rail Working Group of the AAR has done considerable research on rail fatigue life, but has done little to address issues specifically related to light rail sections.

Urgency

Urgency is moderate. Substantial public and private funds are expended upon purchase and rehabilitation of branch-lines each year. Improved understanding of future rail life will allow rational funding decisions.

PROBLEM #200: LOSS OF SHUNT OVER GRADE CROSSINGS

Temporary loss of shunt during passage of trains over standard 120' island circuits located at railroad grade crossings.

Temporary loss of shunt can result in momentary deactivation of crossing gates even when a train is still occupying crossing limits. Such cases can reduce motorists' confidence in crossing reliability.

Objectives

Determine parameters on the rail and wheel that can lead to instances of loss of shunt, and develop mitigation techniques that eliminate or greatly reduce such occurrences.

Related Work

A number of grade crossings where loss of shunt has been observed are being monitored with equipment that records track circuit voltage before, during, and after train passage. This data allows one to determine if shunting is reduced to the level where voltage can "leak" past the wheel-sets of passing trains and provide a temporary and very brief indication that the train has vacated the crossing when in reality train cars continue to cross.

Each crossing has been inventoried and documented as to rail condition, shape, wear and other field parameters. Crossings with more frequent loss of shunt occurrences will be evaluated in detail to determine if films on the rail may be increasing shunt resistance. An attempt will be made to determine if certain car types or groups of cars result in more frequent loss of shunt occurrences.

Data collection and field evaluation activities are presently ongoing, with a data base of occurrences and car types causing loss of shunt being created. Future plans call for evaluation of rail and wheel films and replication of specific parameters at one of the test loops at the Transportation Test Center to allow detailed parametric studies to be conducted without affecting public safety.

Urgency

This research is urgently needed to insure continued safe operation of the nation's railroad crossing warning systems, and to allow mitigation techniques to be introduced in the near future.

A2M02 COMMITTEE ON ELECTRIFICATION AND TRAIN CONTROL SYSTEMS FOR GUIDED GROUND TRANSPORTATION SYSTEMS

PROBLEM #201: RAILROAD ELECTRIFICATION FIXED PLANT INSTALLATION COSTS

Major cost discrepancies exist for railroad electrification fixed plant installation between North America and other parts of the world. While labor costs or rates of exchange vary widely from country to country, the differences cannot be attributed solely to these factors. A detailed comparison of design requirements, installation methods, and specifications would help identify areas of differing requirements and supporting rationale.

Objectives

The objective is to identify and document areas of railroad electrification cost differences including wayside substations, catenaries, and signalling and communication system. Analysis would be conducted to determine if the variance is related to design requirements, manufacturing procedures, installation practices, work rules, operating philosophy, or other factors.

Key Words

Railroad electrification, cost comparisons, electrification costs, overhead catenary power supply distribution, and alternative system capacities and styles.

Related Work

- TRB Committee A2M02 has an active subcommittee dealing with electrification cost differences.
- TRB Committee A2M02 has formal presentations related to comparison cost issues at its semiannual meetings.

Urgency

The results of the research are an important factor in railroad electrification cost/benefit analyses. It appears that a number of recent electrification system installation cost estimates could have been reduced by the incorporation of improved design techniques and/or

more precise cost data. A number of alternative factors have been identified which might result in reduced installation costs—these include simplification and changes in the areas of structural design, clearances, substations, and signal and communication systems. Such reductions in cost might result in a sufficient improvement in investment return to justify electrification implementation.

PROBLEM #202: RAILROAD ELECTRIFICATION SYSTEMS--MODERN TRAIN CONTROL CONCEPTS: THE IMPACT OF ELECTRIFICATION COSTS

The conventional train control systems, in operation on most rail transportation systems where introduction of electric traction is considered, are not compatible with high voltage AC electrification systems. Such train control systems can be made compatible by major replacement of equipment, individual components, and cabling, but only at considerable capital cost, directly attributable to electrification (except when systems are life-expired and due for replacement). This capital cost and the physical replacement work are a substantial part of an electrification project and constitute a major deterrent to authorization of electrification proposals.

Objectives

1. To identify cost-effective techniques and methods for provision of train control equipment and systems that are compatible with AC electrification, and to document those techniques and methods for general application when system replacement or modernization projects are undertaken.
2. To encourage development and application of compatible train control equipment when new systems are installed in previously unequipped or "dark" territory.
3. To establish major reduction of the cost impact on electrification projects related to incompatibility of train control systems with high voltage AC electrification.

Related Work

- Several alternative methods of conversion for non-compatible train control systems have been applied to

recent projects and studies by system suppliers and consultants.

- Many new train system concepts are being developed by industry task forces and suppliers including some with novel and innovative operating features, but system compatibility is not necessarily being regarded as an overriding priority.

- Introduction of track-side fiber-optic cable circuits is making a major contribution to reduced cost of conversion for non-compatible train control systems.

- The TRB Committee A2M02 has formal presentations on compatible train control systems at its semiannual meetings, and is encouraging a wide-ranging review of the subject by authorities in this specialized field.

Urgency

The results of the research are urgently needed for the following purposes:

- To provide better technical and cost data input for ongoing rail electrification studies;

- To encourage use of compatible, interactive systems and equipment when upgrading or replacement is undertaken and whenever new systems are installed, and to encourage shared use of major system components; and

- To mitigate and eventually eliminate a major deterrent to authorization of electrification on North American rail systems.

A2M03 COMMITTEE ON INTERMODAL FREIGHT TERMINAL DESIGN AND OPERATIONS

PROBLEM #203: FINANCING AND IMPROVING HIGHWAY ACCESS TO US INTERMODAL CARGO HUBS

Large US seaports and common-user truck/container freight yards are facing acute congestion access problems. The ISTEA legislation promotes numerous issues including intermodal efficiency, congestion management and remediation, and innovative public/private ventures to finance intermodal transportation projects. Responding to these objectives of ISTEA has been an ongoing effort within the freight community, which has actively sought ISTEA funding for improving highway access to high volume intermodal freight projects. While ISTEA has allowed for some funding of freight mobility enhancement projects, worthy projects far exceed the finite pool of public dollars. DOTs and MPOs in states with key seaports or inland cargo hubs must grapple with strategies to facilitate the flow of international commerce. A recent TRB study indicates that 50% of the major US ports report serious congestion delays at the terminal, and this flow of international commerce is expected to triple over the next three decades.

DOTs and seaports have a shared responsibility to efficiently move commercial freight. Assessing the combined expertise available with electronic highway toll tags and intermodal freight identification tags presents an opportunity to examine electronic traffic tracking devices as a step toward possible tolling projects at cargo hubs. This non-barrier user-fee assessment could be collected without further escalating congestion delays at freight terminal gates. Revenues generated could be used to match or offset construction of dedicated freight corridors into cargo terminals.

Objectives

A pilot investigation into freight terminal access fees could assess an innovative public/private strategy to offset the sharply escalating costs of accommodating peak traffic demands for cargo hubs.

Key Words

Intermodal planning, toll facilities, administration, financing, design.

Related Work

There are some related research projects underway, but none were identified that directly address tolling options at freight hubs:

- 1988 Highway Financing Briefs looks at tolls, taxes and impact fees;
- 1986 NCHRP Project 214 Public Private Partnerships for Financing Highway Improvements;
- 1992 NCHRP Project 2024(7) Alternatives to Motor Fuel Taxes to Improve Surface Transportation Improvements;
- 1993 NCHRP Project 830 Characteristics and Changes in Freight Transportation Demand;
- 1993 NCHRP Project 831 Long-Term Availability of Multimodal Corridor Capacity;
- 1993 Synthesis Project 2502 Methodologies Associated with Freight Planning;
- 1993 Synthesis Project 2511 Toll Plaza Design; and
- 1993 TRB Special Report on Landside Access to US Ports.

Urgency

This is a high priority project that would provide a tool directly applicable to the creation of statewide intermodal management systems mandated under ISTEA. This investigation presents a viable strategy that would collect and leverage user fees at point-of-user impact. Technologies to assess and collect toll fees are readily available. It is likely that the institutional arrangements and the market application strategies would present the larger challenge, therefore, the problem statement investigation would include the following elements:

- Survey of relevant research and practice;
- Determination of possible hub facilities for study;
- Analysis of traffic flows at selected hubs;
- Assessment of acceptability and barriers to application;
- Preliminary assessment of associated costs and benefits;
- Examination of administrative approaches; and
- Technical application issues.

Cost

\$300,000 for the described scoping study.

User Community

Those audiences that may benefit include American Association of Port Authorities (AAPA), AASHTO, FHWA, MARAD, state DOTs, and MPOs.

Effectiveness

This study could examine a possible option to help support the nation's financially pressed seaports that

serve as gateways for commercial and military cargoes. The enormous sophistication in ship capacity, and rapid deployment of cargos to accommodate just-in-time (JIT) logistics, demands seamless accommodation of increasing peak traffic flows through cargo ports. Innovative funding strategies must be examined to keep pace with escalating infrastructure improvements that complement national economic competitiveness. In addition to the potential generation of funds for infrastructure improvements, user fees could secondarily serve as a mechanism to regulate access demand to load centers at peak congestion periods. This research responds to the public/private partnership advocacy outlined in ISTEA.

A2M04 COMMITTEE ON RAIL TRANSIT SYSTEM DESIGN

PROBLEM #204: EVALUATION AND DEVELOPMENT OF STANDARDS FOR GUARD RAIL ON CURVES

Little is known about wheel-rail forces involved when transit vehicles with various truck (bogie) characteristics transverse guarded curves. Based on work previously done at the AAR Transportation Test Center in Pueblo, Colorado, lateral forces are higher than anticipated, and in some cases may lead to lowered vertical forces causing wheel uplift. At least one transit property has experienced derailments. These occurred when an existing car design, using a new and different truck design, was operated over a new guard rail design.

Objectives

This research would allow transit operations to select or modify truck design to match the characteristics of guard rail design or vice versa. Testing of Chevron-sprung trucks is of particular importance.

Related Work

The testing of TTC included only one truck design, and ended far short of determining the causes of very unusual measured forces. No work is currently underway or planned.

Urgency

Many properties are experiencing anomalies in operation of equipment on guarded curves. Both old and new properties have experienced derailments when either track design or car design were changed. This research could result in immediate benefit to track and car designers.

PROBLEM #205: WHEEL LOAD DAMAGE TEST PROGRAM

Excessive transit wheel loads accelerate wheel/rail wear and the degradation of truck and track components. However, quantitative thresholds for what constitute excessive transit wheel impact loads have not been defined.

Objectives

This research would use a field testing program to measure the dynamic range of vertical and lateral loads. Known true wheels will be tested to develop a statistical distribution at various speeds. Unusually high loads caused by flats or out-of-round wheels will be compared with the known true-wheel loads. This threshold will be used to evaluate the severity of the problem and develop appropriate remedial action.

Related Work

Wheel impact load testing has been done at FAST and on Amtrak's Northeast Corridor. Current technologies permit rapid measurement of wheel impact loads using wayside strain gauges and data storage units.

Urgency

Determining excessive wheel load thresholds will provide a basis for more efficient allocation of maintenance resources. Reduction of maintenance costs and decreased noise and passenger discomfort will provide significant immediate benefit.

PROBLEM #206: TRANSIT RAIL PROFILING AND GRINDING TRAIN DEPLOYMENT

Standards for optimal rail profiling and for rail grinding cycles have not been developed for the transit industry.

Objectives

Development of an optimum profile for new rail to improve the wheel/rail fit and standards for re-profiling throughout the useful rail life cycle. Also, progress of a grinding train deployment program with enough flexibility to accommodate urgent backlogged grinding sites.

Related Work

Optimal rail profile and grinding cycle standards for use on heavy-haul railroads are currently being developed.

The proposed activity would extend work in this area to meet the distinct requirements of the transit industry.

Urgency

Rail is the single most expensive track component. Extending the useful life of rail through programmed surface finding will likely produce a significant economic benefit.

PROBLEM #207: IMPROVED USE OF INFORMATION SYSTEMS IN THE FIELD

In recent years, there has been a quantitative and qualitative explosion of information that has become available to transit field personnel. These resources are typically under-utilized.

Objectives

The overall program objective is to make better use of available sources in daily field activities. This could involve automated track inspection and the application of up-to-date maintenance and construction standards to reduce time lags between defect detection and correction.

Job retraining would be tailored to experienced field staff whose work habits were set well before the advent of current information technologies.

Related Work

Many transit properties provide their field employees with basic job training classes at entry level or at promotion to supervisory positions. Some properties combine classroom instruction with hands-on training in the field. Few transit properties provide ongoing training to their experienced employees.

Urgency

The transit industry allocates a tremendous amount of resources to developing increasingly powerful information systems. Line personnel often lack the basic knowledge of what these tools can do for them to obtain the maximum potential return.

PROBLEM #208: RETROFITTING OLDER TRANSIT PROPERTIES WITH PREFABRICATED CONCRETE SLAB TRACK

Construction of transit slab track requires track closures for an extended period of time, particularly where clearances of constant operations restrict movement of men and machines. Transportation departments at older properties cannot afford to disrupt train service for the multiple days necessary to prepare and pour slab track. This study will identify means and methods of slab track prefabrication for use by those properties that cannot currently install slab track on existing lines.

Objectives

Develop a prefabricated design for transit track that allows for the placement of slab track in revenue service within established transit track closure periods. Feasibility and cost of slab track installation would be evaluated including labor, material and machinery. Specialized equipment to achieve this objective and mechanize the process would be favored. The use of railroad continuous action tampers and other heavily automated track equipment including laser track-lining technology may make it possible to adapt recently introduced equipment for this purpose.

Related Work

Concrete slab with direct fixation fasteners is the track design choice on many new or extended transit lines.

Urgency

While construction cost is higher than on conventional track systems, slab track offers greatly reduced maintenance due to its stiffness and ability to hold line, surface, and gage.

PROBLEM #209: DEVELOPMENT OF A MATERIAL MANAGEMENT SYSTEM

Long lead-times are usual when purchasing track components and equipment. This may not be a problem for programmed work, but critical track components that require immediate replacement may not be readily available at a transit property. Expediting emergency

orders incurs additional costs and delays completion of projects in the field.

Objectives

Develop a material management system to ensure that an adequate supply of track material and components is on hand at all times. Inventory algorithms will be incorporated in microcomputer software to permit "just-in-time" ordering. These algorithms will be driven by average component replacement cycles generated by an expert system. Standard kits will be matched to the labor and equipment needs to perform each job, including stock number and material quantity.

Related Work

Material management systems are currently used in manufacturing and in business, but only to a limited extent in public transit. AC Transit has successfully used a Bus Vehicle Maintenance Management System running on a minicomputer since 1985.

Urgency

A comprehensive material management system which incorporates expert knowledge, "just-in-time" ordering, and automated billing and accounts receivable would offer improved field and office operations. A system which defines material needs by kit, utilizing expert systems to correlate supply and demand for components and providing CPM or PERT charts, would be an invaluable tool in the transit industry.

PROBLEM #210: ECONOMICS OF SWITCH FROG REBUILDING

Switch frogs are the most expensive component of a turnout. Railroads have exploited the economic benefits of rebuilding frogs and the AREA has developed frog rebuilding standards. Few North American transit properties have frog rebuilding programs, and standards unique to transit applications have not been developed.

Objectives

Evaluate the costs and benefits of rebuilding frogs to extend their useful life over one or more rebuilding

cycles. Develop transit-specific frog rebuilding standards. Rebuilt frogs hold the prospect of significantly longer life on transit than on railroads because lower axle loadings induce fewer fatigue related deterioration and failures.

Related Work

Several large transit properties are currently engaged in the development of frog rebuilding standards, but generic standards (applicable with only minor modifications) have yet to be developed for the transit industry.

Urgency

This program would address industry-wide needs to determine whether transit frog rebuilding is cost effective. If such an advantage is shown, the standards will be made available to all properties.

PROBLEM #211: RAIL WEAR DETECTION AND MEASUREMENT

A variety of methods of detecting and measuring rail wear are currently in use on North American transit properties. Each transit property has developed its own standards for rail condemnation.

Objectives

Develop measurement standards for high and low-side head area loss by rail section and metallurgy. Automated rail wear measurement systems will afford transit properties a greatly improved level of accuracy in predicting useful service life of rail.

Related Work

Hand-held mechanical gauges are the typical method of measuring rail wear in the field. Portable rail wear measuring systems are currently under development, capable of storing data on magnetic media for subsequent analysis. Automated track geometry cars at certain transit properties are equipped to measure gauge face loss and top wear while in motion, using either ORIAN or LITESLICE technologies.

Urgency

Competing technologies are being developed at various properties. Little of this effort has been coordinated and the effectiveness of the research could be improved by an industry-wide program.

A2M05 COMMITTEE ON GUIDED INTERCITY PASSENGER TRANSPORTATION

PROBLEM #212: SAFE EGRESS FROM MAGLEV SYSTEMS UNDER EMERGENCY CONDITIONS

Some maglev systems may be elevated or go through tunnels. The location of the maglev vehicle and guideway affects the safety of passengers during an emergency evacuation. Stopping areas must be long enough and wide enough to allow immediate egress of all passengers from a crowded train. The absence of a safe means of leaving the vehicle and the inability of emergency response personnel to reach or evacuate passengers may cause injury or aggravate existing injuries. A stop at a location over an inaccessible area such as an elevated segment over a swamp or a lake could prevent or delay evacuation of passengers and crew from the vehicle. Additionally, a stop on a steep curve may present difficult or dangerous conditions for passengers to exit onto the sloping guideway. This is particularly true if the guideway condition is in an icy or other weather related condition.

Objectives

The objective of the research is to evaluate the effectiveness and the impact on vehicle/guideway design of walkways, railings, platforms with ladders or other such means to assist evacuation such as chutes or rope arrangements. Consideration must be given to access by emergency response organizations, emergency lighting, ventilation, communications and support equipment (i.e., access tools, fire extinguisher). The special needs of elderly and disabled passengers must be addressed.

Related Work

- German Trans-rapid Development.
- FRA and VNTSC reports and projects on safety of high speed maglev trains. VNTSC is conducting an in-house effort to develop "Emergency Preparedness Guidelines for HSGGT Systems". A report is planned for February 1993.

Urgency

High priority.

PROBLEM #213: HIGH SPEED GUIDED GROUND TRANSPORTATION SYSTEM COLLISION AVOIDANCE AND ACCIDENT SURVIVABILITY

As high-speed maglev and rail transportation systems emerge in the United States, the question arises as to whether there are adequate safeguards to prevent collisions and to protect passengers and train crews in the event of collisions with other objects. Are standards necessary to ensure survival and minimize injury by requiring design strengths and configurations of vehicles? With the increase in system speeds there is a need for collision avoidance and accident survivability research.

Objectives

Perform an analytical study and testing program sufficient to establish collision survivability requirements for HSGGT systems. Determine the areas such as operating environments, railway and maglev train control, fully automated operation, guideway protection and grade separation, cruise speed, passenger restraints. Consider tradeoffs to crash-worthiness and attempt to quantify the tradeoffs. Possible tradeoffs must include financial and economic considerations. Investigate possible alternate strategies for collision energy absorption.

Related Work

As part of the National Maglev Initiative, a broad agency announcement was issued requesting proposals for research in this area.

The FRA is conducting studies of collision avoidance and accident survivability of HSGGT systems. Work is planned that will address issues such as validation of crush calculations, and simulations. An extended analysis of selected scenarios is also being considered.

The A.D. Little report, Collision Avoidance & Accident Survivability, is an example of the work being done.

Urgency

High priority.

PROBLEM #214: MAGLEV BRAKES

Because of the non-contacting feature of maglev the specific braking equipment differs greatly from that on steel-wheel-on-rail systems. Generally the linear synchronous motor (LSM) is the primary brake. The secondary or emergency brake may use eddy currents, skids or other friction contact devices, or aerodynamic retarders. Existing safety regulations enforced by the Federal Railroad Administration (FRA) cannot be directly applied or transferred to maglev systems. The intent of these regulations, however, to ensure that a safe braking system is always available on any operating train is appropriate. Because maglev systems may generally be operating at a height of about 4.5 to 15 meters (15 to 50 ft) above ground level, some systems feature programmed braking to the next safe evacuation location for a situation that requires an emergency stop rather than an immediate maximum acceleration stop by the operator. Because of the high acceleration and deceleration rates available, and automatic central station control, maglev systems are being proposed with headways that are far from traditional, and possibly unsafe, for high density mixed traffic services (e.g., individual vehicles, trains, freight, passenger local, and express). A research program to look at all of these issues is needed.

Objectives

The overall objective of this proposed activity is to identify and evaluate performance-based characteristics leading to a generic specification. To meet the objective the following tasks should be performed:

1. Review current, proposed and other possible alternate maglev brakes for both primary and secondary (emergency) braking;
2. Consider fault tolerance and redundancy requirements for maglev braking systems;
3. Consider full emergency brake application vs programmed braking to the next emergency evacuation location and operator control;
4. Investigate the interrelationship of braking rates/deceleration limits, stopping distances, train separation/headways and capacities considering passenger comfort and restraint, energy implications, lead train assumptions and switch or junction assumptions; and
5. Develop a generic set of performance criteria for primary and secondary (emergency) maglev braking systems as a function of braking rates and headways.

Related Work

FRA is conducting an assessment of the Safety of High Speed Magnetic Levitation Transportation Systems. To date four reports have been issued on one system. It is understood that FRA plans to develop a Rule of Particular Applicability for the Florida Maglev Demonstration Project and, ultimately, a Rule of General Applicability for all maglev systems.

Under the National Maglev Initiative (NMI) program four System Concept Definition (SCD) contractors are studying technical feasibility, performance, capital and operating costs for new maglev systems for the year 2000. Many technical, operational and economic issues in the preliminary and final design of new maglev systems will require the application of appropriate safety standards. Timely information is needed to provide the basis for rational subsystem selections.

Urgency

High priority.

PROBLEM #215: DEVELOPMENT OF STANDARDS AND GUIDELINES FOR HIGH SPEED RAILWAY BRAKES

In order to ensure safety in high-speed rail, it is necessary to issue brake performance standards/guidelines that will provide acceptable levels of safety for high speed train operations with multi-type brake systems.

Objectives

The objective is to identify acceptable levels of safety and performance for high-speed rail braking systems. The safety and performance criteria will define the objective to be met in the design and qualification of braking systems. This process should include a review of the foreign standards that have been used on existing high speed rail systems and those being proposed for future high-speed rail systems.

Related Work

The FRA task force is reviewing the safety and performance standards that have already been defined and implemented by foreign high-speed rail regulating bodies.

Urgency

High priority.

PROBLEM #216: HIGH SPEED RAIL AND MAGLEV VEHICLE INTERIORS

In order to ensure the future usefulness of maglev and high-speed rail systems in the United States, it is essential to insure that the safety level afforded by such systems equals or exceeds that of other high-speed ground transport systems worldwide. It is imperative that occupant safety be granted a high priority. The construction of maglev and high-speed rail vehicle interiors will be critical to occupant safety. Thus, every effort must be made to maximize the safety of the vehicle interiors.

While the means of egress/access and the operating environment may vary between maglev and high-speed rail systems, the vehicle occupant's safety level should not vary nor should it be compromised for those reasons.

Objectives

Consideration should be given to the establishment of guidelines and standards pertaining to performance and safety standards (flammability, smoke emissions, toxicity, etc.) for passenger seating, applications and types of materials, retention of items of mass, and requirements for onboard emergency equipment. Although these restrictions need not stipulate emergency condition procedures regarding occupant egress, it would be well to consider standards aimed at requiring all operators to have such procedures in place.

The rapid transit, automotive and airline industries and AMTRAK have accumulated a great deal of experience in their efforts to maximize vehicle interior safety and have been able to implement many key safety designs economically. Parties involved in designing maglev and high-speed rail systems should consider gathering the technical and economic information that has been developed as a result of research in other transportation modes. Criteria used for the interior design for foreign HSR systems should also be reviewed for suitability and adaptability to U.S. applications.

Related Work

The following are suggested information sources:

- AMTRAK Specifications;

- SAE Aerospace Standard (AS) 8049;
- SAE Aerospace Recommended Practice (ARP) 767;
- NFPA 130 Standard for Fixed Guideway Systems;
- ASTM 906 Ohio State University Test;
- ASTM 119 Floor Structure Fire Barrier;
- UIC 564-2 OR 3rd edition 1191, "Regulations relating to fire protection and firefighting measures in passenger-carrying railway vehicles or assimilated vehicles used on international services" (*UIC 564-2 OR contains a list of test methods for various materials including: rigid non-thermoplastic, rigid thermoplastic, coated and uncoated textiles, rubber door and window seals, foam materials, floor coverings, seats, electric cables, and full scale fire tests. The section also contains guidelines for vehicle design to enhance fire protection.*)

Urgency

High priority.

Maglev and high-speed rail system design parameters will require the implementation of appropriate safety standards. Should regulations establishing such standards be promulgated subsequent to design competition, expenditures to correct safety deficiencies could be large.

PROBLEM #217: AUTOMATION LEVELS AND HUMAN FACTORS RELATED TO HIGH-SPEED RAIL AND MAGLEV SYSTEMS OPERATIONS

There exists a question as to the degree of control that may be entrusted to the vehicle operator/attendant and the central control operator of a high-speed rail or maglev system under various operating scenarios, ranging from fully decentralized vehicle operator control to fully automatic centralized control over vehicle and system operation.

Automation Levels (At very high speeds it is assumed all systems will have an automatic speed supervision system that will not allow the safe speed limit, determined by the control system, to be exceeded to any extent that would contribute to an unsafe situation):

- Fully automatic, no manual operations except for maintenance facilities and emergencies;
- Fully automatic/Manual, automatic with override capability at the vehicle operator's level with or without control by central operator; or
- Manual, vehicle operator must control all aspects of vehicle operation.

Automation Types

- Centralized, no vital vehicle born components or inputs
- Centralized/Decentralized, vital components located in both a central facility and the vehicle and/or the wayside; or
- Decentralized vital components located only on the wayside or vehicle or both.

This research topic would include an analysis of those physical and psychological elements that might impact a vehicle or central control operator's ability to function safely for varying levels and types of automation. These elements should include such items as performance fatigue; work-rest cycles; impact of being a sole operator; emergency responses; and issues related to the use of a computer system as a diagnostic tool.

This topic would also include a determination of what devices are needed for relaying information to the vehicle operator for given levels of automation. For example, at what speeds or other situations do wayside signals become inappropriate to convey signals to the vehicle operator. Also, what kinds of displays and information is necessary for the vehicle and central control operators to fulfill their job function for varying levels of automation.

Objectives

The object of this research activity is to determine the safety criteria under which each form of right-of-way geometry, guideway, vehicle/train control and overall system operation can exist based on human factors, operational requirements, limitations of the technology involved, and environmental considerations. This research should also determine the requirements for information content and presentation method to the vehicle operator/attendant and central control operator for the different automatic/manual options for system operation and the methods available for addressing the various human factors needs. Thus, in general, all relevant issues involving the man/machine interface for vehicle and system control should be considered while addressing research in this subject area. The man/machine interface must also be studied to determine what issues exist for varying levels of automation. Additionally, a determination should be made as to what circumstances unmanned operation would be practicable.

In addition, the output from this research should be sufficient to determine the necessary selection and

training processes and employee knowledge, skills, and ability levels compatible with the safety-related goals and objectives of any high-speed rail or maglev system.

Related Work

Current HSR and maglev systems utilize different operator control concepts. The advent of new signal and train control systems now in development for U.S. application and the potential implementation of some form of existing HSR or maglev system in the U.S. may require consideration of modifying the currently accepted methods of train operation in the U.S. Thus the implications of operation under these new systems must be addressed if safety is to be maintained at its current levels or enhanced to higher levels. The Volpe National Transportation Systems Center is undertaking work in this area.

In addition, the U.S. freight railroad industry is conducting research on information requirements for displays in locomotive cabs.

Research on the issue of cockpit automation is underway in the aerospace sector (FAA, NASA, industry), including work loads, stress levels, display designs, complacency dangers, appropriate simulation training, and related factors.

Also one example of the vehicle operator's and central control operator's environment currently under investigation is the U.S. Department of Energy's work on elements related to electromagnetic fields and their potential physiological effects as well as reaction times and attention spans.

PROBLEM #218: HIGH SPEED RAIL AND MAGLEV COMPUTER/SOFTWARE SAFETY

New systems for high-speed guided ground transportation (HSGGT) rely extensively on computers for operational control and/or monitoring of safety-related subsystems. Applicable standards do not currently exist in the United States for assessing the safety and reliability of these systems. There are no domestic standards against which the determination of acceptable levels of risk for safe HSGGT system operation by computer software and hardware may be made.

Objectives

Research to develop and evaluate techniques for assessing the safety of computer software and hardware.

System safety standards and evaluation techniques need to be established to evaluate the adequacy of proposed system designs, to determine and document the validity of vital equipment and software (including microprocessors), and to test design safety features through qualification and reliability testing. Resulting standards should cover hardware and software validation techniques, documentation, quality assurance and test protocol.

Related Work

The Advanced Train Control Systems (ATCS) project has standards for software quality assurance. However, in spite of much effort there are no set standards for software error rates. An appropriate reference is ATCS Specification 140 "Recommended Practices for Safety and Systems Assurance," draft version No. 2, December 1990.

A somewhat relevant, small review project is presently being conducted at the Volpe National Transportation Systems Center (VNTSC) to identify existing electrical and mechanical standards, regulations, and guidelines applicable to HSGGT. Although computer software and hardware are not being addressed explicitly, the review of relevant electrical and mechanical codes has a peripheral bearing. VNTSC has a narrowly defined task to conduct a safety analysis of a specific electronic interlocking design underway. The objective is a comparison of the role of the microprocessor, safety verification, and the driving software with traditional FRA inspection and maintenance requirements.

Relevant National Maglev Initiative work includes a Broad Agency Announcement (BAA) contract titled "Verification Methodology for Fault Tolerant, Fail-Safe Computers Applied to Maglev Control Systems".

Urgency

Urgent priority.

PROBLEM #219: HIGH SPEED RAIL AND MAGLEV WAYSIDE ELECTRIC POWER SUPPLY STANDARDS

The current activity in the field of high-speed rail (HSR) and maglev in the United States centers around the feasibility and preliminary design studies for several intercity corridors. For HSR, the next step may involve

facility design and the selection of a railroad system and equipment for a specific corridor. For maglev, feasibility studies and a demonstration are currently planned. Technical information for the electric traction system safety standards, design codes, and practices reside principally with HSR and maglev suppliers in Europe and Japan. There is a need to assess the applicability of these safety standards and practices to U.S. operations. Both HSR and maglev systems will be electrified, therefore, there is also a need to ensure safe compatibility with the electric traction power supply and telecommunications industries.

Objectives

The objective of this proposed research is to develop information from foreign technologies that can be useful to regulatory agencies for the development of standards to govern the safety and compatibility of HSR and maglev systems designed for operation in the U.S. environment.

Related Work

The FRA has established a maglev-HSR task force that has been collecting data on candidate foreign technologies, but little data on electric wayside power has been collected. The Volpe National Transportation Systems Center contracted for a comparison of U.S. standards (industry and government) and those specified in the German report Safety Requirements High Speed Maglev Trains, RWMSB.

Urgency

High priority

Many technical and operational issues in the preliminary and final design of maglev and HSR systems will require the application of appropriate safety standards. To the extent possible, the standards, codes, and practices to which these systems have been designed for operation in Europe and Japan should be adapted to the U.S. conditions. Should different regulations establishing U.S. standards be developed after designs have been completed, the modification expenditures needed to comply with these regulations would be large.

PROBLEM #220: HIGH SPEED RAIL AND MAGLEV MAGNETIC AND ELECTRIC FIELD EFFECTS

Epidemiology as well as laboratory experimentation on cells, animals and people indicate that there are biological effects in the extremely low frequency (ELF) fields (3 to 3,000 Hz) which may have health implications. Current concern focuses on abnormal cell growth, reproductive issues, and neurophysiology. Elevated risks of diseases such as leukemia, brain tumors, and male breast cancer have been identified in electrical workers.

The most urgent issue at present is the identification of an appropriate set of parameters for electric and magnetic fields (frequency and intensity range, intermittency, orientation mechanism of earth's magnetic fields, biological interaction, etc.).

Objectives

- Become fully apprised of state-of-the-science research to modify and support replication of key experiments with maglev technology in mind (Pacemaker and prosthetic-implant effects constitute a separate but important issue.);

- Differential epidemiological studies should be performed on transit, railroad, and other transportation workers for comparison with others who perform work in electromagnetic environments;

- Undertake a full characterization of the electric and magnetic fields environment of HSR and maglev concepts (in time and space) including spectral analysis, under standard operations and special conditions (start-up, emergency braking, idling, etc.);

- Establish a comparative data base defining the actual exposure regime. As a complement, perform personal exposure dosimetry to gain an understanding of worker and passenger exposure; and

- Establish the risk factor attributable to electromagnetic fields (EMF) based on the epidemiology of occupational groups in the transportation field.

Related Work

Extensive work has been in progress for some time by the U.S. Department of Energy and EPRI as well as programs abroad (notably in Sweden, Italy, and Japan). FRA has reimbursable agreements with the EPA and DOE/ANL research support, and is part of an interagency and international R&D coordination effort.

Some 50 occupational studies (by NIOSH, NIH, and foreign institutions) on the effects of electric and magnetic fields are currently under way.

FRA initiated an EMF survey in 1990. Measurements on TR07 maglev and the Northeast Corridor Amtrak technologies have been completed. Electrified light rail systems representative of urban mass transit and commuter rail, as well as foreign HSR technologies proposed for U.S. applications will be surveyed in 1992. Extensive exposure assessments are carried out by EPRI, DOE, EPA, Electricité de France, etc. on utility workers.

Urgency

High priority to initiate activities. As it may take many years to obtain conclusive results in this area, there should be no restriction on the implementation of HSGGT systems with electric and magnetic field environments of equal or lower intensity than those currently operating in the United States.

PROBLEM #221: HIGH SPEED RAIL AND MAGLEV EMF MITIGATION AND SHIELDING

Passenger compartments require shielding from excessive magnetic fields, excessive gradients, and rapid transients which may have adverse health effects.

Objectives

Develop economically realistic magnetic field reduction options and establish a sensitivity analysis for relevant design parameters.

Related Work

There is little work in progress in this area, but the basic problem is fairly simple. Detailed designs will be required only when detailed propulsion and levitation mechanisms are being developed.

Under the National Maglev Initiative a Broad Agency Announcement (BAA) contract titled "Novel Cryogen-Free, Actively Shielded Super-conducting Magnets for Maglev Vehicles" is underway.

Urgency

Medium priority. This topic should be considered in propulsion and levitation design work also.

PROBLEM #222: TRACK GEOMETRY, INSPECTION, AND MAINTENANCE PRACTICES: HIGH SPEED RAIL IN THE UNITED STATES

Existing federal track safety standards are not suitable for application to high-speed rail (HSR) systems in the United States for several reasons:

- Existing standards were intended as a compromise approach to accommodate the very broad unit heterogeneity of the freight and passenger car fleet in the U.S. This is evident in terms of vehicle design/performance characteristics and the widely varying states of vehicle maintenance.

- For the most part, current track safety standards are empirical, having been based on "best practice" concepts, developed by the independent railroad companies over the years, for application to train operations seldom exceeding 45 m/s (100 mph). There is little rational analysis supporting these standards, which rules out any attempt to extrapolate contemporary experience to the high-speed train operating regime.

- HSR geometry standards for operations to 89.4 m/s (200 mph) abroad are also empirical with each railway having its own version of a standard. The differences between the various foreign railway standards may be attributed to measurement methods.

There is a distinct division of opinion in the U.S. rail research community as to whether it is technically feasible to proceed at once with the development of generic high-speed track safety standards that would be universally applicable to all possible candidate systems. There is a substantial belief that there first must be accumulated a body of knowledge based on site-specific experiences built up over some years of operating foreign-origin systems in the U.S. for the purpose of providing guidelines for the creation of the generic version. If this is a valid assumption, the production of versatile, generic domestic HSR track safety standards may not be likely for many years.

Objectives

Develop recommended safety standards for construction, inspection, and maintenance of HSR track. Performance

standards are desired. In the event that pure performance standards may not be achievable, a given performance standard may have to be expressed parametrically in terms of design constituents. Examples of various design parameters are modulus, lateral resistance, spacing, spiral design, fastener holding force, etc., for given lateral and vertical wheel forces on the rail.

Related Work

FRA has scheduled two concurrent activities that concern track safety standards; revision of Title 49 Code of Federal Regulations Part 213, more familiarly known as the FRA track standards, which are in effect on the national railroad plant today, and development of a matrix of standards (including track), referred to as "Rules of Particular Applicability". The latter concerns site-specific high-speed guided ground vehicle operations in the U.S. which, currently, are based on foreign technology.

Performance standards, particularly concerning track geometry and mainly reflecting foreign practice, are being evolved in the second activity. Additionally, design-type standards will be part of the track sub-matrix, e.g., concerning the lateral stability of CWR track exposed to the extremes of climate and the conduct of certain track maintenance operations that can de-stabilize track temporarily. Track inspection frequencies will be specified according to the component failure experience noted abroad. Instrumentation calibration procedures will be described.

In addition, the Volpe National Transportation Systems Center has work planned for a CWR Track Stability and HSR study by the end of this fiscal year. A more extensive track shift and HSR project is planned for early FY 1993.

AAR has designed, constructed, and successfully tested a Track Loading Vehicle, which provides unique track measurement capabilities such as the tie/fastener and track panel shift resistances for given lateral and vertical wheel/rails. The TLV has already surveyed over 3,000 miles of mainline track to develop a statistical distribution of the gage widening strength of North American Revenue track. Other test capabilities include measurement of rail longitudinal forces on CWR track, dynamic response characteristics of bridges, track modulus, and simulation of flange climb derailments.

Experimental and analytical work are being conducted, in conjunction with track geometry cars, to develop techniques to relate track geometry to car-body loads for the establishment

of performance based track geometry standards. The AAR has developed an instrumented test vehicle which is currently being operated on high speed revenue trackage to locate those track irregularities which cause high car-body loads.

The research work outlined above can be applied to high speed rail environment with relatively minor modifications.

Urgency

High priority.

PROBLEM #223: HIGH SPEED RAIL HIGHWAY CROSSINGS AT GRADE

As HSR is developed in existing rail corridors, grade crossing warning devices in use in the U.S. today providing adequate protection for low speed operations will not be adequate for higher speed trains. HSR operations will considerably increase the danger and risk to both rail and highway users at grade crossings. Closing the crossroads or providing grade-separations are two possible solutions, although the first could generate local opposition while the second may be prohibitively expensive. Research is needed to identify potential grade crossing protection devices that would permit higher operating speeds and to determine the safe threshold speed for high-speed rail operations.

Objectives

Determine the safe threshold speed for HSR operations above which grade crossings should either be closed or separated. Consideration should be given to both the speed and frequency of operations and whether slower

speed freight and local passenger trains will operate on the same track.

Determine the most effective mix of grade crossing protection devices (4-quadrants, active advanced warning signs, traffic signals, etc.) for HSR grade crossing. What measures could be taken to provide adequate protection while maintaining safe high-speed operations?

Investigate grade crossing protection devices used in other countries (i.e., Sweden, Germany, etc.) for HSR operation. Evaluate and compare these devices with existing systems.

Related Work

Demonstration projects for 4-quadrants and various active advanced warning signs are proposed by FRA's Office of Research and Development. FRA is initiating a contract for problem definition of HSGGT system at-grade crossing safety. This work is to include a problem statement, analysis of existing standards, assessment of new technology for enhancing grade crossing safety, and analysis work conducted to date on related projects.

The Volpe National Transportation Systems Center is developing a grade crossing safety program for high-speed rail. It will draw upon the well established grade crossing safety research currently underway for current U.S. railroad operations.

Urgency

High priority.

New devices require considerable lead time for development and approval. This work must be completed by the time HSR operations begin. Failure to develop adequate safety protection will prohibit increased train speed and frequencies in existing corridors.

A2M06 COMMITTEE ON RAILWAY MAINTENANCE

PROBLEM #224: IDENTIFYING AND MODIFYING THE INFLUENCE OF SUBGRADE ON TRACK MAINTENANCE REQUIREMENTS

Subgrade is the platform on which the track superstructure, ballast and sub-ballast are placed. Subgrade stability is thus expected to have a significant influence on ability to maintain track geometry. There are also indications that the stiffness of the subgrade affects the life of the track components such as rails, ties, and ballast. Thus the required amount of track maintenance and the associated costs are expected to be related to subgrade conditions. However, this relationship has not been adequately established, nor has the effectiveness of means to alter the subgrade effects been adequately determined. These means include modifying the subgrade or modifying other track components.

Objectives

Establish the relationship between subgrade conditions and track maintenance requirements. Determine feasible means to alter the adverse effects of subgrade to reduce maintenance costs.

Key Words

Subgrade stability, subgrade stiffness, maintenance costs, track geometry.

Related Work

Valuable information on this topic is being obtained on the FAST track at the Transportation Test Center in Pueblo, Colorado. However, little related work has been done on revenue track.

Urgency

This topic has received little attention in the past, but it could have a big effect on track maintenance costs. Increasing pressure on maintenance budgets makes it a high priority topic to investigate.

Cost

\$1,000,000 to \$5,000,000 minimum

User Community

FRA, AAR, individual railroads

Implementation

Reports, papers, workshops, presentations, AREA manual.

Effectiveness

Improve economy and safety of railway operation.

PROBLEM #225: DEVELOPMENT OF PREDICTIVE TRACK MAINTENANCE MODELS WHICH UTILIZE FIELD DATA

A shrinking work force in many engineering departments coupled with limited budgets for maintenance and rehabilitation (capital improvement) M&R projects necessitates the need for effective planning models. A key management objective is to determine when, where, how much, and how best should M&R be accomplished. However, models do not exist that are sensitive to such variables as operating speed, annual tonnage, axle load repetitions, and climatic conditions. The models should utilize information that is routinely collected such as geometry car, rail flaw, and inspection report data.

Although these models could be developed by individual railroads, a significant investment would have to be made. Many railroads cannot afford this investment and those that could may not be willing to share their findings. Accordingly, little work has been accomplished to date. Thus, a joint or pooled industry effort is needed.

Objectives

The objective of the research is to develop a family of predictive M&R planning models. The models would be used to determine M&R needs in future years based on

differing strategies and scenarios. Accordingly, they would be sensitive to key variables such as annual tonnage, expected axle loads, desired FRA class, etc. Different models should be developed for component groups such as ties, turnouts, ballast and subgrade, etc. as well as interactive composite models that integrate the component group models.

Key Words

Predictive models, track maintenance, maintenance planning, maintenance management, track management.

Related Work

General models exist to help plan tie renewal and rail replacement projects. Also, some railroads, organizations, and consultants/vendors have developed models for predicting component life and/or various economic models for planning M&R. However, applicability is limited based on the assumptions and data used in the development. Most recent effort have been directed towards heavy haul traffic, but low volume lines have been virtually ignored. Much work still remains.

Urgency

This suggested work has high relevance within the railroad industry. The development and implementation of these models could reduce track safety problems which has high relevance for train operating personnel, passengers, freight owners, and the general public. Also, these models would help to ensure that limited M&R resources are allocated effectively. This is essential to the economic well being of private railroad companies and public owned track networks. Within the Track Maintenance Committee, this suggested work is within the top three recommended priorities.

Cost

\$1,500,000

User Community

The user community includes all public and privately owned railroads, including military and industrial track

networks as well as such organizations as the FRA, AAR, and ASLRA.

Implementation

The models should be made available to all railroads for use on an optional basis. Distribution could be made through the FRA, AAR, ASLRA and military. Training courses on use could be sponsored regionally through those same organizations. The trainers could be consultants, model developers, or sponsoring organization personnel. Introduction and training on model use could also be offered through existing short courses on track maintenance and be included within university offered railroad engineering curriculum.

Effectiveness

The societal impact are twofold; economic viability of the railroad industry and safety for railroad personnel and the general public (train passengers and those living and working near railroads).

Millions of dollars are spent in the railroad industry annually on track M&R. If models were available to do long range M&R planning, those dollars could be allocated much more effectively than at present. Overall track maintenance management would become much more proactive and less reactive. The wise and efficient spending of limited M&R resources is essential to the economic well being of the railroad industry.

A large percentage of derailments are due to bad track. In many instances derailments result in safety hazards to train crews and the general public. Through M&R predictive models, the economies of a proactive M&R program can translate to better track condition for given expenditures. Better track condition will directly reduce derailments.

PROBLEM #226: MECHANISMS OF BALLAST DETERIORATION AND METHODS OF PREDICTING BALLAST LIFE

Recent research has shown that ballast breakdown is a major cause of ballast fouling leading to deterioration of track performance. However the mechanisms of ballast degradation are not understood. Repeated load, impact and vibration forces from traffic and environmental induced forces cause breakage and abrasion. However the linkage between the character of the forces and the resulting amount and nature of degradation has not been

established. Fatigue of the rock particles may be a factor but this has not been investigated. How the fouling process develops beginning with clean ballast until it is at the end of its life has not been established. For these reasons means to predict the relative life of ballast in track are very limited. As a result an accurate economic assessment of ballast alternatives is not possible.

Objectives

Determine the mechanisms of ballast breakdown in track in relation to the various causes and the ballast particle properties. Establish tests for reliably measuring ballast life.

Key Words

Traffic loads, impact, vibration, fatigue, breakage, abrasion.

Related Work

Field studies have been conducted to define the sources and causes of ballast fouling. Attempts have been made to simulate in laboratory tests on ballast some of the loading conditions in the field. Petrographic studies have been performed to assess the connection between rock properties and performance in index tests. Field tests to measure the rate of ballast breakdown with traffic are in progress. However, a lot more work is needed to achieve accurate prediction of ballast life.

Urgency

The costs of ballast and related maintenance are substantial and reoccurring. Thus there is a considerable economic benefit to be gained from an improved ability to predict ballast life. The potential cost savings make this a high priority item.

Cost

\$2,000,000 to \$5,000,000 minimum

User Community

FRA, AAR, individual railroads

Implementation

Reports, papers, workshops, presentations, AREA manual.

Effectiveness

Improve economy of railway operations.

PROBLEM #227: DETERMINE WHEN TO CLEAN OR REPLACE BALLAST

As ballast deteriorates through breakdown and other causes of fouling its ability to perform its functions decreases, and track maintenance costs increase. Eventually cleaning or replacing is needed. The maintenance engineer needs a means to assess the condition of ballast in track combined with guidelines for determining whether to clean or replace the ballast. This will permit better utilization of maintenance budgets by carrying out these operations at the optimum time.

Objectives

Develop procedures for field inspection of ballast to quantify condition. Establish criteria for determining whether to clean or replace ballast.

Key Words

Maintenance, ballast deterioration, ballast cleaning, ballast replacement.

Related Work

Studies have been initiated to establish ballast fouling limits based on drainage requirements. Work has yet to be done on defining limits based on ballast mechanical behavior. Preliminary tests have been made to evaluate the use of nuclear devices for monitoring the degree of ballast fouling.

Urgency

Better use of maintenance funds would result from improved procedures for determining ballast cleaning/replacing needs.

Cost

\$1,000,000 to \$4,000,000 minimum

User Community

FRA, AAR, Individual Railroads

Implementation

Reports, papers, workshops, presentations, AREA manual.

Effectiveness

Improve economy of railway operations.

**PROBLEM #228: EFFECTS OF HEAVY AXLE
LOADS ON BRIDGE MAINTENANCE AND LIFE**

The upcoming decision to increase axle loads on rail vehicles translates into higher infrastructure costs. In order to insure that the rates established for moves utilizing these cars correctly reflects these high maintenance costs, the detrimental effects must be quantified.

Objectives

Assess the detrimental effects on bridges caused by 125-ton or higher car traffic, to predict increased bridge maintenance requirements and remaining bridge life.

Key Words

Bridge fatigue, bridge type.

Related Work

The Association of American Railroads Research & Test Department performed considerable studies and testing at its Transportation Test Center in Pueblo, Co. in evaluating the economic of 125-ton cars. Results of these studies indicate that when considering transportation and maintenance costs, exclusive of bridge costs, it was

economically favorable to permit the heavier 125-ton car traffic on North American railways. According to the study, bridge costs, which may vary considerably by structure, are to be evaluated on an individual basis. The Burlington Northern Railroad, in evaluating its northern coal route, published in 1990 a study on the economics of the heavier car effects and took into account track and structure costs for the route. Also, various authors have done studies on the effect of heavier axle loads which have been presented at four International Heavy Haul Railway Conferences. Although the AAR is currently performing economic analysis of heavy-axle load traffic on generic bridge types, a more detailed analysis is required for site specific decisions.

Urgency

Due to the number of railway structures over 75 years old that are still utilized for daily mainline service, it is imperative that their remaining life and future maintenance costs in consideration of heavier loadings be predicted. Major structure replacements involve substantial capital costs which must be planned for to insure the financial welfare of the railroads.

Costs

\$500,000

User Community

- American Railway Engineering Committee 15, Steel Structures;
- American Railway Engineering Committee 8, Concrete Structures;
- American Railway Engineering Committee 7 Timber Structures;
- Association of American Railroads Research & Test Department;
- Class 1 Railroad Chief Engineers; and
- International Heavy Railway Conference.

Implementation

Being able to predict bridge maintenance costs and life in relation to structure loading would provide valuable information to railways. Life cycle bridge costs could be predicted and policies for bridge utilization and replacement could be better planned. Computer bridge

loading assessment models could provide output for various bridge configurations.

Effectiveness

The ability to evaluate increased axle load effects on bridge maintenance and life would provide railway officers with a tool to assess various operating strategies that could take into account bridge costs.

PROBLEM #229: WOOD TIE DEFECT DETECTION

The decision to replace a wood tie is based almost entirely on subjective criteria. Virtually no objective criteria are available to classify a wood tie relative to its fitness in track. Moreover, given the 3000+ ties in a mile, tie inspectors are given only several seconds to make a \$30 replacement decision. Other industries have developed inspection techniques for treated wood products. Similar techniques might be applied to wood ties thus removing the subjectivity and speeding the inspectors work.

Objectives

To develop a nondestructive practical method to detect deficient wood tie condition(s) in-track, using an automated or semi-automated method.

Key Words

Tie condition, track strength, track tonnage, tie clusters, track gage.

Related Work

There has been some activity to try to better evaluate in-track tie condition and strength. For instance, a hand held device named Panalogger, developed by Pandrol Inc., evaluated tie hardness, similar to the Brinell test used for steel. The Association of American Railroads and The Federal Railroad Administration developed two track loading vehicles, both of which implicitly evaluate tie condition by loading the rail and determining track strength. Also, Holland Company and Zeta Tech

Associates are building a device by the name of "Tie Scan." "Tie Scan" will utilize ultrasonics to evaluate individual wood tie condition when passing over the track. This device will soon be tested on the Burlington Northern Railroad.

Urgency

Research has been needed in this area for some time, to better evaluate wood tie condition in scheduling replacements. There are substantial economies to be realized by railroads if an accurate automated means is developed.

Cost

\$150,000

User Community

- American Railway Engineering Association Committee 2, Track Measuring Systems;
- American Railway Engineering Association Committee 3, Ties and Wood Preservation;
- Railway Tie Association;
- Association of American Railroads Track Maintenance Research Committee;
- Class 1 Railroad Chief Engineers;
- American Wood Preservers Association; and
- American Public Transit Association (APTA).

Implementation

A possible system envisioned would involve automated measurement of track strength with the capability to assess an individual tie's condition. Such a system would take into account effects of tie cluster strength, individual tie condition, track tonnage and tie replacement renewal in pinpointing which individual ties should be replaced.

Effectiveness

Impacts of this research would be substantial savings to the railroads in performing and accurately identifying tie replacements. Inherent characteristics would be better maintenance planning and track reliability.