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Research Problem Statements

Design and Construction of Transportation Facilities

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RESEARCH PROBLEM STATEMENTS

DESIGN AND CONSTRUCTION OF TRANSPORTATION FACILITIES

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GENERAL NOTE

This circular supersedes Circular 272, February 1984. Additional statements emanating from Group 2 Committees are contained in Circulars 327 and 328, February 1988, and 340, November 1988.

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

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3 rail transportation

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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, periodically technical committees 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 231 problem statements in this circular represent a composite of efforts by 38 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

Each contributing committee, except the committees in the Railway Systems Section, has given a priority rating for its 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," "Relevancy" and "Implementability" 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 evaluation or priorities.*

Research Problem Statements

Section Designation	General Subject	Number of Problem Statments
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Research Problem Statements

A2A01 Committee on Photogrammetry, Remote Sensing, Surveying, and Related Automated Systems

PROBLEM 1: Develop the Use of Digital Cameras (CCD) and Digital Files in Analytical Photogrammetry

Photogrammetry has become a digital-automated process; however, the original taking imagery must be digitized before being used in the analytical process. Software and an evaluation of accuracy are needed.

The military, especially, has developed digital (CCD) cameras for use in remote sensing to a satisfactory degree of utility for accurate surface mapping.

Objectives

a. Perform literature search.
b. Select a CCD camera from those commercially available.
c. Develop software for direct use of digital files in an analytical instrument in a robotic environment.
d. Adapt a present technology for presentation of digital files in black and white or color imagery (graphic display).
e. Evaluate the accuracy and resolution probable using this procedure.
f. Report findings.

Current Activities

a. Unknown (predominantly military and space).
b. Key words for literature search:

1. CCD cameras
2. Digital cameras
3. Digital Image Processing
4. Electro Optical Imaging Systems

Urgency

The use of large digital files based on geographic positioning is currently of priority interest. Affordable computers are available to make processing possible. Applications in transportation engineering are extensive.

PROBLEM 2: Pavement Condition Inventory and Management by GIS, GPS, and Remote Sensing-Photogrammetric Techniques

A key to pavement management systems is the determination of pavement condition and the development of a systematic inventory technique. Such a system is prime to developing and setting priorities, and establishing budgets for performing pavement management processes. In many cases, this information is collected by manual techniques which are man power intensive, time consuming, and expensive. Additionally, the necessity of repetitive measurement of highway segments to determine changes in pavement condition requires a good base geographic reference system.

Objectives

a. Support pavement conditions systems by the use of new improved image motion compensation cameras and other imaging systems and data media.
b. Develop the base map by the use of GPS and GIS technology to provide a positional and base map for recording data.
C.Use automated computer based data systems to analyze and present pavement conditions and place information into a pavement management inventory system.
d. Key Words: Pavement inventory, pavement evaluation remote sensing, photogrammetry, GIS, GPS.

Related Work

Some testing was done many years ago on aerial remote sensing techniques to locate voids under pavement. No current work on combining newer remote sensing-photogrammetry, GIS and GPS techniques to provide a pavement analysis and inventory system for management use has been done.

Urgency

The need for the development of pavement management system by all states makes research in this area urgent.

Cost: $450,000

Effectiveness

Good pavement management practices allow the most expeditious use of funds to provide the best highway system possible within funding constraints. Pavement evaluation and inventory techniques are essential for such pavement management systems.

PROBLEM 3: Hazardous Waste Area Location and Area Determination by Use of Remote Sensing Techniques as Applied to Transportation Systems Corridors

Identification of hazardous waste areas in existing or proposed transportation system corridors may involve various types of hazardous waste disposal areas that often cannot be foreseen by simple ground observations. It is important to discover these areas prior to final corridor selection or to implementation of construction activity in existing corridors.

These waste areas may be extensive or of very limited point source. To discover these sites after construction has started is very disruptive and usually involves costs that are unplanned and that can be more costly than if the sites had been discovered prior to any activity.

Objectives

Using Remote Sensing technology develop a methodology that allows discovery of hazardous waste area sites.

a. Review existing remote sensing techniques to determine effectiveness of detecting changes that indicate possible sites.

b. Develop the best mix of remote sensing methods that apply to the detection of various types of waste area, terrain and vegetative cover. These mixes may involve most modern techniques and historical photography as an example.

c. Demonstrate the developed technologies under field conditions.

d. Provide training manuals and texts for application of those selected methods.

Current Activities

a. Key Words:

1. Remote sensing
2. Image processing
3. Historical aerial photography
4. Electro-optical imaging systems
5. Aerial photography
6. Multispectral sensing

Urgency

Transportation development organizations are constantly faced with surprise hazard waste areas during construction in new ways or reconstruction of existing facilities. These result in increased cost and difficult clean up activity. These costs could have been reduced or eliminated had the waste sites been determined in advance. The need for this research is urgent if we are to reduce these remedial costs.

Cost

Research on this subject is relatively high, but when compared to the cost of an unforeseen waste site it is equal to the cost of a small cleanup.

a. Literature search	$30,000
b. System investigation	80,000
c. Application testing	130,000
d. Technology transfer	45,000
Total cost	$285,000

PROBLEM 4: Requirements for Accurate Development of Digital Terrain Models (DTM) for Earthwork Estimates and Pay Quantities by Photogrammetric Methods

The use of DTM's is becoming more and more widespread by consultants and DOT's. Whereas standard and specifications for flying heights, field control procedures, cross-section spacing, and data collection procedures exist for cross-section data collection, standards and specifications do not exist for DTM's. Quite often DTM's are constructed and cross sections are extracted from the DTM without any real knowledge of the accuracy of the cross section.

Standards and specifications for the entire DTM development process need to be developed to insure the integrity of this process.

Objectives

a. Research DTM software packages to determine strengths and weaknesses of the various programs.

b. Review procedures used by states and consultants in the DTM development process.

c. Review mathematical relationship of DTM.

d. Determine procedures, standards, and specifications for DTM development for earthwork estimates and pay quantities by photogrammetric methods.

Current Activities

a. Key words:

1. Digital Terrain Models
2. Photogrammetry
3. Progressive Sampling

Urgency

The use of DTM's is rapidly spreading. It is critical that our knowledge keep up with this pace.

Committee

This statement was prepared by:

Gerald Dildine, NCDOT
Committee A2A01, Photogrammetry and Aerial Surveys
Tom Carlsen, WisDOT, Chairman

PROBLEM 5: Use of Airborne Remote Sensing Technology and Geographic Information Systems (GIS) for Highway Planning Applications

The graphical component of the preliminary and final design process has continually become more digitally automated through the use of Computer-Aided-Drafting (CAD) systems interactive graphics roadway design software, and other automated systems, while functional design, on the other hand, has remained a very manual process. The functional design process has usually involved the collection and analysis of environmental, economic, and other highway related data to evaluate various roadway alternatives. The graphical component to this process usually involves the use of aerial photography to construct mosaics and colored tape to depict the design alternatives. This graphical presentation is used for public hearings, environmental assessments, environment impact statements, finding of no significant impact statements, and for many other planning activities throughout the preconstruction process.

Recently remote sensing equipment previously utilized in satellites has been placed in aircraft and used to collect lower altitude digital imagery. This imagery or scanned aerial photography can be digitally mosaicked together in an image processing system. Geographic Information Systems can be used to control the digital mosaicking process and supply additional information for the functional design process. These combined technologies can potentially be used for planning activities throughout the preconstruction process.

Objectives

a. Review remote sensing technologies for transportation uses.
b. Review image processing technology for transportation uses.
c. Demonstrate the integration of GIS and remote sensing technologies to accomplish automating the functional design process.
d. Report on the needs to make these technologies more functional for transportation planning.

Current Activities

a. Key Words:

1. Geographic Information Systems (GIS)
2. Remote Sensing
3. Image Processing
4. Electro-Optical Imaging Systems
5. Multispectral Sensing Devices

Urgency

The use of GIS technology for transportation is currently being implemented in many states. The timing is appropriate to do this kind of research now.

Committee

This statement was prepared by:
Gerald Dildine, NCDOT
Sky Chamard, Skyjettes Consultants
Committee A2A01, Photogrammetry and Aerial Surveys
Tom Carlsen, WisDOT Chairman

PROBLEM 6: Operational and Safety Effects of Reduced Lane and Shoulder Widths on Urban Freeways

Transportation agencies are faced with problems such s increased travel demand, construction costs, and safety and environmental concerns. At the same time, available funds for highway improvement are not keeping up with the need. Several states have increased the number of through lanes on urban freeways by reducing lane widths and reducing or eliminating shoulders.

The desirable design standards for freeway cross sections are lane widths of 12 feet and shoulder widths of 8 to 10 feet on both sides of the roadway. Reducing lane and shoulder widths on urban freeways may result in operational problems such as adjacent lane encroachments, problems in critical ramp merging areas, reduced emergency parking areas, and reduced rideability of the pavement surface.

Objectives

The research objectives of this study would be to determine the operational and safety impacts of reduced lane and shoulder widths on urban freeways, and, if appropriate, to develop guidelines for the implementation of reduced lane and shoulder widths on urban freeways.

a. Key words for this study include the following: freeways, lane widths, shoulder widths, freeway operations, and freeway safety.

Current Activities

One related work is "Freeway Modifications to Increase Traffic Flow," Technology Sharing Report, FHWA-TS-80-203, Federal Highway Administration, January 1980.

The federal Highway Administration has a proposed contract for fiscal year 1986 titled "Safety of Wider Trucks on Narrow Roadways." The operation of trucks 96 inches and 102 inches in width will be studied to determine the effect of truck width on overall highway operations and safety.

Urgency

Increasing the capacity of urban freeways without major reconstruction could be very cost-effective. This proposed study should have a high priority.

Cost: The estimated cost of this study is $250,000.

User Community

The research results would be useful to highway design engineers in evaluating alternatives for urban freeway improvements.

Implementation

The research results could be included in courses dealing with highway design and traffic operations, packaged as a design guide and distributed through articles in professional publications.

Effectiveness

The research reports could make possible improved urban freeway operations at a nominal cost. The anticipated benefits include: reduction in travel time, air pollution, fuel consumption, and construction costs without compromising safety.

PROBLEM 7: Evaluation of Substandard Stopping Sight Distances on Existing Highways

Stopping sight distance (SSD) is a fundamental element of highway safety. Today, most highway designs are for 3R/4R-type projects. To properly address available SSD on existing highway, three elements must be available:

a. A theoretical SSD model
b. an analytical tool to determine the available SSD, and
c. a technique to evaluate the adequacy of available SSD.

AASHTO presents its theoretical model in the 1984 "Green Book." NCHRP 270, *Parameters Affecting Stopping Sight Distance*, presents a theoretical model which has monumental differences from the AASHTO model. It will likely be several years before these differences are resolved. NCHRP 270 also presents excellent analytical tools to determine the available SSD at crest vertical curves (sight distance graphs) and horizontal curves (middle ordinate graphs). What is lacking, however, is a technique to evaluate the adequacy of the available SSD. If such a technique were developed, it

could be used to decide whether or not geometric improvements are warranted.

Objectives

The first objective would be to determine the magnitude of the problem for various functional classes of highway. A field investigation on a random sample of highway segments might be used to estimate the extent of substandard SSD's on existing highways. The second objective would be to develop an evaluation technique which would incorporate some or all of the following elements:

a. Time Duration-The time for which a driver does not have desirable and/or minimum SSD is obviously related to safety. The greater the time duration, the greater the safety deficiency and the greater the potential benefits from a construction improvement.

b. Extent of Deficiency-Also directly related to safety is the amount by which the existing crest vertical curve or horizontal curve fails to meet the required SSD.

c. Variance of SSD Model Elements-The analytical tools in NCHRP 270 allow the designer to vary the SSD model elements (driver eye height, object height, speed, friction factors, and controlled or locked-wheel stop). The designer is then able to determine for what set of assumptions the existing SSD is sufficient. There is, however, currently no evaluation technique which addresses the sensitivity of each model element to safety. For example, the object height of 4 inches (NCHRP 270) or 6 inches (AASHTO) is perhaps much less important to safety than the available tangential friction.

d. Accident Reduction-Ideally, an accident reduction factor would be available to determine the safety benefits of improving SSD. Given the great number of factors in the SSD model, however, it may be impossible to set up a controlled study which would yield results with a universal application. At a minimum, however, the evaluation technique would discuss how to evaluate the accident history in order to judge when the safety problem is severe enough to warrant correcting substandard SSD.

e.Traffic Control Devices-The evaluation technique will often lead to the conclusion that it is not warranted to correct the substandard SSD. In these cases, a standard warning sign is needed to warn the motorists of the hazard. As of today, the FHWA is proposing to eliminate the existing "Limited Sight Distance " sign (W14-4) from the MUTCD. An effective replacement sign is needed.

f. Key Words-Key words for this study include the following: stopping sight distance, driver eye height, object height, tangential fiction, controlled stop, locked-wheel stop, and braking distance.

Current Activities

Related work includes the following:

a. *A policy on Geometric Design of Highways and Streets*, AASHTO, 1984

b. NCHRP 270, *Parameters Affecting Stopping Sight Distance*, TRB, June, 1984. NCHRP 270 contains 75 references directly related to SSD.

Urgency

This research could provide valuable information to the design engineer for a rational evaluation of substandard SSD's. Considering the large number of existing substandard SSD's, the significant costs of improving crest vertical curves and horizontal curves, and the potential tort liability problems, this research should have a high priority.

Cost: The estimated cost of this study is $100,000.

User Community

The research results would be useful to highway agencies at the federal, state, and local levels.

Implementation

The results of this research could be distributed through articles in professional publications, through an NCHRP report, or by federal and state internal circulation procedures.

Effectiveness

Implementing this project should lead to more cost-effective, supportable decisions on when to make geometric improvements to correct substandard SSD's.

PROBLEM 8: Passing Behavior on Two-Lane Rural Highways

Passing sight distance is a major input in two-lane rural highway design. Although there have been some limited scope studies which investigated passing under certain

assumptions or conditions, a comprehensive and extensive passing study has not been conducted in the U.S. for four decades. A two-lane highway without adequate passing sight distance may experience deterioration in its safety level and reduction of capacity. Therefore, an investigation to determine if the current passing sight distances are still adequate is both necessary and timely.

Objectives

The purpose of the proposed study is to investigate the distance and time elements involved in the passing process. These include the travel time and distance while the overtaking vehicle is in the left (opposing) lane, safety margin at the end of the process, gap acceptance behavior of passing vehicles, and the exact location of the point of "no return."

a. Key Words-The key words for this study include the following: passing, two-lane highway, speed, distance, gap-acceptance, and safety.

Related Work

A few previous prominent studies have been done on this subject. These include U.S. studies by Holmes (1939), Norman (1940), Prisk (1941), and Lieberman (1982); Australian studies by Miller and Pretty (1968) and Troutback (1981); and an English study by Crawford (1963).

Urgency

In order to get better use-in terms of safety and capacity of existing two-lane highway facilities, the information sought in this study is needed as first priority.

Cost: The estimated cost of this study is $250,000.

User Community

The research results could be useful to state highway departments, AASHTO, D.O.T., safety research institutes, and design agencies.

Implementation

The research results could be used in the design of new two-lane highways, in evaluation of capacity problems of existing facilities, in examination of sign and marking procedures, and in-depth investigation of existing problem sections.

PROBLEM 9: Geometric Design for the Impaired Driver

A great deal of attention has been focused on driver education and enforcement approaches to dealing with the safety problems caused by drivers who have been drinking or are otherwise impaired. These approaches, however, have been basically unsuccessful in restraining drinkers from driving. Impairments may involve not only alcohol, but also drugs, poor vision, or fatigue. Because the problem is so widespread, it is apparent that engineers must consider the impaired driver when designing or upgrading roadway facilities. There is, however, a dearth of objective information on the relationship between impairment and driver ability to deal with the highway environment. Knowledge of the relationship between impaired driver performance and geometric design is especially limited. The information that is available shows a direct relationship between impaired driver accidents and road alignment. As a first step to providing highway engineers with guidance in this regard, there is a need to synthesize what is known about the impaired driver (from the human factors standpoint) with current geometric design considerations.

Objectives

The proposed study would involve identifying existing and needed research which examine the effects of geometric design on impaired drivers and identifying geometric characteristics that are compatible with the impaired driver. Specific objectives are as follows:

a. To conduct a thorough review of the geometric design and human factors literature to gather information on performance of impaired drives and the relationship to geometric design.

b. To prepare a synthesis of current knowledge relative to impaired drivers and geometric design (including preliminary guidelines for the impaired driver.

c. To identify specific areas where additional research is needed to address unanswered questions.

d. To develop specific research plans for the identified areas.

e. Key Words-The key words for this study include the following: accident countermeasures, accident, design standards, driver behavior, geometric design, human factors, impairments, and incompatibilities.

Related Work

Related work includes the following:

a. Johnston, I.R., "The Role of Alcohol in Road Crashes," *Ergonomics*, Vol. 25, No. 10, 1982, pp. 941-946.
b. McKeen, F.P., "The Human Factor in Driving Accidents: An Overview of Approaches and Problems," *Ergonomics*, Vol. 25, No. 10, 1982, pp. 867-877.
c. Sabey, B.E., "A Review of Drinking and Drug-Taking in Road Accidents in Great Britain," *TRRL Supplementary Report 441*, Transport and Road Research Laboratory, 1978, pp. 1-9.

Urgency

This synthesis should be compiled in the very near future to provide objective guidelines for considering the impaired driver in highway design and re-design. Upon implementation of the countermeasures, a significant reduction in accidents could be expected.

Cost: The estimated cost of this study is $150,000.

User Community

The research results would be useful to primarily state (and secondarily county and local) engineers responsible for the design, re-design, and reconstruction of highways and streets.

Implementation

The guidelines developed as a result of this research would be immediately useful to highway agencies in decision-making relative to roadway design.

Effectiveness

Research results will be useful in enhancing safety for impaired drivers traveling on highways and streets. This would have the added benefit of increasing safety for the driving public in general.

PROBLEM 10: Truck Dynamics Contribution to Rollover by Tight Curves

The design of interchange ramps in highly developed urban areas often calls for the use of tight (high degree) curves to reduce right-of-way requirements. The standard design method does not account for the changing dynamics of large trucks as they negotiate these curves, thus creating a potential hazard for overturning. Of particular importance are the high centers of gravity and shifting loads of trucks such as liquid tankers and livestock haulers. Ramps expected to accommodate large truck should be designed so as to account for the trucks' changing dynamics.

Objectives

This study has two research objectives. The first objective is to gather accident data on numerous ramp sections of this type as a means to statistically measure the relationship between truck rollover accidents and ramp curve design. The second objective is to prepare, using data gathered and analyzed, a design chart or table for use by design engineers.

a. Key Words-The key words for this study include the following: ramp superelevation and truck rollover accidents.

Related Work

Related work includes the following:

a. Ervin, R.D. et.al. "Influence of the Geometric Design of Highway Ramps on the Stability and Control of Heavy-Duty Trucks," Transportation Research Record 1052, 1986, pp. 77-89.

Urgency

The priority of this study is moderate.

Cost: The estimated cost of this study is $150,000.

User Community

The research results would be useful to AASHTO and FHWA.

Implementation

The research would lead to the refinement of the basic guidelines used by design engineers.

Effectiveness

The primary benefit of this research would be the improvement of design practices that would lead to an increase in motorist safety through accident reduction.

PROBLEM 11: Guidelines for Median Control of Two-Way Left-Turn Lanes at Signalized Intersections

Median two-way left-turn lane sections are being designed for use on roadway sections in urban areas. This situation leads to the question of whether major intersections, those that are signalized, should be further controlled by the use of a center median curb. When left uncontrolled, operational problems could develop. If a parcel at an intersection generates any traffic at all, left-turn ingress and egress from driveways within 200 feet will have a negative effect on the intersection operation.

Objectives

There would be two research objectives for this study. The first objective would be to determine if and when the center curb should be introduced in the median two-way left-turn lane section. Second, the study's findings should provide guidelines relating to vehicle volumes, number of driveways, and proximity of driveway to intersection, as to when the center curb should be introduced.

PROBLEM 12: Guidelines for Selecting Barrier Curb or Two-Way Left-Turn Lane Cross Sections on Urban Arterials

An urban section of roadway, through a commercial or industrial business area with numerous driveways, usually sustains substantial through traffic volumes. The problem the engineer must face is which type of roadway cross-section should be used.

A choice must be made between using a barrier curb to control left-turn access or a median lane with two-way left-turn capabilities to allow left-turn access. Selection of the wrong roadway section could lead to operational problems that may adversely affect the capacity of the roadway. A decrease in capacity would increase the accident potential of the roadway section. Therefore, the need exists for guidelines for design engineers when selecting the most desirable roadway cross section to use.

Objectives

There would be two research objectives for this study. The first objective would be to determine at what point the type of traffic generators, volumes, and density of driveways would determine the use of barrier curb median control over the median two-way left-turn lane. The second objective would be to prepare a chart or table to be used as a set of guidelines.

PROBLEM 13: Operational and Safety Effects of Offset Left-Turn Lanes

Many channelized intersections have been constructed providing left-turn lanes. It is becoming apparent that left-turn accidents are still occurring. Observations reveal that left-turning vehicles waiting to turn are blocking the view of the opposing left-turning vehicles. Accidents are occurring when one of the vehicles begins a turn and collides with a through vehicle that was hidden from view by the opposing left-turner.

Objectives

The objectives of this research would be to determine if there is a practical way to provide better visibility for all vehicles in the intersection by offsetting the left-turn lanes from each other.

PROBLEM 14: Geometric Accommodations for Traffic Control Devices

It is common practice to place traffic control devices in the best locations available on an already designed or constructed street or highway. This has always presented a certain number of problems. These problems are becoming more acute, however, with the increased use of flush cross-sections (e.g., center 2WLT lanes) and larger intersection corner flares required by larger trucks.

Objectives

The study objectives would be to identify problems relating to the effective placement of critical traffic control devices and to determine geometric features, improved traffic control devices, or supports that would aid in proper placement of such devices. Guidelines, standards, etc. need to be made available to assist the designer and traffic engineer in determining ways of effectively displaying critical traffic control devices. The greater use of devices such as raised pavement markers that can be placed on the pavement surface should be considered.

PROBLEM 15: Risk Assessment of Highway Geometric Design Features

The combined effects of states losing their sovereign immunity, the increasing cost of higher defect case losses, and changes in design criteria which have taken place since a highway was designed and built are forcing the states and local transportation agencies toward risk management of their highways, roads, and streets. This study will review the last five years of design defect cases to provide the states with a better understanding of the history, trends, and distribution of claims made against them. These will be reviewed according to the most prevalent defect cases, the frequency of plaintiffs' successes, and the distribution of awards.

Objectives

There are three objectives to be achieved by this research. The first objective is to improve the geometric design criteria of the features receiving the most prevalent defect claims. The second objective is to better prioritize safety improvement projects. The third objective is to prepare a more informed defense for design defect cases.

a. Key Words-The key words for this study include the following: design defects, geometric design, highway operations, highway safety, legal liability, risk assessment, risk management, and tort liability.

Related Work

There has been no work in this specific area. All previous studies of geometric design, highway operations, highway safety, legal liability, and risk management are related to this research and will provide appropriate background information.

Urgency

This research should receive the highest priority because of continuously escalating design costs.

Cost: The estimated cost of this study is $250,000.

User Community

The research results would be useful to AASHTO, FHWA, state and local transportation agencies and their legal staffs, and foreign Department/Ministries of Transportation

Implementation

The improved design criteria can be implemented at all levels of highway activity from maintenance through construction, and the results of the risk assessment can be used immediately to reprogram safety improvement projects. Also, the better understanding of the underlying issues of the design defect cases will provide the basis for better defense in design defect cases, as well as better selection of cases to contest. These improvements will, in turn, provide a higher ratio of cases where actions of the transportation agency are found appropriate to the situation.

Effectiveness

Society will benefit from this research in two ways. First, a safe and more operationally efficient highway will be maintained, thus reducing fatalities and injuries. Second, taxes will be reduced due to reduced numbers of design defect claims and reduced numbers of "lost" cases.

PROBLEM 16: Highway Sight Distance Requirements

There has been increasing concern that the needs for a safe sight distance vary by highway location according to traffic volume and speed, vehicle classification, level of development, and a combination of existing geometric and route elements. Yet, with this kind of complexity, the AASHTO sight distance requirements are based on questionable operational abstractions, employ inconsistent assumptions about driver and vehicle characteristics, and do not directly relate to the critical need for sight distance.

The need, therefore, is to critically synthesize existing information, perform functional analyses, and conduct additional research to fill existing gaps in our knowledge in order to validate existing design standards and/or make recommendations to change them so they are consistent with the functional requirements of highway operations.

Objectives

The research objectives for this study involve examining the validity of current AASHTO criteria for the following: stopping, passing, decision, and intersection and railroad grade crossing sight distances.

a. Key Words-Key words for this study include the following: sight distance, clear view, sight triangle, and stopping distances.

Related Work

There is an ongoing FHWA contract on intersection sight distance. There also are several recent NCHRP, TRB, and FHWA studies.

Urgency

This study should be of high priority.

Cost: The estimated cost of this study is $400,000.

User Community

The research results would be useful to federal, state, local, and consulting highway design engineers.

Implementation

The research results would lead to the development of more comprehensive and flexible design policy.

Effectiveness

More optimal application of sight distance principles will improve safety on highways at existing sight restricted locations.

PROBLEM 17: Driveway Intersection Sight Distance Requirements

The recently adopted *A Policy on the Geometric Design of Highways and Streets*, AASHTO, 1984, indicates that access driveways constitute intersections with the public highways and streets. It further indicates that such intersections should be designed in the same manner as the intersection of two public facilities of the same functional classification. This implies that the sight distance at all intersections along a major highway or street should be appropriate for the speed of the major route. On-street parking is presently permitted on many state highways in small urban areas. This results in restricted sight distance of private access driveways. Vegetation, advertising signs, and off-street parking immediately adjacent to the intersection are other common restrictions to sight distance. Also, the new AASHTO policy includes specific criteria for two-lane, two-way roads only.

Objectives

The main objective of this research would be to identify sight distances at driveways on a sample of the on-system highways within urbanized areas. The distribution of sight distances would be summarized by various cross-classification as city population, number of traffic lanes, parking angle, and adjacent land use. Minimum and desirable sight distance requirements would be developed for highway designs other than two-lane roadways based on the 1984 AASHTO criteria.

a. Key Words-The key words for this study include the following: intersection sight distance and driveway sight distance.

Related Work

There is an ongoing FHWA contract on intersection sight distance, as well as several recent NCHRP, TRB, and FHWA studies.

Urgency

Data should be made available for inclusion in the next AASHTO revision.

Cost: The estimated cost of this study is $220,000.

User Community

The research results could be useful at city, county, and state levels.

Implementation

The sight distance requirements for various roadway designs (number of traffic lanes and median design, etc.) would complement those contained in the 1984 AASHTO policy.

Effectiveness

This research will provide a basis for developing minimum sight distance criteria which can be uniformly and consistently applied.

PROBLEM 18: Critique of AASHTO'S Superelevation Criteria

The new AASHTO "Green Book" provides limited guidance on the advantages/disadvantages or benefits/-shortcomings of distributing "e" (superelevation) and "f"

(side friction factor) in areas of transition from highway tangents to the circular curve. Similarly, the positive and negative features of spiral transition curves, while strongly advocated in the new publication, are not well documented. Furthermore, current policy recommends reduced pavement cross-slopes in urban areas with greater dependence on side friction. Although tolerable by the passenger car, recent evidence indicates that the high center of gravity of trucks can cause them to "rollover" under low speed situations where side friction demand is high and superelevation is low.

Objectives

The main objective of this research would be to prepare a critique of AASHTO's current policy on the development of superelevation. This examination should be done in close coordination and cooperation with AASHTO. A comprehensive report would establish the state-of-the-art.

a. Key Words-Key words for this study include the following: superelevation, transition, runoff, runout, and side friction factor.

Related Work: There is no related work in this area.

Urgency

With the significant increase in reconstruction/rehabilitation efforts, a critical review is very timely.

Cost: The estimated cost of this study is between $100,000 and $300,000, depending on field/test track testing.

User Community

The research results would be useful to FHWA and state and local agencies.

Implementation

It is envisioned that this effort would be performed in a series of coordinated tasks, monitored and guided by an AASHTO Technical Advisory Committee.

Effectiveness

The project tasks should be conducted with practical implementation of the findings as a principal objective to ensure adoption by AASHTO.

PROBLEM 19: Handbook on Geometric Design Consistency

The FCP Project 1S Review Panel, at its final meeting on October 31, 1985, identified "Development of Guidelines and Procedures to Promote Design Consistency in Highway Geometric Design" as one of the eight most important areas for RD&T development. The consequences of design inconsistencies are becoming more critical as the trend toward larger trucks and smaller cars continues. If this handbook and training materials are not developed, there will be less attention given to the correction of design inconsistencies with a likely increase in both the frequency and severity of related accidents.

Objectives

A survey will be made of the various U.S. and European procedures for obtaining design consistency. A handbook will be prepared to describe these procedures with some explanation of how they are used. The handbook will also describe common design inconsistencies which sometimes cause safety and operational problems. Innovative highway design elements will be described along with criteria for their application. Various methods for analyzing costs and benefits of various alternative design improvements will be examined and recommendations made for use of the most feasible method. Also, a workshop format will be developed for one day instruction into the various consistency procedures and will be pilot-tested. The workshop materials will then be developed for use by RTAP centers.

a. Key Words-Key words for this study include the following: geometric design, design consistency, and safety.

Related Work

Related work includes the following: "Driver Perception of Risk," "Highway Geometric Design Consistency and Driver Expectancy," "AASHTO Manual Driver Expectancy Checklist-Design Review Tool," and "Driver Needs on Two-Lane Rural Highways."

Urgency

This study is identified as a high priority by the FCP Project 1S Review Panel.

Cost

The estimated cost for this study can be divided as follows: Data Collection, $30,000; Handbook Preparation, $30,000; Editing, $10,000; Training Material Preparation, $20,000; Pilot Presentations, $10,000. The total estimated cost is $100,000.

User Community

The research results could be useful to highway designers.

Implementation

Handbooks, manuals, and training courses could be used to implement the results of this study.

PROBLEM 20: Trade-Off Between Roadway Width and Foreslopes on Two-Lane Rural Highways

The Federal-Aid Highway Act of 1976 amended Section 101 of Title 23 U.S.c. to allow the states to apply federal funds to resurfacing, restoration, and rehabilitation (RR-R) projects. In response to that legislation, the FHWA has tried on several occasions (e.g., June 28, 1976; August 25, 1977; and August 23, 1978) to develop minimum design standards for RRR projects, but their proposals have drawn objections from the states for being too restrictive, and from safety advocacy groups for being too permissive.

The most appropriate combinations of lane width, shoulder width, shoulder surface type, and rate of foreslope are four design elements which are part of the RRR controversy. These four elements have been studied in part, but usually as individual elements. The conclusion of these studies were not only inconsistent, but also contradictory in many cases. A study of the effect of these four elements on highway safety is needed to determine the benefits and costs of various combinations of these elements.

Objectives

The main objective of this study would be to determine the benefits and costs of various combinations of lane widths, shoulder widths, shoulder surface types, and rate of foreslopes.

a. Key Words-The key words for this study include the following: lane width, shoulder width, side slope, foreslope, and roadside safety.

Related Work

There is an ongoing FHWA Research Contract looking at the comparative safety of various cross-section dimensions.

Urgency: This is a critical question in current RRR projects.

Cost: The estimated cost of this study is $350,000.

User Community

The research results could be useful to operating highway agencies.

Implementation

Results should lead directly to implementation.

Effectiveness: The results should lead to more optimal designs.

PROBLEM 21: Process for Identifying, Developing, and Implementing AASHTO Geometric Design Guidance on A Continuing Basis

Design of transportation elements is a dynamic science which changes with technology, conditions, legislation, vehicles, drivers, public concerns, research, etc. Because of this fact, the need to design a process which will assimilate scientific data and field practice into the geometric design policy guidance on a dynamic basis. Although technology transfer is a key element in keeping design current, there is a need to formalize the accepted policy guidance in the authoritative resource document on a regular basis.

Objectives

The main research objective for this study would be to determine a process for identifying, developing, and implementing Geometric Design Policy Guidance on a continuing basis.

a. Key Words-The key word for this study is geometric design policy.

Related Work

There is an ongoing AASHTO Task Force on geometric design.

Urgency

Effective design policy commands ongoing high priority.

Cost: The estimated cost for this study is $40,000/yr. ongoing.

User Community

The research results could be useful to federal, state, local, and consulting highway design engineers.

Implementation

Research results would lead to updated design policies.

Effectiveness

This study could have incalculable impact on traffic efficiency, highway safety, and cost effective highway construction programming.

PROBLEM 22: Clear Recovery Zones

At present, no warrants or guidelines exist to aid engineers or administrators in determining what width clear recovery zones should be provided for each functional classification of highway facility and system for both new construction and RR construction. With traffic accidents, deaths, injuries, and property damage being substantial due to an insufficient clear zone in which to recover, it is critical that we find some way to reduce this hazard. With the perpetual shortage of construction and reconstruction funds, these warrants and guidelines should incorporate the most cost and safety-effective method to be obtained. Clear zones are generally defined as those widths measured from the edge of the outside travel lane which are relatively free of potentially hazardous obstacles.

Objectives

The main objective of this study would be to develop warrants and guidelines that will allow the engineer and the administrator to choose, design, and apply the most cost and safety-effective method to be obtained. Clear zones are generally defined as those widths measured from the edge of the outside travel lane which are relatively free of potentially hazardous obstacles.

a. Key Words-The key words for this study include the following: roadside safety, side slopes, foreslopes, guardrail, traffic barriers, and clear zone.

Related Work

NCHRP Report 247 deals with this issue.

Urgency

This study has a high priority.

Cost: The estimated cost of this study is $300,000.

User Community

The research results could be useful to highway design engineers.

Implementation

Research results could led to more comprehensive design procedures.

Effectiveness

Results should lead directly to implementation.

PROBLEM 23: Geometric Design to Minimize Snow Removal Problems

The design of many roadways creates special problems for snow removal personnel. These problems include inadequate storage room for snow plowed from the roadways, on ramps and other narrow roadways. Problems also arise from highway hardware, some of which creates snow removal problems.

Objectives

This research should determine roadway design parameters that are applicable to areas subject to snow.

PROBLEM 24: Meeting The Clear Zone Requirement on Non-Limited Access Controlled Highways

Transportation agencies are faced with increased construction and maintenance costs, increased safety and

environmental concerns, and the reduction of available funds to accomplish the increasing demand for more and better highways. While the design of recovery areas beyond the normal shoulder width provides the traveling motorists with a large degree of safety, it also increases the overall cost of the project.

Objectives

This study has two research objectives. The first objective is to develop guidelines for the assessment of providing a recovery area beyond the normal shoulder. The second objective is to include all types of barrier systems and slope combinations in the analysis process.

PROBLEM 25: Design Guidelines for Identifying and Correcting Operating Speed Inconsistencies in Horizontal Alignment on Two-Lane Rural Highways

Accidents on rural highways can be related to vehicular speeds which are inconsistent with the roadway conditions presented to the motorist. A method for identification of horizontal alignments which create speed transition problems for the motorist and guidelines for correcting them for example, through the RRR program, would help improve highway safety on this important portion of the roadway network as well as for new designs and redesigns. Such methods are already a routine part of design practices in several Western European countries.

Objectives

This study has several research objectives. The first objective is to establish the correlation between design parameters and traffic volume data on operating speeds and accident rates. The second objective is to develop design graphs for these relationships. The third objective is to determine appropriate ranges for operating speed changes and accident rates to identify and prevent abrupt and unsafe transitions between successive design elements. The final objective is to develop a design procedure including recommendations for good and fair designs.

PROBLEM 26: Determination of Truck Driver Eye Height

Current information on truck driver eye height is limited; that which does exist appears to be conflicting. The differences illustrate the need to determine a representative value (and observed variations) in truck driver eye heights.

Objectives

An explicit procedure for determining truck driver eye height is envisioned. This procedure would specify the vehicle model years to be sampled, the driving population, and the procedure by which measurements must be taken. In addition to manufacturer's data/specifications, actual field observations would be performed to photograph unaware drivers seated in their natural positions.

PROBLEM 27: Optimum Spacing of Crossovers on Divided Dual Lane Highways

On expressway type facilities, there is always a question concerning number and location of crossovers. It is also questioned whether they should be limited to public road connections or not, and whether there should be some maximum spacing between crossovers. One school of thought says that it is better to provide more crossovers and scatter the turning traffic rather than limit the number of crossovers and concentrate the turning traffic.

Objectives

The main objective of this study is to provide a factual location of crossovers on the expressway type facilities.

PROBLEM 28: Operational and Safety Effects of Median Acceleration Lanes at Highway A—Grade "TEE Intersections"

Designers are uncertain of the operational and safety effects of an acceleration lane in the median of the through road for merging of the left-turn traffic movement from a tee approach. The solution frequently is to use a traffic signal that is believed to provide greater safety when, in fact, it may not. Also, the signal may be operated to result in considerable time delay to the through traffic without a compensating reduction in delay to the tee approach traffic.

Objectives

The main objective of this study is to determine the operational and safety effects of providing a median acceleration lane at the tee intersection. The research should cover a combination of traffic speed and volume ranges that would represent both rural and urban conditions.

PROBLEM 29: Guidelines for Upgrading Highway Safety Features and for Maintenance Operations

Transportation agencies are faced with increasing demands for highway safety, coupled with declining revenues in most cases. The demand is manifested by ever-increasing tort claims. A very common allegation in these claims is that a substandard condition existed at the time of the accident, such as a guardrail whose height was too low or whose post spacing was too large. Most such features were standard at the time of their installation.

Another aspect of the problem pertains to maintenance operations. Maintenance personnel generally repair damage in-kind. This damage repair activity offers unique opportunities for safety upgrading. Guidelines are needed to accomplish this goal.

Objectives

Develop objective guidelines to assist a transportation agency in ascertaining which of its highway safety features needs to be upgraded. It is suggested that these guidelines by based on a benefit/cost analysis procedure. Factors that should be considered include, but are not limited to, the following: performance limit of existing feature, cost of alternatives, difference in societal costs associated with existing system and alternatives, maintenance costs, and roadway type.

The same rationale can be applied to maintenance operations on damaged roadside safety hardware. For example, should a damaged guardrail be repaired if current technology says that it is no longer needed? It might be as economical and more cost-effective to remove the entire guardrail or at least the unneeded length.

Current Activities

Efforts are underway within FHWA to develop guidelines for the use of safety features on new construction. However, there are no known studies to address the subject problem.

Urgency

This research was ranked at the top in terms of need by TRB Committee A2A04, "Safety Appurtenances." The need for the research was also underscored in a workshop sponsored by A2A04 in July 1984, on "Tort Claims Involving Roadside Safety Features." It is believed that most state transportation agencies would endorse the research.

a. General estimate of cost to accomplish.

Cost to accomplish depends on scope of merely applying current technology or doing needed research to find solutions.

PROBLEM 30: Development of Improved Vehicular Encroachment Data

There is an increasing use of benefit/cost (B/C) analyses to evaluate highway safety alternatives. Of foremost importance in B/C analyses is the estimation of accidents expected to occur during the analysis period. If the frequency and nature (speed, angle, and lateral extent of movement) of vehicle encroachments on the roadside are known, or can be estimated, the number of accidents with a given roadside feature for a given period of time can be inferred. At present there is a very limited vehicular encroachment data base.

Objectives

The objective of this research is to collect vehicular encroachment data for a variety of roadway types and roadside conditions. The data may be derived from observations of encroachments, directly by sensing devices and/or maintenance records.

Current Activities

There are no studies currently being conducted that address the problem.

Urgency

This research is of major importance and will have a direct impact on the development of roadside safety policies and guidelines. Committee A2A04 rated the research a high priority need.

PROBLEM 31: Barrier Warrants for Embankments

Current barrier warrants are based on studies reported in HRR-174 and HRR-460. The basic concept is to

develop a boundary of equal severity between the barrier and the embankment. These criteria may warrant re-evaluation based on the following:

a. Slope Conditions-Field tests have been run on slopes which were relatively smooth and relatively well-rounded. Although construction may initially provide these conditions, it is uncertain for how long the slope may retain these desirable features. It may be warranted to somehow reflect the probable future slope conditions in barrier warrants.

b. Occupant Risk-Field tests have been run on slopes which were relatively smooth and relatively well-rounded. Although construction may initially provide these conditions, it is uncertain for how long the slope may retain these desirable features. It may be warranted to somehow reflect the probable future slope conditions in barrier warrants.

c. Barrier Type-The evaluation in HRR-460 assumed heavy-post guardrail with blockouts. For a given impact condition, the flexible barrier systems (G1, G2, G3) may result in lower occupant risk. This suggests that the equal severity line maybe be different. If so, there may be certain combinations of embankment heights and slopes where a flexible barrier system is the safest roadside condition.

d. Accident Study-TRR-819 reported a New Mexico study on fatal rollover accidents. Many of these occurred on embankments which did not satisfy the existing barrier warrants. The paper especially questioned existing warrants for low embankment heights. Depending upon relative severity with various barrier systems, this study suggests that barrier warrants may merit a re-evaluation.

Objectives

The research objective would be to re-evaluate existing barrier warrants. If justified, the criteria may be revised to reflect a greater variety of roadside conditions. The results of the research may be used in either a relative severity and/or a benefit/cost approach.

Current Activities

The draft of the new AASHTO Roadside Design Guide presents criteria for barrier warrants on embankments based on a benefit/cost model.

Urgency

This research is moderately urgent. Any revised warrants will not likely be significantly different from existing warrants. However, there may be enough uncertainty related to the issue that the research should be pursued.

PROBLEM 32: Determination of Impact Severity Values for B/C Analyses

Impact severity refers to the probability of occupant injury resulting from a vehicular collision with a roadside feature. This includes safety appurtenances, fixed objects and terrain features. The knowledge of the consequences of impacting these features is essential to the accuracy of B/C analyses.

Impact severity can be estimated by crash tests, computer simulations and/or accident reconstruction. However, all of these methods have their limitations. These include costs, available data, and accuracy (i.e., how closely do the results match the consequences of real-world impacts). Therefore, it is desirable to examine the issue of impact severity in depth to determine the best approach to gather the necessary data to perform accurate, meaningful B/C analyses.

Objectives

The objectives of this research would be to conduct an extensive investigation of impact severity to:

a. Identify the list of roadside hazards for which an impact severity is needed

b. Document the existing bank of data on impact severity

c. Develop strategies for the "best" method of estimating impact severity (crash tests, computer simulations and/or accident reconstruction)

d. Implement the strategies

The results of the research would then be used in B/C analyses.

Current Activities

Several ongoing projects are directly or indirectly addressing the issue of impact severity for roadside hazards.

Urgency

There is a growing demand to make roadside safety decisions based on economic analyses. However, this objective is severely handicapped by the lack of knowledge on the consequences of collisions with roadside

hazards. For B/C analyses to provide more accurate results, it is important to gather better information on impact severity.

PROBLEM 33: Safety Treatment of Parallel Drainage Structures and Roadside Ditches

Parallel drainage structures are common along the highway roadside, and they are often within the roadside clear zone. They occur where roadside ditches intersect driveways, roads or median crossovers. The design treatment typically results in a driveway or intersecting slope and a pipe opening which are perpendicular to the flow of the traffic on the mainline. Vehicular impacts at approximately 90 degrees with these features can result in undesirable, and sometimes violent, consequences. The problem is compounded by the possibility that the roadside ditch, which may otherwise be safely traversable, will channel a run-off-the -road vehicle into the parallel drainage structure.

Over the years, a rule of thumb has developed for the safe treatment of parallel drainage structures. For high-speed facilities, 10:1 has been considered desirable and 6:1 acceptable. In addition, it has been recommended that pipe openings greater than 18" should be cut to fit the slope and should include a grate which will support a vehicular tire. However, it is uncertain if these criteria, especially the 6:1 slope, would meet any occupant risk criteria. On the other hand, meeting the existing suggested criteria can become prohibitively expensive. More stringent criteria based on impact severity (occupant risk) could become uniformly unacceptable.

The 1977 Traffic Barrier Guide presents criteria for the limits of safe traversability of roadside ditches. These are based on criteria presented in NCHRP 158 "Selection of Safe Roadside Cross Sections" (1975). Many of the underlying assumptions within these criteria may warrant re-evaluation. This includes:

a. The impact speed assumed in the criteria is 60 mph. considering the wide range of design speeds on highways with roadside ditches, it would be desirable to establish the limits of safe traversability for other speeds.

b. The tests were performed at a 25 degree angle of impact and with a full-size passenger car to determine occupant risk. These test conditions are inconsistent with Test 11 from NCHRP 230 for the assessment of occupant risk (2250 lb. vehicle at 15 degrees).

c. The limit of traversability was established according to the Severity Index formula; SI = 1.0 for an unrestrained occupant was used. A better understanding of occupant risk may provide a more accurate evaluation for the limits of safe roadside ditch traversability.

Objectives

The overall objective of the research would be to develop criteria for the safe, cost-effective design of parallel drainage structures and roadside ditches. The first objective would be to estimate the limits of safe traversability based on occupant risk (i.e., impact severity). This might be accomplished through crash tests, computer simulation, accident reconstruction or a combination of all three. The second objective would be to develop suggested design criteria based on the consideration of construction costs, practical field applications and potential safety benefit. This may be accomplished through the use of a benefit/cost methodology.

Current Activities

Chapter 3 of the new AASHTO "Roadside Design Guide" addresses parallel drainage structures and roadside ditches. Its suggested design criteria for parallel drainage structures are basically consistent with the preceding discussion in this research problem statement. For roadside ditches, the new Guide apparently incorporates the criteria from the 1977 Traffic Barrier Guide with some refinements.

The Texas Department of Highways and Public Transportation is currently sponsoring research to address the problem of parallel drainage structures. The objective is to use a benefit/cost approach to develop suggested design criteria. However, it is recognized that the ongoing research is limited by the lack of knowledge on occupant risk (impact severity).

Urgency

The observations on:

a. The frequency of parallel drainage structures and roadside ditches along the roadside

b. The lack of data on their severity, which may be very high

c. The relatively high cost of corrective action

All of these combine to make this a very important roadside safety research objective.

PROBLEM 34: Field Study of Roadside Safety to Collect Data for B/C Analyses

The highway community's understanding of roadside safety in the real world is, in general, based on a paucity of information. Crash tests may or may not accurately represent real-world impacts; accident data from police reports may or may not be complete and they do not capture drive-away impacts; and accident reconstruction has not been undertaken on a widespread basis. This situation has adversely impacted the use of B/C analyses.

Objectives

The objective of this research would be to conduct an in-depth, long-term field study of roadside safety. The study could be conducted via the selection of several highway segments which are representative of various highway conditions (urban/rural, functional classification, traffic volumes, design speeds, terrain, roadside environment, etc.). Each highway segment may range in length from 10 to 30 miles.

A research team would closely monitor the roadside for unintentional encroachments (e.g., downed roadside appurtenances, wheel tracks). The monitoring would likely take place for several years. Police accidents reports could be supplemented by in-depth accident reconstruction. The data gained from this extensive field study could add immeasurably to the understanding of roadside safety and could provide invaluable input data to B/C analyses.

Current Activities: None to our knowledge.

Urgency

Roadside safety has, for many years, been recognized as a major national problem. However, the highway community has not been able to determine the true nature of run-off-the-road accidents to an acceptable level of confidence. This understanding could provide information toward the objective of realizing a significant reduction in the number of severity of run-off-the-road accidents. A field study of roadside safety could potentially provide valuable insights into the real-world nature of run-off-the-road accidents. Therefore, this research should be considered very important.

PROBLEM 35: Simulation of Vehicle—Roadway Interaction Problems

The impact performance of roadside safety features in difficult to evaluate. Full-scale vehicular crash tests are used for this purpose to a limited extent. However, the wide array of vehicle and safety feature parameters that must be considered, combined with the high costs of crash testing, precludes widespread use of testing. There is a need for a state-of-the-art, comprehensive computer program that is capable of accurately simulating vehicle-safety feature impacts.

To date, computer simulation programs have been used, with varying degrees of success, as an aid in the design and analysis of roadside safety features. HVOSM, GUARD, and BARRIER VII are three of the more widely used programs. Each program as its own advantages, disadvantages, limitations, intended applications, etc. While numerous changes and improvements have been made to these programs by various users, documentation is fragmented and inadequate in many bases. Coding is inefficient, time consuming from a CPU standpoint, and difficult to adapt to various compute systems.

Objectives

Develop a state-of-the-art computer program suitable for simulating an array of vehicle-roadside safety feature problems, including traffic barriers, crash cushions, sign and luminaire supports, and roadside geometric features. Develop a comprehensive user's manual for the program. If possible, the coding should be written for use with desk-top computers.

Current Activities

Research agencies and the FHWA continue to use and modify on a piecemeal basis, the aforementioned programs. Certain FHWA and NCHRP studies require their use. However, there is no major, concentrated effort under way to develop a comprehensive, state-of-the-art program.

Urgency

This research should be given high priority in view of the high costs of crash tests, the increased demand for safety features, and the continuing need for design changes resulting from changes to design vehicles.

Cost

For this effort to succeed, it must be adequately funded, over a reasonable period of performance. Cost is estimated at $275,000 minimum, with a minimum 2-year period of performance.

PROBLEM 36: Determination of Societal Costs for B/C Analyses, Especially the Value of a Human Life

Societal costs are necessary to determine the economic benefit of proposed roadside safety improvements. The predicted number of fatalities which will be saved (or increased as the case may be) requires that a value be assigned to human life. This value has been a long-standing controversy among highway safety specialists, and a wide range of values and approaches have been promulgated by Federal, State and private entities. The problem is compounded by the fact that, in many B/C applications, the selected value of human life will drive the results of the analysis. In the opinion of some, this leads to potentially skewed results from the B/C analysis and, thereby, may diminish the theoretical advantages of performing an economic analysis.

Other societal costs include the cost of serious personal injury, property damage and indirect costs (e.g., accident investigation and insurance administration). Problems, similar to those for determining a value for human life, also exist for these societal costs.

Objectives

The objectives of this research would be to:

a. Determine what entity should select the societal costs for B/C analyses (e.g., at the national level or at an individual state level or some other variation)
b. Determine which societal costs should be reflected in the B/C analysis
c. Determine which approach should be used for the cost of a human life (e.g., human capital, willingness to pay)
d. Determine what dollar values should be used for the selected societal costs

Current Activities

Many past and ongoing studies have attempted to address this problem.

Urgency

The absence of a nationwide consensus on the range and value of societal cost has produced uncertainty and a lack of uniformity in the application of B/C analyses to make roadside safety decisions. For economic analyses to ever gain widespread usage, it may be necessary to reach this consensus. Therefore, this represents an important issue which needs resolution.

PROBLEM 37: Compilation and Dissemination of the Results of Research on Highway Safety Devices

A great deal of research on highway safety devices has been sponsored in recent years by FHWA and others. The research is usually well documented in thick research reports. Unfortunately, there is no ongoing organized system to distribute all reports in this area to state transportation agencies and other users. Furthermore, the reports that are received are not in a form easily used by traffic and design engineers. Complete plans are often lacking and there may be other gaps in reports. Overall, the reports can be intimidating and formidable for those who want to review and implement the test results. The AASHTO Barrier Guide which is being updated as a reference text and user's manual will be very useful, but it may not be updated again for a number of years. The continuing technical information explosion will soon again cause lags in the implementation of important research.

Objectives

The contractor, after study and consultation, would recommend what national agency should compile and disseminate research results. They would layout standard forms that summarized research on safety devices. These forms might be 1-4 pages long, would be short and simple, would include plans and specifications for the device, research report references, information contacts, and any other information that showed compliance with standards, important test results for comparison with similar devices, accident experience, if any, and any other information needed by designers in a simple, clear standardized format. The contractor would recommend how often information should be compiled and disseminated and who should receive it. Presumably this would set in motion an ongoing process. The contractor would produce a reasonable sample of these information update forms. Users would then maintain a binder of these forms that were regularly updated or added to.

Urgency

Moderately urgent. In order for research results on highway safety devices to be understood and used quickly, this work seems as important as the actual research.

Cost: It is estimated this research would cost $100,000.

PROBLEM 38: Vehicle/Highway Safety-Interface Design

Every year highway accidents in this country cause thousands of deaths and injuries and cost approximately $40 billion (National Safety Council). The highway system has three key elements: the drivers, the highway, and the vehicles. No government agency or business has control over all three elements; therefore system design methods can rarely be used to improve highway safety. At present the highway system is not designed conservatively enough. For example, drunk drivers are not prevented from driving at the top speed available with a vehicle, and vehicles are not strong enough to withstand some elements on the roadway during accidents such as steep banks or utility poles. Much work has been done on the elements separately, but there is little record, for example, of vehicle manufacturers and highway engineers working jointly to solve safety problems. In fact, there has been an adversarial relationship between the private and public sector on some controversial issues such as airbags. Some type of joint effort may be needed between the highway community and the vehicle manufacturers to achieve a more conservative highway system design.

Objectives

A "neutral" research consultant is needed to start the dialogue and recommend detailed areas of mutual research and further dialogue. The research process might proceed as follows. First, the consultant would need to do some data gathering and interviewing, one at a time, of highway design departments, AASHTO, NTSB, NHTSA, and FHWA highway safety research department, foreign and domestic automobile manufacturers, the National Safety Council and others.

The consultant would be searching out problem areas involving both the vehicle and the highway. Some examples of this would be:

a. Vehicle speed-Speed can be controlled through vehicle design and also through highway signing and enforcement. Would electronic speed controls on cars that varied with light, rain, slipperiness, driver intoxication or other conditions be practical, or is speed law enforcement the only feasible method?

b. Skid resistance-Both vehicle and roadway surface roughness contribute to problems in this area. Would research on tire design or new rough pavement overlays be more productive? If rough overlays are used, can vehicle designers minimize road noise and rough riding qualities?

c. Rollover-This phenomenon also involves both the vehicle and the roadway. Do track widths need widening, tires less tendency to trip when a vehicle moves sideways, or should the roadway surface and profile be smoothed out, with all dikes and curbs eliminated as one measure?

d. Vehicle body strength-Do more obstacles need to be removed from the highway including stiff "safety" barriers, or should the passenger compartments of all vehicles be made inviolable for impacts up to 55 mph? Is it possible to prevent passenger ejection in all impacts?

e. Light-Many accidents occur in the absence of good light conditions. Should better light be provided by the vehicles, the highway departments, or both?

Having focused on problem areas and current technology, the consultant then could pick the most promising areas and organize and record dialogues between vehicle manufacturers and the highway agencies. Mutual problem solving would be the ultimate goal; thus, the consultant should be talented in the areas of communication, mediation, brainstorming, and the facilitation of problem solving. Special preparation might be necessary to prevent accounting and legal department's participants from unnecessarily hampering govern dialogue and real problem solving work.

To conclude the research the consultant would prepare a summary report of his/her work and recommend areas of further work. These recommendations should include specific courses of action. For example, perhaps the government should fund research by a vehicle manufacturer to develop needed technology, or should subsidize vehicle safety improvements that show promise of great accident severity reduction. Recommendation should also be made about the best way(s) to continue dialogue between those who can make changes in highway system design.

Urgency

The casualties from highway accidents in this country are a staggering loss, the equivalent of an ongoing civil war with almost 50,000 fatalities and 2,000,000 injuries per

year (per National Safety Council). Much of this loss could probably be avoided if current technology was applied properly. Any reasonable new approaches to this problem should be explored soon.

Cost: The estimated cost of this research is $100,000.

PROBLEM 39: Development of a Roadside Safety Tort Liability Data Bank

In recent years the concept of sovereign immunity from tort liability has been sharply diminished. Most states are now without this protection. The basic legal defenses of discretionary and design immunity have been weakened by court decisions. This is coupled with a huge increase in litigation, an increase in successful suits, and an increase in the skills and knowledge of attorneys specializing in tort liability as pertains to the highway. As an example, the number of annual new tort claims in California has tripled in the last 12-15 years.

The need is to make tort liability related to roadside safety a more manageable problem. An aid in achieving this need is to develop a comprehensive national data bank concerning types and frequencies of claims, outcomes, solutions, etc., that would serve to increase knowledge about the subject.

Objectives

A logical progression in developing and utilizing the data bank would be as follows:

a. Inform the states about the development of the system
b. Develop standardized codes and forms
c. Obtain input data from the states
d. Store the data
e. Output the results and provide feedback to the users

Current Activities

Currently, there is no centralized activity concerning the development of a comprehensive tort liability data bank. Record keeping is left to the discretion of individual states, and little information is exchanged.

a. Key Words-tort liability, roadside safety appurtenances and data bank.

Urgency

Tort claims are growing in frequency each year, and states are forced to divert more personnel and time to deal with the problem. Learning how to better manage tort claims would result in improved use of available resources.

Cost

The estimated cost of this research is approximately $100,000.

PROBLEM 40: Performance Requirements for Truck Mounted Attenuators (TMA's)

NCHRP 230 does not adequately address performance requirements for TMA's. As a result, the FHWA Office of Engineering does not pass judgment on whether or not individual TMA's are to be declared operational systems.

Objectives

The objective of the research effort would be to develop a reasonable set of recommended procedures for the safety performance evaluation of TMA's. The most important issues to be decided are:

a. What impact speed should be required?
b. How will the variability of truck weights be addressed? The mass of the truck, to which the portable impact attenuation device is attached, will greatly affect crash test occupant risk parameters.
c. What occupant risk factors should apply?
d. What distance should be assumed for the truck roll-ahead?

Current Activities

At the present time, TMA's are designed and fabricated by private sector firms for the highway construction and maintenance industry and transportation agencies. This procedure is done with a subjective interpretation and nod to the NCHRP 230 statement on the TMA. The draft version of the new AASHTO Roadside Design Guide has a brief section on TMA's.

Urgency

There is definitely an urgent need to provide greater protection for the motorists of errant vehicles and for

highway and street work crews. Annually, about 700 lives are lost due to work zone accidents. The actual number of fatalities due to truck under-ride is not known. However, where they occur, they are indeed tragic accidents.

Truck mounted attenuators have existed for over 15 years, and their use in increasing rapidly. Without guidelines to work with, the Federal Highway Administration cannot pass judgement on the effectiveness of an individual TMA and State DOT's have difficulty comparing the relative merits of different TMA's.

PROBLEM 41: Standard Drawing Review for Highway Safety Designs

Many state standards are prepared by designers that do not have the time or background to fully understand the principles of a highway safety device (e.g., guardrail, crash cushion, breakaway support).

As a result, design drawings do not accurately reflect the intent of the device designer/developer. The net result is an unacceptable drawing or a drawing that does not accurately "detail" the design concept.

Objectives

Objectives of this research are to screen state standards for errors in application. This screening would be accomplished by a contractor with R&D experience in highway safety design applications. This contractor would have the budget to solicit comments from device designers as required.

A confidential report would be submitted to the sponsoring agency with recommendations for revisions.

Current Activities

None known.

Urgency

This is an important problem and could result in improved safety and reduce later upgrading requirements.

Cost: The estimated cost for this research is $100,000-$500,000.

A2A05 Committee on Landscape and Environmental Design

PROBLEM 42: Cost Effective Design, Construction, and Maintenance Criteria for Roadside Vegetation

There is presently no consistent nationwide procedure to determine the need or scope of roadside development in the programming, design, and maintenance process. The result of the current design process ignores some roadsides while others are overdesigned and constructed. Both extremes often cause extensive perpetual maintenance. When, because of funding limitations, these required maintenance levels cannot be obtained, costly investments deteriorate and design intents are lost unless funds are diverted from other areas. Last but not least, departments do not have a tool that offers a rational explanation to the public as to what level a project's roadsides should be developed in order to adequately serve all needs. The results have often been controversial.

Objectives

The objective of the research is to develop a methodology which identifies the degree of roadside development on the basis of cost effectiveness. With this methodology it will be possible to distribute the available funds on a priority basis and analyze the maintenance levels. A methodology will be developed which integrates the physical and psychological functions of roadsides with highway traffic and location factors, such as use, exposure, and sensitivity. This will be used for a roadside classification system. Criteria will be developed to select suitable vegetation types for the needs and conditions of the roadsides. Cost analyses, based on a representative number of plant selections and communities will be developed. Correlation of the roadside classes with the vegetation type cost factors will provide for minumum development standards for the roadsides. These minimum standards are related to the most cost-effective vegetation types.

Current Activities

a. Research in progress: not determined.
b. Related research activities: "Esthetics and Visual Resource Management in the Highway Development Process", a manual prepared by Jones and Jones, Seattle, WA.

Urgency

Immediate-Roadside vegetation involves construction and scarce, long-term maintenance funds. The nation is involved in a major program of completion and update of Interstate and other highway construction projects. Cost-effective roadside vegetation will save large dollar amounts.

Cost: $98,000

Duration: 3 years

PROBLEM 43: Significance of Visual Resource Assessments on Transportation Projects

Transportation projects affect (impact) the visual environment. Although several methods have been developed to determine and identify the significance of visual issues on a project, there is no method to relate the level of effort necessary to produce an adequate visual analysis with the scope of the project.

Objectives

Project impacts, once identified, must be meaningfully assessed. However, the level of effort required to produce an adequate assessment must be related to the significance of the project.

Current Activities

a. Research in progress: not determined.
b. Related research activities: FHWA-V.I.A. for highway projects 1981.

Urgency

Transportation projects impacts are everywhere! There is no end in sight to transportation construction therefore no end to the impacts.

Cost: $150,000

Duration: 2 years

PROBLEM 44: Comparison of Functional Values of Created Wetlands Versus Existing Natural Wetlands

Construction of highways located in floodplains and surrounding low-lying areas usually results in wetland involvement. Executive Order 11990 and the Section 404 permit program of the Clean Water Act has resulted in several regulatory agencies requesting replacement in wetlands for those wetlands eliminated by highways. Naturally occurring wetlands generally possess characteristics absent from created wetlands: e.g., high net primary productivity, increased species and habitat diversity, excellent wildlife habitat, and low maintenance costs. Wetland involvement generally dictates a request for replacement instead of protection of existing wetlands. Because of the incomplete enforcement of current laws and because it is not illegal to drain wetlands (as long as there is no discharge of material), many acres of wetlands continue to be lost yearly. Therefore, retention of high-quality natural wetlands would appear to be viable mitigation. Substantial savings could be generated if transportation agencies could document the increased functional values of existing wetlands versus created wetlands.

Objectives

Identify those characteristics of naturally occurring wetlands over created wetlands and substantiate that expenditures on a cost-benefit ratio favor retention and protection of existing wetlands versus created wetlands.

Current Activities

a. Research in progress: not determined

b. Related research activities: Ongoing research directed towards value of existing wetlands, creation of wetlands, and utilization of wetlands as waste management purifiers. Little emphasis directed toward comparison of cost/benefit ratio of natural versus created wetlands.

Urgency

Continuing emphasis on wetlands by regulatory agencies and attendant request for replacement on an acre-per-acre basis results in increased costs for transportation projects wherever there is wetland involvement. Substantial savings could potentially result from satisfactory documentation on cost/benefit ratio favoring retention of natural wetlands over creation of new wetlands

Cost: $500,000

Duration: 5 years

PROBLEM 45: Economic Benefits of Safety Roadside Rest Areas

Transportation funds nationwide are stretched to cover basic services. Many types of projects with compelling justifications compete for these funds. Rest areas are typically viewed as comfort and convenience facilities and are frequently given low priority when competing for public tax dollars.

When deciding between programs, systems or projects for funding, transportation agencies need to be able to place a dollar value on the benefits to users and administering agencies. Such a measurement would permit rest areas to be systematically compared to other proposed transportation improvements for purposes of budget allocations.

Objective

Determine tangible values of the economic benefits of rest areas to users, to the agencies building and operating rest areas, and to communities.

The effort should address both the validation of the benefits of rest areas identified by previous research and valuation of the benefits.

Current Activities

a. Key Words-Rest area, benefits, economic value, safety roadside rest areas, user benefits, community benefits.

b. Related Research Activities-NCHRP project entitled: *Identifying, Measuring and Evaluating the Benefits of Safety Roadside Rest Areas*, preliminary draft dated July 1989, by G.F. King, P.E., KLD Associates, Inc., Huntington Station, New York 11746.

Urgency

A research project to identify rest area benefits was completed in 1989. Its conclusions will have limited application without the value of the benefits being quantified.

Cost: $ 150,000 over a 2 year period.

Statement Prepared by: Edward N. Kress, California Department of Transportation, December 1989.

PROBLEM 46: Cost-Effectiveness of Roadside Revegetation in Providing Physical and Psychological Functional Needs to the Motorist and the Community

Inflation and reduced revenues are causing severe cutbacks in transportation construction, including roadside development. Roadside development and vegetation restoration are necessary elements in transportation systems to provide physical (safety, glare screen), psychological (buffers and visual relief) and community values.

Restoration of roadside vegetation disturbed during construction is presently done by seeding of grasses and legumes and/or planting of woody vegetation. The vegetation used for revegetation is most often considered exotic and not necessarily compatible with existing environmental conditions or competitive with native vegetation unless certain maintenance measures are undertaken. Maintenance measures include weed control, brush control, mowing, fertilization, among others. These actions are normally perpetual and therefore their cumulative costs are high.

Objectives

a. Identify and prioritize roadside development needs which are essential elements in satisfying physical and psychological needs of the motorist and the community.

b. Develop methods for revegetating roadsides that will satisfy motorist and community needs and are cost effective to construct and maintain.

c. Evaluate methods of revegetating roadsides with plant communities that are competitive and compatible with site conditions.

d. Identify plant communities that will answer the following:

1. Compatibility with the primary function of transportation facility:

a. relationship of height to sight distance, icing conditions, etc;

b. maintaining structural integrity of pavements, structures;

c. littering caused by branch breakage, leaf drop, fruit drop.

2. Competitive durability with existing vegetation and invading weeds.

3. Establish methods and feasibility:

a. availability of seeds and plants;

b. propagation methods;

c. seeding and planting methods (without irrigation);

d. natural revegetation;

e. herbicide programs and soil management;

f. cost.

4. Visual qualities.

Current Activities

a. Research in progress: not determined.

b. The following reports related to the subject have been published:

1. Washington State Department of Transportation Report FHWA Highway Research Report No. 34.1 "Chemical Weed Control in Roadside Vegetation on Highway Rights of Way", 1979.

2. Washington State Department of Highways Report FHWA Highway Research Report 14.1, "Vegetative Cover for Highway Rights of Way", 1973.

3. Washington State Department of Highways Report FHWA Highway Research Report 14.2, "Vegetative cover for Highway Rights of Way", 1976.

Urgency

Increased cost of petroleum-derived products such as fuel, fertilizers and herbicides are increasing roadside maintenance costs. The length of study required for this requires an early start in order to have results that can be applied on large enough scale that would have practical results when maintenance activities would otherwise be cost-prohibitive.

Cost: $100,000

Duration: 3 years, 2 man-years

PROBLEM 47: Wetland Replacement Techniques-Case Studies

a. Presidential Executive Order 11990 (1977) requires the avoidance of wetlands, whenever practicable, or action to minimize direct and indirect effects upon wetlands.

b. Since the FHWA has adopted the U.S. Fish and Wildlife Services Classification system, wet environments typically encountered on bridge replacement projects or highway relocation projects result in involvement with wetlands.

c. Pennsylvania is required to replace wetlands on projects in the State.

Objectives

Develop conclusions and recommendations based on case studies regarding wetland replacement efforts associated with highway project development comprising pre-construction, construction, and post-construction in the following areas:

a. Replacement area locations.
b. Effective design and revegetation of wetland replacement areas.
c. Overall cost effectiveness of various replacement designs.
d. Vegetation, topography, soils, hydrology, etc. of wetlands to be impacted and wetlands to be created.

Current Activities

a. Research in progress: not determined.
b. Related research activities: not known.

Urgency

There is little or no data or experience available from transportation or environmental agencies on the development of acceptable, low-maintenance, functional wetlands.

Cost: $100,000

Duration: 5 years

PROBLEM 48: Increase Energy Efficiency and Reduction of Maintenance Costs by Enhancement of Natural Communities Within Highway Rights-of-Way

The rights-of-way of highways have been maintained on an annual basis by mowing for safety considerations and maintenance of the existing facility. This cost has been considered as a yearly necessary expense and incorporated into transportation budgets without consideration for the planned reduction in expenditures. Budget and personnel reductions, affecting all transportation agencies, have resulted in decreased acreages of rights-of-way mowed and maintained at the expense of the motoring public. This problem could potentially be alleviated by selecting those naturally occurring plant communities which provide suitable traits to reduce the increased energy costs of intensive maintenance.

Objectives

Identify those naturally occurring plant communities which by their growth form, morphology, and vegetative traits would reduce energy expenditures and maintenance costs by incorporation into highway rights-of-way.

Current Activities

a. Research in progress: not determined.
b. Related research activities: Ongoing investigations in several states directed toward establishment of native plant communities in terms of restoration. No research directed toward reduction of energy and maintenance costs aspects that naturally occurring plant communities could provide.

Urgency

As a yearly expense is programmed for mowing of highway rights-of-way, the selection and identification of naturally occurring plant communities could potentially provide substantial cost reductions for transportation agencies nationwide.

Cost: $400,000

Duration: 5 years

PROBLEM 49: Visual Perception of The Roadway and Roadside Elements by the Observer in Motion

The roadway and roadside or non-pavement portion of the highway facility performs essential functions for visual traffic guidance and aesthetic quality for the traveler.

Traditionally, design of the human environment is based on a stationary observation perspective. Comprehensive and rational data regarding factors that relate to the visual perception by the observer in motion are not available to the disciplines involved in roadway and roadside design. Consequently, visual functions may be less effective than intended. This may have an un-

desirable effect of the safety, visual quality and cost effectiveness of the facility.

Objectives

a. Analyses of the following factors and how their interrelationship affects the visual perception of the user in motion:

1. User characteristics:

- Age
- Sex
- Occupation
- Fatigue level (long distance versus commuter)

2. Effect of motion:

- Cone of vision
- Length of observation period
- Concentration level
- Repeat observation of similar roadside elements
- Single observation of roadside element

3. Appearance of roadside elements:

- Mass
- Shape
- Color
- Texture
- Background
- Scale relationship to overall scene

4. Facility Type:

- Rural
- Urban
- Two-lane
- Freeway
- Traffic volume
- Elevated structures

5. Result of visual perception.

- Conscious realization
- Unconscious or intuitive reaction

b. Development of guidelines in order to achieve the optimum benefit of, and relationship amongst, roadside elements. Guidelines shall include the following:

1. Hierarchy of roadside functions
2. Appearance of elements
   - Dimensions
   - Color and texture
3. Location
4. Repetition of elements

Current Activities

a. Suggested Key Words-visual perception, observer in motion, roadside elements, roadway elements.
b. Related Research Activities-None determined.

Urgency

The location and appearance of roadside elements is based on experience and some incidental research. Comprehensive data based on user perception are not available to the designer. The roadside elements convey important messages that direct the user or provide enjoyment. A rational design data base is urgently needed in order to provide the most effective facilities.

Cost: $150,000 over one year.

Statement Prepared by: Hans A. Littooy, Washington Department of Transportation, April 1989.

PROBLEM 50: Comparison of Values of Properties Adjacent to Transportation Rights of Way Before and After These Rights of Way Have Been Landscaped

Construction of transportation projects is perceived to have both negative and positive effects on adjacent properties.

Landscaping of transportation rights of way is often used to mitigate visual impacts. The effect that different levels of landscaping may have on the real estate values of adjacent properties is unknown.

Often, adjacent property owners and community organizations press for landscaping of the roadsides. Because of fund shortages, the transportation agencies sometimes negotiate funding participation by the local government. Participation levels are most often negotiated on perceived needs rather than founded on accurate benefit data.

Economic enhancement is a value presently not available for the establishment of proper landscape development levels.

Objectives

Research whether landscape development has an effect on land values adjacent to transportation rights of way.

Develop a methodology to be used to determine the correlation between values of land adjacent to transportation rights of way and landscape development levels.

Current Activities

a. Suggested Key Words: property values, landscaped transportation rights of way, value of roadside landscaping.

b. Related research activities: None determined.

Urgency

This research may result in substantial savings by providing an additional tool to establish proper landscape levels in economically sensitive areas. The methodology will assist in arriving at fair levels of participation by benefited parties.

The shortages of funding for landscape development projects create an urgent need for this research.

Cost: $100,000 over three years.

Statement Prepared by: Hans A. Littooy, Washington Department of Transportation, April 1989.

PROBLEM 51: Cost/Benefit Ratio of Establishing and Maintaining Wildflowers in Highly Competitive Grass Areas of Roadsides

There has been growing public interest in wildflowers and requests to plant wildflowers along roadsides are common. Also, new provisions mandated by federal regulations require that landscape projects include wildflower planting. Wildflower beds are generally taken over by grass and other competitive plants after the first year and very few, if any, wildflowers survive the competition.

Objectives

- Identify maintenance requirements of wildflowers in competitive grass areas and develop efficient maintenance practices.
- Identify flowers that persist in roadside grass areas and also enhance the view as perceived by the traveler.
- Identify minimum and maximum size of plantings which will provide the desired enhancement and be cost-effective to maintain.
- Identify costs and the overall impact of a wildflower program on existing maintenance forces.
- Determine cost/benefit ratio.

Current Activities

a. Suggested Key Words: wildflower, grass competition, wildflower maintenance.

b. Related research activities: some on-going research by seed companies.

Urgency

Wildflowers are currently being used on projects to satisfy federal requirements. Finding cost-effective methods of planting and maintaining wildflowers in highly competitive grass areas is critical to the long-term success of a wildflower program.

Cost: $100,000 over two years.

Statement Prepared by: Merlyn Anderson, Oregon Department of Transportation, April 1989

PROBLEM 52: Perceive Roadside as a Managed Resource Rather Than Controlled Vegetation

The roadside is thought of as a necessary evil where the grass must be mowed, the weeds controlled and the advances of woody plants held at bay. This attitude colors the thinking of workers and supervisors so that the real potential of the roadside in terms of function and aesthetics is often not realized.

Objectives

Examine roadside vegetation from the standpoint of the land that supports it, types of vegetative cover, associated life forms, methods or practices to sustain the system and controls for safety and aesthetics.

Current Activities

a. Research in progress: not determined
b. Related research activities: Believe there are studies about wildlife, nesting habits, habitat etc., but the information should be incorporated into a total program, and should recommend practical applications.

Urgency

This is timely because we are becoming more aware of public concern over what is being done on public lands. Practical guidelines from a management rather than control point of view would be timely as a means of preserving resources and heeding the reasonable concerns of the general public.

Cost: $75,000

Duration: 2 years

PROBLEM 53: Wetland Replacement-Enhancement

In the course of highway construction, wetlands are encountered. According to federal mandate the agency must identify the resource, evaluate, avoid or minimize the impact. If no alternative exists for using the wetland, a mitigation plan must be implemented.

Objectives

Define the methods of minimizing impacts to wetlands, methods of mitigating impacts to wetlands, methods of defining wetlands.

Current Activities

a. Research in progress: An on-going inventory is being conducted to identify wetlands created by construction.
b. Related research activities: none known.

Urgency

Mitigation of wetlands destroyed by highway construction is critical and we must replace wetlands or enhance existing borrow area which has wetland potential.

Cost: $100,000

Duration: 2 years

PROBLEM 54: Utilizing Wetlands for Treatment of Highway Runoff

One of the main concerns of resource agencies when a proposal exists to upgrade or build a major expressway is the impact of highway runoff to receiving streams.

With runoff constituents consisting of nitrates, phosphates, heavy metals such as lead, zinc, and copper as well as many other compounds the potential exists for receiving streams to receive high concentrations of pollutants, especially if certain environmental factors exist, i.e., long periods of having no rain thus allowing pollutants to build up on and along the highway, and if the surrounding area receives industrial air pollution.

Objectives

To create or utilize existing wetlands for receiving highway runoff. Runoff should be monitored for the components before entering the wetland and the existing waters should be monitored for the components which are not retained by the wetlands.

As this is new research, size of wetlands, type, vegetative cover, soils and all receiving water sources will have to be fully described and factors listed which will be controlled as well as ones which are not controlled will have to be fully listed and described.

Current Activities

a. Research in progress: not determined.
b. Related research activities: Past research has generally been directed to highway impacts to wetlands, creation or enhancement measures for irrigation, and overall assessment of wetland functions.

Urgency

An immediate need exists to be able to relate to regulatory agencies what the constituents of highway runoff are and whether or not these pollutants can be trapped, filtered, and retained by wetlands before entering any watercourses. If wetlands can effectively and efficiently filter our pollutants without any long-term degradation of the wetland or surrounding environment, then utilization of such should become commonplace as well as a useful mitigation tool by highway agencies.

Due to close scrutiny of achieving and maintaining high water quality standards, highway department should be aware of any pollutants which are being added to the stream environment by their actions. Pollutants which enter the water system from highways should be moni-

tored in order to determine if they pose a threat to the drinking water supplics.

Cost: $125,000

Duration: 5 years

PROBLEM 55: Computer Graphics for Identification and Mitigation of Driving Hazards

There are numerous highway segments with unusually high accident rates which cannot be attributed to flaws in highway geometry or other mechanical problems. In these situations, there is some reason to suspect that something in the visual character of the highway corridor is contributing to the problem. Conventional statistical tools can be applied to these situations to determine if weather, sun angle, seasonal variation, or other quantifiable variables are contributing to the problem. However, these tools cannot provide visual models of the conditions on the numbers describe. Computer and video animation technology seem to offer a new tool uniquely suited to defining and solving non-quantifiable problems.

Analysis of these problem sites involves coordinated study of statistical data and video taped footage under a variety of light or weather conditions. Together, these media may uncover new information about why drivers lose control of their vehicles. The hypothesis is: that drivers depend a great deal on visual clues that cause them to alter their speed, redirect their attention, or in some way prepare for what lies ahead. If the visual clues become confused or in some way convey misinformation, drivers will become disoriented and lose control. If the misleading visual clues can be identified, new conditions can be modeled using either video or computer animation techniques to determine the most cost effective solutions to the problem.

Some of the more common problems are light, shade and shadow, related. Many times the vertical alignment of a road juxtaposed with the shade and shadow cast by bridges, embankments, and overhead structures can combine to have a disorienting effect on a driver.

The research proposes to look at one or more stretches of urban freeway where there is an abnormally high accident rate. Combined statistical and video analyses will be prepared to identify possible causes of driver disorientation. Computer animation will then be prepared to test driver response and possible mitigation procedures.

Objectives

Visualization-Animation Technology is uniquely adopted as a tool by such agencies as NASA, NOAA, USGS, and the Medical Profession. Given the dynamic nature of the driving environment, it should also be an invaluable tool in highway research. The objective of this research is to first test the hypothesis that the constructs of the visual environment can have a negative impact on driver performance. Then develop and test a set of computer-based Visualization tools that can be used to develop and test means of hazard mitigation.

Current Activities

a. Key Words: Visualization, Visual Hazards, Driving Hazards Mitigation, Driver Safety.

b. There is a considerable body of research dating back to the decade of the 50's that deals with the impact of the visual context on human performance. Much of the literature is focused on pilot performance but there is also a substantial body of work on driver performance. This literature and the successful development of very complex flight simulators suggest that a similar technology would be successful to examination of and developing improvements to the driving environment. Economics is probably the reason that there is not wide spread use of this technology in the transportation area. However, recent developments in computer hardware and software have made the technology affordable and easily adapted to transportation applications.

Urgency

Protecting the safety of the driving public has had and continues to be one of the top research priorities. Computer technology offers a new set of tools for accomplishing this mission if appropriate applications are developed.

Cost: Three man-years.

Statement Prepared by: Harlow C. Landphair, Texas Transportation Institute, The Texas A&M University, April 1989

PROBLEM 56: An Analysis of Design Features in Mitigating Highway Construction Impacts on Streams

The biological impact of stream relocation and culvert construction associated with the construction of the first

stage of the Allegheny Valley Expressway Completion Project are documented in the Final Report for Research Project 79-10, "The Impact of Stream Relocation on Fish Populations and Bottom Fauna." The second stage of this highway project, which includes additional stream relocation and construction of three miles of limited access highway was scheduled for completion in the fall of 1984. An analysis of the cost and effectiveness of the mitigative design features incorporated into the entire project (Stages 1 & 2) to post-construction biological evaluation of the stream is need to determine the total impact of the second stage construction. This information is important for increasing our understanding of the impacts of stream relocations and culvert construction and the cost effectiveness of mitigative design features.

Objectives

The objectives of this research are to (1) determine the effectiveness of the mitigative design features incorporated into the project to avoid or minimize the adverse stream impacts; (2) compare the design features; (3) determine the biological impacts of constructing the three miles of limited access highway in the Bull Creek and Little Bull Creek watersheds after all construction activities are completed and (4) produce an illustrated report and slide presentation which provide useful documentation for highway designers and environmental professionals to use in designing cost-effective mitigative design features for projects affecting streams.

Current Activities

a. Research in progress: not determined.
b. Related research activities: none known.

Urgency

There is an important need to understand the impacts of stream locations and culvert construction and the cost effectiveness of mitigative design features.

Cost: $50,000

Duration: 12 months

PROBLEM 57: Refertilization to Improve Existing Vegetation to Reduce Erosion and Weeds

Most projects receive fertilizer on initial installation and the grasses are not developed enough to utilize the supplied nutrients, then the areas receive no additional maintenance. Many projects are constructed with poor quality topsoil, and fertilizer in subsequent years would contribute to plant vigor, reduce weeds, and slow erosion.

Objectives

Research objectives are, develop specific rate of application, time of application, type of fertilizer , and cost effective method of operation.

The research objective should show that correctly supplied fertilizer will improve the erosion control potential of existing vegetation.

Current Activities

a. Research in progress: not determined.
b. Related research activities: In 1979 the Montana Department of Highways refertilized most of the interstate system with results the prime goal. No check plots were used and due to an abnormally wet spring and summer, it was difficult to quantitatively evaluate the response of the vegetation.

Urgency

With rising cost for maintenance, it is imperative that erosion be controlled. Improved vegetative vigor will reduce noxious weeds and control erosion.

Cost: $200,000

Duration: 5 years

PROBLEM 58: Assess the Benefits of Transportation Corridor Landscaping on Urban Heat Island Effect

Urban heat island effect is the increase in temperatures in urban areas caused from cutting down trees, introducing paving and roofs, and other dark, heat absorbing surfaces. Since 1940, there has been a steady increase in downtown temperatures of about 0.25 to 1.00°F per decade. If the global warming trend continues, then the summer heat island effect is even more critical to those living in our urban centers.

Typical electric demand in the cities increases about 1.5-2%/°F. Therefore, it has been estimated that 5 to 10% of the current urban electric demand is spent to cool buildings to compensate for the heat island effect. In major cities, there are no smog episodes below about

70°F, and smog becomes unacceptable by 90°F, so the rise of 10°F, because of past and future heat island effects, is very significant.

Objectives

Those studying this problem believe that it should be possible to reduce heat islands at the rate of about 1°F/decade through techniques such as using whiter surfaces (particularly asphalt, roofs and walls to transform heat absorbing surfaces into heat reflecting ones) and to replant trees to shade structures and their environs.*

The objective of this research would be to determine the potential positive effects of planting placed on transportation properties or other urban space to offset the loss of vegetation removed for transportation improvements.

Current Activities

a. Key Words-Urban Albedo, Anthropogenic condition, Microclimate, Urban Climatology, Urban Forests, Urban Forestry Plan, Urban Heat Island Effect, Urban Pollution, Urban Profile.

* Source of the above data is "Abstract, Recent Developments in Heat Island Studies: Technical and Policy", by Hashem Akbari, Art Rosenfeld, Haider Taha, Applied Science Division, Lawrence Berkeley Laboratory, University, of California, Berkeley, CA 94720, presented at a workshop on February 24, 1989.

b. RELATED RESEARCH ACTIVITIES-There has been considerable research activity, particularly in methods of measuring albedo and the effect of trees on buildings, in the area of Urban Heat Islands. Present knowledge and completed research will be employed to quantify potential reductions in the urban heat island effect.

Urgency

Urgent. The problem exists now. This project needs to get underway as soon as possible. The results will be valuable to transportation agencies planning and prioritizing future transportation projects that affect urban environments.

The urgency stems in part from the great length of time that it takes for trees to grow large enough to become effective. It will take a decade after planting, on average, for a tree to reach moderate size.

Cost: $250,000 over a three year period.

Statement Prepared by: Edward N. Kress, California Department of Transportation, April 1989.

PROBLEM 59: Assessment of Optimal Herb, Shrub, and Tree Species for Mitigation, Enhancement, and Restoration of Habitat Conversion by Channelization

Highways generally involve channelization during construction because of engineering constraints at stream crossings. Channelization is typically located in low-lying areas which are generally considered as the most valuable wildlife habitat. Because involvement with regulatory agencies is usually mandatory, mitigation is almost always requested on an acre-per-acre basis for the habitat converted. Due to difference physiographic regions located within geopolitical boundaries no single mixture of herbs, shrubs, and trees is applicable on a statewide basis. consequently, there exists a need for an appropriate selection of species on a physiographic basis which would optimize the restoration of habitat along channelized areas associated with highway construction.

Objectives

Identify those herbs, shrubs, and trees which would provide the optimal wildlife habitat, soil retention properties, reduced maintenance costs, and aesthetic qualities for areas of channelization of a physiographic basis.

Current Activities

a. Research in progress: not determined.

b. Related research activities: Investigations by private, state, and federal agencies primarily directed toward assessment of impacts of channelization. Other studies directed toward reclamation from introduced or non-native species.

Urgency

A continuing need exists for this information due to comments received from regulatory agencies on transportation projects

Cost: $300,000

Duration: 6 years

PROBLEM 60: An Engineering Approach to Roadside Vegetation Research

The management and control of roadside vegetation is a major recurring expense in each year's budget. Recent estimates in Texas alone, indicate that in fiscal 87-88 costs for mowing and herbicide application were about 50 million dollars. Each year these costs continue to increase, and will continue to do so, unless means are sought to actually reduce the requirement for mowing and spraying. Recent literature on the subject of vegetation management continues to focus on the cost effectiveness of mowing systems, herbicide application, and other chemicals as the primary means of vegetation management. This approach fails to recognize that the real problem lies in our understanding of the vegetation itself. This is clearly illustrated by the annual increase in the use of herbicides on the roadside to remove vegetation from troublesome places. What is not being recognized is that the offending plants are simply responding to a favorable habitat for growth and development. Herbicides are a "Band-Aid", not a cure. To solve the problem, the offending vegetation must be replaced with a plant that will be visually or structurally acceptable or the habitat created by the design of the structural element must be removed.

The focus of our vegetation management research efforts away from traditional agricultural methods and measurements and develop a new focus on the engineering properties of common roadside plants. In the context of the highway environment, it must be recognized that plants are an engineering material not an agronomic or horticultural subject. The principle has long been recognized with respect to soils which have a unique agricultural classification system as well as an engineering classification system. The same approach must be taken with plant materials.

Objectives

- To reduce the number and extent of mowing cycles required, while maintaining and improving the safety and visual appeal of driving environment.
- To reduce the need to use herbicides as a means of controlling undesirable vegetation.
- To identify and provide alternative design solutions to those roadside facilities and structures that contribute to increased use of herbicides and decrease mowing efficiency.
- To develop seeding and management techniques that will require very little mowing.
- To develop an engineering classification for common roadside plants and vegetation associations that can be used to guide designers and maintenance personnel.

Current Activities

a. Suggested Key Words: Vegetation Management, Roadside Maintenance, Landscape Design.

b. The methods for establishing and maintaining vegetation on highway rights-of-way has generally been extrapolated from or tested using standard agricultural research methods. This heat, air quality, soil (type and condition), economic level of maintenance, etc., and the primary reasons for the vegetative stand. In general, research done by agricultural interests seem to discount these very important differences. Agronomic interests usually focus on establishment, nutritional value, biomass production and to some degree cover and erosion protection. Turf science interests are looking for ornamental properties of color, mowing tolerance, seed head production, traffic resistance, density of turf, etc. For the most part none of these considerations is of any major concern in the highway environment.

This project proposes to build on the considerable body of research that currently exists but with a total change of focus away from agricultural concerns toward strong engineering emphasis. More specifically, this work proposes to look at roadside vegetation as an engineering material measuring its characteristics and value according to engineering concerns such as: behavioral characteristics of plants in roadside communities, resistance to encroachment, plant nuisance hazard, potential fire hazard value, hydraulic behavior in drainage channels, performance in highly compacted soils, potential root damage to pavement and roadbed, moisture holding characteristics in pavement edge environments, root strength and reinforcing value in slopes and embankments, silt and erosion protection characteristics, etc. These are all very important plant characteristics that is quantified could be used to good advantage by those charged with the responsibility of roadside design and management.

Urgency

The annual cost of roadside maintenance continues to mount and will continue to do so unless we begin a long range program of research that can considerably reduce the need for certain kinds of roadside maintenance. Vegetation with a mature height of 4 to 6 inches growing in the safety zone and around structures would only have to be mowed once in a while for cultural purposes. If the requirement for vigor is met, then the need to use

herbicides under guard rails and around supports would be eliminated. Vegetation associations that offer high reinforcing value in their root system could go a long way toward reducing shallow slope failures, grasses with good hydraulic characteristics will go a long way toward minimizing the need to spray and clean drainage ways.

This program is not one that can be accomplished in a short period of a few years. It will take patience and a commitment over time. However, the long term potential to produce meaningful savings in roadside maintenance will be worth the time and certainly the cost of the research. The organization of a project such as this would best be accomplished by the formation of a national consortium representing the various ecological zones of the country. One primary laboratory should be developed to provide the exotic equipment, specialized instrumentation, and laboratory facilities required to do specialized tasks. This facility would have the overall responsibility for directing the research program and coordinating the activities of the consortium.

a. Primary Laboratory Development Costs: $350,000. Annual operating expenses of main laboratory $120,000-$150,000. Annual operating costs of regional centers $35,000-$55,000. Total duration of project to produce meaningful reductions in maintenance costs estimated to be 10-15 years.

Statement Prepared by: Harlow C. Landphair, Texas Transportation Institute, The Texas A&M University, April 1989

PROBLEM 61: Root Zone Requirements of Trees in Pavements

Increasingly, the urban transportation systems use trees as one of the environmental impact-mitigation measures. A large number of these trees are surrounded by pavement. This pavement often causes root zones that are restricted and different from the natural, undisturbed environment. A less than favorable root zone will result in limited growth and greater susceptibility for diseases. Thus, often urban trees do not perform as desired and are costly to maintain.

Objectives

The objective of this research is to develop criteria for selection of tree species and root zone development and management in pavement areas. These criteria will be used to develop guidelines which will result in improved tree development and lower maintenance cost.

Consideration will be given to variables such as:

a. Tree Species/variety selection.
b. Soils.
c. Soil penetration resistance.
d. Groundwater availability.
e. Air exchange with adjacent soils.
f. Backfill mixture composition.
g. Pavement type (solid versus open).
h. Climate/evapotranspiration.
i. Environmental setting.

Current Activities

a. Research in progress: not determined
b. Related research activities: various research by:

Dr. C.E. Whitcomb-Oklahoma State University
Dr. T.O. Perry-North Carolina State

Urgency

Large numbers of trees are being planted in urban areas that, because of unfavorable root environments, will not develop to the size intended. Often maintenance and replacement costs involve large dollar amounts.

The research will take considerable time. Therefore, immediate start is urgent.

Implementation at state levels will result in improved performance of urban tree plantings, thus improved acceptance of new transportation facilities.

Cost: $60,000

Duration: 3 years

PROBLEM 62: Expediting Utility Adjustments on Highway Projects

The coordination of utility relocation and adjustment work on highway construction projects is one of the main causes of construction delays. Utility conflicts cause an increase in the cost of construction when contractors file claims for damages or request time extensions. Damage to utility plant is costly and public annoyance results from interruption of utility service. Also, injury of death can occur.

Some of the causes for delay are inadequate liaison and coordination in the preliminary engineering stage, the inability to locate and identify underground utilities, lack of mutual cost considerations, varying definitions of "Public Interest", inadequate right of way or late right of way acquisition, delays in processing approvals, unreliable project schedules, limited source of materials or work forces, insufficient cash flow, and organizational structures.

Objectives

It is the purpose of this problem statement to propose that a comprehensive study be made and recommendations suggested of the ways to expedite the relocation, adjustment and coordination of utility facilities on highway construction projects.

Cost: Funding $100,000

Urgency

Contract time period is 18 months.

PROBLEM 63: Utility Attachment to Highway Bridge Structures

Utility lines must cross streams, highways, railroads and other physical obstructions during their normal practice of connecting source or supply to treatment or usage. Construction of these crossings usually involve disturbance to the stream or traffic flow and always involve considerable expense to the utility owner.

There is a great disparity, from state to state, with regard to how and what utility is allowed to utilize a bridge structure to cross a physical obstruction.

Some governmental agencies do not allow a pipeline carrying certain hazardous materials on a bridge structure, while not limiting surface transportation, even though experience shows the likelihood of an incident involving the pipeline to be a fraction of that hazardous material transported via surface transportation. Some agencies do not permit utility access through bridge abutments; some do not permit anchor attachment to the bridge structure. A definite need exists to investigate the possibility of developing recommended design parameters for utility attachment to highway bridge structures that could be utilized by the various bridge authorities.

Objectives

a. Survey present installation practices on all types of highway bridges (freeway, limited access, primary/secondary roads and city streets).

b. Initiate study to quantify experience of the effects of utility attachment to bridges.

1. Effect of pipeline electrolysis
2. Effect of installation of hanger anchors
3. Effect due to use of utility sleeves (conduit)

c. Correlate data obtained from viewpoints of highway agency and utility.

Cost: Funds to be made available: $100,000.

Urgency

Contract time period: 24 months

PROBLEM 64: Clear Zones for New and Existing Aboveground Utilities Facilities

Utility facilities often represent the missing link to a "forgiving roadside." The presence of above ground utilities along the roadside represents a potential hazard to the motoring public as well as a potential liability problem for the utility owners. To date, it has been very difficult to accurately assess either the costs or benefits associated with instituting a roadside safety program for above ground utility structures.

Objectives

It is the purpose of this problem statement to propose that a comprehensive study be made of the costs and

economic benefits associated with the various options already available for providing a clear zone for new above ground utility facilities, during reconstruction on existing overhead facilities for highway purposes (both when utilities conflict with highway improvements and when utilities will not conflict with highway improvements), and as a single purpose safety retrofit procedure. The proposed study should include the impact of a safety treatment on any adjacent utility structures. Also the possible replacement hazards (i.e. a tree, bridge abutment,...etc. which was shielded by a utility pole would remain as a (possibly more serious) hazard even if the utility pole was removed) should be included in the proposed project.

Current Activities

a. Key Words are roadside safety, utility relocation, clear zone, and retrofit.

b. Related Research Activities-Several studies have been completed presenting the cost-effectiveness of various hypothetical safety treatments for above-ground utility structures; however, in most cases, little if any real cost or benefit data has been available. Since these earlier studies, there have been field demonstration projects as well as full-scale crash tests of successful retrofit and new installation designs. The additional information obtained from these projects makes possible a more comprehensive study of the cost-effectiveness of the available safety treatments for above ground utility facilities.

Urgency

In many locations above ground utility structures are the last remaining roadside hazard to the motoring public. Implementation of these research findings could result in immediate and dramatic reduction of serious fixed obstacle accidents along out nation's highways.

a. Estimated time to complete: 24 months

Cost: Estimated cost to accomplish: $150,000.

PROBLEM 65: Restoration of Utility Patches

The failure of utility excavation patches is a major cause of urban roadway deterioration. The proliferation of buried utilities and the aging of the basic underground facilities is resulting in the need for thousands of excavations each year in the streets of moderate sized cities. The resulting patches tend to sag and separate from the existing roadway. Any depressional lows wheels to drop, pounding the patch until it finally fails. Any separation allows water to enter the road base, softening it in the summer and in northern areas, freeze-thaw cycling. Any analysis of the problem must examine two elements: the backfill and the patch itself.

The backfill presents a number of problems. If the excavated material is reused, it is almost impossible to attain the density of compaction of undisturbed soil. To approach the best compaction requires very good equipment and excellent quality control and inspection. The problem is complicated in water works repairs because the excavated material is often mud which will not support traffic loading as backfill for months. Various materials have been used to replace the excavated material. Gravel, crushed stone, low strength soil concrete, and sand are common. The stone and concrete may not require much compaction; however, these substitutions for the original excavated material have different characteristics from the original soil. This is especially evident in the deep frost areas where many utilities require deep trenches and where the frost action is severe. The stone and concrete for example, may provide a stable surface elevation, bur during deep frost periods, the remaining roadbed may rise around it creating a pavement separation. It is difficult to match the expansion characteristics of the original soil.

Another problem arises from the disposal of excavated material. It is becoming difficult to find suitable disposal sites and often very expensive. Even if the excavated material is reused for backfill, it may be necessary to use a selected material such as sand for bedding and protecting the utility installation; therefore, there is always some surplus for disposal.

The remaining problem concerns the nature of the patch itself. Some road builders advocate a rigid concrete roadbed. The patch can then be cast of concrete with tapered sides so that it may bridge minor settlement in the backfill. This is practiced in Toronto, for example. Otherwise, it is difficult to compensate for backfill problems with patch construction. The stresses upon the patch make it very difficult to establish a lasting seal around its periphery. All of these problems become exaggerated in cold regions with extensive frost.

Objective

It is proposed that a survey be made of practices and results of backfill and pavement patching in the major cities with special attention to the effects of frost. The survey could include the number of lane miles involved,

number of patches and patch failures per year, backfill material technique, pavement and patch construction and patch edge sealing technique.

Cost: Funding: $40,000

Urgency

Contract time period: 9 months

PROBLEM 66: Analysis of the Transportation 2020 Programs as to the Effects on Existing and Future Utility Accommodations on Highway and Other Public Rights-of-Way

America is nearing the completion of the largest public infrastructure project in the history of this nation (the Interstate and Defense Highway System). In recognition of this and the need to redefine and refocus America's surface transportation program, the American Association of State Highway and Transportation Officials (AASHTO) initiated the TRANSPORTATION 2020 program.

Plans and proposals are being developed by the Transportation Alternatives Group (TAG), and umbrella organization funded by private industry, public-sector groups and corporate foundations. TAG is discussing and studying 132 issues that could affect future legislation for post-interstate Highway and Transit funded programs. Issues such as competition for road space, land use relationships, highway safety, rural access, suburban congestion and privatization can have direct effect on utility operations regarding the technical and legal aspects of accommodation, relocation, maintenance and planning.

Information on the various aspects, policies, proposals and trends being developed by TRANSPORTATION 2020 will be of assistance to utilities. This is especially evident as there has been no known utility industry input or evaluation of needs, interests or even assistance that may be warranted in such planning.

Objectives

It is proposed that a review and study be made of the TRANSPORTATION 2020 alternatives and recommendations as to their long and short term effect on utilities. Such analysis would cover areas that would affect the utilities use and accommodation on public rights-of-way, aspects of private sector highway funding, liaison requirements, relocation needs and arrangements. This study would also reflect possible changes or revisions from present Federal and AASHTO regulations and guidelines.

Cost: Funding: $30,000

Urgency

Research time: 6 months

PROBLEM 67: Utility/Roadway Authority/Contractor Roadway Project Liaison Principals and Suggested Guidelines

Ineffective liaison or lack of liaison between utilities, roadway authorities and contractors is a common problem. The problems have increased as roadway officials have:

a. Accelerated their construction schedules in order to maintain the Nation's deteriorating roadway infrastructure. Thereby shorting the planning and construction intervals of the affected utilities.

b. Begun to acquire right of way for road projects well in advance of the actual engineering and construction (or reconstruction) of a roadway. Thereby causing utility conflicts that otherwise could possibly be avoided.

c. Allowed land developers to fund highways to new developments, ahead of when they might otherwise have been constructed. Thereby changing and shorting the planning and construction intervals of the affected utilities.

Since utilities, of all types, occupy a majority of the nation's roads, effective liaison is necessary to assure that utilities can budget, schedule and accomplish their relocation work to eliminate, or at least, minimize utility delays of roadway construction. In addition to delays, ineffective liaison causes increased cost to all parties involved, due to idle equipment time, rush work, damaged plant, revised plans, unusable materials and contractual cost penalties.

Past efforts to address this problem include:

1. A slide/tape presentation, titled "Three Phases of Liaison", which was made about fifteen years ago and which was recently updated as a presentation to the International Right of Way Association, June 1988, Seminar in Baltimore, MD
2. A mid-1960 vintage 16 mm film covered this same subject but that is now outdated as to the media format, as well as the styles of clothes, vintage of vehicles,...etc. used for the movie.

Objectives

It is proposed that an updated presentation on effective liaison should be made. A videotape would be the preferable medium. The purpose of the presentation would be as a training aid for utilities, roadway authorities, consultants and construction contractors to encourage all those involved to practice good coordination techniques. This presentation would also be useful for showing at local utility coordination meetings and other group meetings related to general coordination and liaison efforts.

Cost: Research and development of subject: $10,000, Video Production: $25,000, Total: $35,000

Urgency

Estimated time: 6 months.

PROBLEM 68: Utility Relocation and Accommodation: An Analysis of the Legal Aspects

State highway agencies have a continuing need for updated information covering the legal aspects of relocation of utility facilities on highway projects. Further, it would be useful if information could be summarized on State utility relocation payment practices when other public projects, such as light rail or urban renewal, require adjustment of utilities located within public road and street rights-of-way. A summary of State approaches to the recent Uniform Relocation Act amendments would also be of interest.

Additionally, information regarding the legal aspects of utility use and occupancy of public right-of-way would be a most useful addition. Information on historical legal trends, recent changes, and current practices, both at the State and Federal level, should be compiled.

Objectives

It is proposed that a comprehensive study be made of the legal aspects of:

a.Payment for relocation of utility facilities on highway projects and other public purpose projects.

b. Utility use and occupancy of highway right-of-way.

The study would summarize and update information on the legal aspects of utility relocation presented in the three TRB documents cited above. It would also be expanded to include information on the legal aspects of relocation for other public purpose projects and the aspects of utility accommodation.

Current Activities

a. Key Words-Utility relocation, utility accommodation and legal aspects.

b. Related Research Activities-Information on the states' legal authority to pay for utility relocations on highway projects was published in Special Report 21, "Relocation of Public Utilities Due to Highway Improvement, An Analysis of Legal Aspects," (1955). Experience over the next decade was then presented in Special Report 91, "Relocation of Public Utilities 1956-1966, An Analysis of Legal Aspects," (1966). The last updating on these matters was Research Results Digest 116, "Payments to Public Utilities for Relocation of Facilities in Highway Rights-of-way," (1980).

Urgency

Up-to-date information on State law regarding utility use of highway right-of-way and payment for utility adjustments on public projects is of immediate use to most states.

a. Estimated time to complete: 18 months

Cost: Estimated cost to accomplish: $125,000

A2B01 Committee on Pavement Management Systems

PROBLEM 69: Interfacing Network and Project-Level Pavement Management Systems

A comprehensive Pavement Management System (PMS) is designed to assist in decision-making at two levels--network and project. The network-level PMS addresses programmatic and policy decisions for an entire highway network. These decisions include: establishing pavement preservation policies, identifying maintenance priorities, and estimating and allocating maintenance budgets.

Engineering decisions related to the selection of rehabilitation actions for individual projects are analyzed by the project-level PMS.

Although the two levels of a PMS are distinct in terms of their objectives and intended users, they need to be compatible and consistent with each other. For example, the selection of rehabilitation actions for individual projects should match with network policies regarding the appropriate combination of pavement conditions, and traffic and environmental factors for which a specific type of a rehabilitation action should be selected. The project-level decisions should also satisfy constraints on total available pavement preservation budget for the network and the minimum performance standards for individual projects implied by the network-level analysis.

Objectives

The primary objective of the proposed study is to develop a methodology for interfacing the network and project-level subsystems of an overall PMS. The current PMS technology adequately addresses the development of the two individual subsystems, but is lacking with regard to achieving consistency between them.

Frequently, the decisions regarding the selection of projects for rehabilitation and the choice of specific actions for individual projects are made by district personnel. These decisions may not reflect the network perspective of the headquarters administrators, namely to maintain the overall network of pavements in acceptable conditions with minimal total cost. The interfacing methodology between the network and project-level PMS subsystems should take into account these differing perspectives and provide an appropriate balance between them. The methodology should also account for the differences between the amount, types, and accuracy of data available at the network and project levels. For example, much more detailed data on such factors as deflection, core tests, and material properties would be generally available only at the project level.

Since the PMS developed by different highway agencies vary widely with regard to the types of data and methods of analysis, the interfacing methodology to be developed in this study should be sufficiently flexible to permit its application to the variety of network and project-level systems currently in use.

Accomplishment of the research objectives will involve the following specific tasks:

a. Task 1-Define the key requirements for the methodology to interface the network and project-level PMS subsystems.

b. Task 2-Evaluate pros and cons of the alternative approaches to developing the interfacing methodology and identify the methodology which could best meet the requirements identified in Task 1.

c. Task 3-Develop the analytical models and necessary software for the methodology identified in Task 2.

d. Task 4-Test the methodology, and revise as appropriate, for two highway agencies which have existing PMS with different characteristics.

e. Task 5-Document the methodology, software, and test results in a final report.

Current Activities

a. Many highway agencies are implementing network level pavement management systems. A few agencies are developing project level systems. However little work is ongoing to interface network and project level PMS.

b. Suggested Key Words-Pavement Management, Network Management Systems and Project Management Systems.

PROBLEM 70: Basic Research in Pavement Management Concepts

In 1965, a major open ended research project was developed in NCHRP as a result of problem statements presented at TRB. This was NCHRP-10 and resulted in the development of pavement management concepts.

Since that early work, PMS has developed well, and most states and major cities are now implementing PMS is some form. However, no basic research has been funded in pavement management since the mid 1970's. Implementation is very worthwhile. However, it is now essential to initiate broad basic research in Pavement

Management. Such research will point the way for progress over the next 20 years as NCHRP 1-10 did for the past 20 years.

Objectives

Important subtopics of proposed research include:

a. A study of the interface of PMS with BMS and other aspects of Highway Management.
b. Research into the organizational and institutional aspects of good PMS. We must understand these institutional issues to truly move forward.
c. Evaluation of true optimization aspects and economics as major tools in improved pavement management.
d. Introduction of "benefits" into the data processing and decision making aspects of Pavement Management.

Potential Implementation

Every state, county and major city in the world can use the results to save great amounts of money.

Interface With SHRP

There is much misunderstanding about PMS and its interface with SHRP. SHRP is structured to produce a great deal of new pavement information. This information will be useful in PMS but it will not advance the state of the art of the concepts of improved management.

Cost

A three year project funded at $500,000 minimum is needed to advance the frontiers of Pavement Management. This project should begin as soon as possible and not later than January 1, 1991.

PROBLEM 71: PMS Performance Models

The Federal Highway Administration has mandated that all state highway agencies shall develop and implement a Pavement Management System for their roadway system by 1993. Most state agencies have begun this implementation process; however, the complexity and details of each PMS program vary widely across the U.S. In addition to the state agencies, many local governmental agencies (cities and counties) are also in the process of implementing and maintaining a PMS program. One of the weaknesses of these programs is the pavement performance models which are critical to an affective long term prediction/planning tool for budget preparation and prioritization of funds.

In response to this weakness, one of the goals of the SHRP LTPP program is to collect pavement performance and other structure data for developing performance models in support of PMS programs. In specific, the SHRP LTPP project P020 is to generate improved models for pavement design and pavement management. These improvements should include traffic, environmental and subgrade effects on pavement structures. However, all models for each distress that are to be developed from P020 will be confined to the type of materials data and performance measurement, being collected on the GPS (General Pavement Studies) projects. These type of data may not be compatible with a particular state agency's data base and models initially included in the PMS to predict pavement performance. Material properties will be measured with different types of equipment and the performance measurements could be different. Thus, there will be, in all probability, compatibility problems with using the SHRP results or models.

Objectives

As such, there appears to be a need to: first, review the type of models (performance measures considered and required input data currently being developed for PMS in the state agencies; secondly, determine if there is sufficient data so that state agencies can use the LTPP data base to develop and/or verify these performance models in their own system; and thirdly, determine if the expected models developed in P020 can be implemented and directly incorporated into the PMS process. It is expected that some of the significant independent variables included in the models from P020 may not be available to the state agencies on their roadways. Thus, there is also a need for a simplified procedure to generate and verify these models through data and correlations from the state agencies roadways compared to that being collected by SHRP.

Rather than restrict state agencies from using the P020 results, PMS model implementation should be closely coordinated to ensure that any discrepancies or differences are pointed out and minimized.

Current Activities

a. Suggested Key Words-Pavement management, performance models.

b. FHWA has a short course to advance PMS activities. A third International Conference on PMS is being developed.

Urgency

Many agencies are now involved in PMS development and implementation. The SHRP LTPP project P020 will be initiated in 1990 to develop improved models for pavement management. This proposed project would assist agencies in the implementation of the P020 results and identify procedures to be used to eliminate or minimize compatibility problems between existing data bases and future models

Cost: Estimated cost is $150,000

PROBLEM 72: Integration of PMS into Roadway Management

The Federal Highway Administration has mandated that all state highway agencies develop and adopt a pavement management system by 1993. Many local agencies, cities and counties have also developed or adopted pavement management systems. As these are used, it becomes apparent that other elements compete for funds with pavement maintenance. Some pavement management systems include information about drainage in the data structure. Bridge management systems are currently under development and study.

Other elements related to the pavement and highway could be integrated with the pavement management. These include drainage ditches, culverts, and other related elements. The pavements compete for funds with all of the other roadway elements including bridges, drainage, signage, guardrails, etc. In addition, such activities as right-of-way mowing consume funds from the highway budget. Mowing is often considered only aesthetic activity; however, failure to mow the right-of-way may lead to earlier drainage ditch blockage.

The pavement management systems should be developed to allow integration of fund needs with the other infrastructure elements in the roadway system to allow unified fun needs determination. Methods to connect the pavement management systems to maintenance management systems need to be developed. The roadway management system should also provide a mechanism to consider the impact of funding allocation to each element on the performance of the overall roadway system.

Objectives

The objectives are to develop approaches which can be used to integrate other roadway elements into the pavement management system, to develop methods to connect the pavement management system to maintenance management systems, and to determine how to allocate funds among the several elements in a roadway system such as the pavement, drainage, bridges, signage, etc...

Current Activities

a. Suggested Key Words-Pavement management, infrastructure management system, and roadway management.

b. FHWA is short course on advance PMS activities. A third International Conference on PMS is being developed.

Urgency

Many agencies are involved in PMS development and implementation. This would assist them in developing a more complete roadway management system and would provide a more accurate method to distribute funds among the various activities.

Cost: $400,000

PROBLEM 73: PMS Implementation

The Federal Highway Administration has mandated that all state highway agencies develop and adopt a pavement management system by 1993. Several agencies have already developed systems. Many local agencies, cities and counties have also developed or adopted pavement management systems. However, it appears that the analysis of results of these systems are often not used to their full potential. In some agencies, those personnel who should be using the results to assist with their decision making refuse to use the results. In other agencies, results of the analysis are not used to assist with the budget process.

Developing and adopting a PMS is only one element of effective pavement management. We must get all of those affected by PMS to use the system. There is the feeling among the users of the PMS, that the concern expressed about use, is from the developers of the system who are miffed that their work is not being used. The intent of this problem statement is to address how

to make the PMS a usable tool at all levels where it can assist pavement professionals. This will require that a communication dialogue be developed between the developers and users, both downward and upward. It may also require that the developers modify the PMS to provide different information, or present the current information in a different form.

Objectives

To develop guidelines for implementation of a PMS which will assist an agency in developing a PMS which addresses the needs of each potential user and how to establish and conduct the necessary dialogue among users required to develop full usage of the PMS. This will include use by district personnel and by those who develop budget requests and justification.

Current Activities

a. Suggested Key Words-Pavement management, implementation of pavement management systems.

b. FHWA is short course on advance PMS activities. A third International Conference on PMS is being developed.

Urgency

Many agencies are involved in PMS development and implementation. This should assist them in structuring their system to make it more usable at all levels. It should also assist those with existing systems by helping them get the most effective return on their investment in a PMS.

Cost: $200,000

PROBLEM 74: Development of Sub-Base Friction Information for use in Design of Concrete Pavements

Mid-slab cracking has been experienced in a number of jointed reinforced concrete pavements, and this has been followed by wide cracks, then faulting that produces a rough riding pavement. With CRCP, occasionally a much smaller crack spacing occurs than planned in design, thereby increasing the probability of punchouts. Both of these problems maybe traced to the friction characteristics between the slab and the sub-base.

An important parameter in the design of CRCP and JRCP is the frictional resistance to movement that is developed at the interface between a concrete pavement slab and the sub-base. This factor affects the joint movement and selection of the percent steel (longitudinal and transverse) in jointed concrete pavements. It also affects the crack spacing, crack width and amount of steel needed in a continuously reinforced concrete pavement. Unfortunately, all studies reported in the literature for this type of data were developed for smooth sand and granular type sub-bases. For a number of years, stabilized sub-bases have been used under portland cement concrete pavements and the frictional characteristics are substantially different. Thus, at the present time, designers must "guesstimate" the friction characteristics of the sub-base material.

Objectives

The objective of this research is to determine the coefficient of friction between PCC rigid slabs and the various types of sub-bases currently being used and anticipated in the future. A review of all the currently used sub-base types would be made for the measurement program. These studies would be made on test slabs and verified to a limited extent by observation on small slabs cost at actual construction projects. Information could be compiled into charts that may be inserted into the design manuals.

Current Activities

Suggested Key Words: Coefficient of friction, crack, crackspacing, joint movement and rigid pavements.

Urgency

The information collected for each of the sub-base types would be compiled into tables for insertion into design manuals. Designers would than have the proper properties for sub-base friction, thus more reliable reinforcement designs for projects currently being designed.

PROBLEM 75: Construction and Evaluation of Roller Compacted Concrete Pavement Structures

Roller compacted concrete has been used primarily in massive concrete structures. Now agencies are considering building pavement structures with roller compacted concrete. These are often for heavy intermodal transfer facilities. Presently, no design procedures are available to assist in design of these structures, especially for heavy freight transfer equipment.

Objectives

Roller compacted concrete is a relatively new material which seems to have significant cost advantages over conventional concrete pavements in some circumstances. The objective of this research is to construct roller compacted test sections and observe their performance under various traffic loading conditions. A follow-on goal is development of a design approach considering both thickness and jointing requirements.

Current Activities

a. Roller compacted concrete has been used more widely in heavy duty, intermodal facilities.

b. Suggested Key Words-roller compacted, concrete, response and performance.

Urgency

The roller compacted concrete may present a viable alternative to conventionally constructed concrete pavements. Performance of existing installations needs to be monitored.

PROBLEM 76: Evaluation of the Performance of Rigid Pavement Rehabilitation Strategies: Restoration Versus Structural Rehabilitation

In recent years, there has been tremendous emphasis and funding of concrete pavement restoration (CPR)

projects. CPR techniques are intended only to restore to the structural integrity of the existing pavement. During the preliminary engineering of proposed rehabilitation projects, however, very little attention has been given to estimating the remaining structural life of that pavement. As a result, CPR has been attempted on some pavements which have already served as much as two to three times their original deign traffic (have little or no remaining structural life) and where structural improvement through major rehabilitation was warranted. Conversely, there are examples where major rehabilitation such as cracking and seating with a structural overlay have been completed on sound pavements with remaining load carrying capacity. Presently, no criteria exists to aid the designer in determining the appropriate rehabilitation strategy: restoration vs. major rehabilitation.

Objectives

The objective of this research is to evaluate the performance of rigid pavement rehabilitation strategies (restoration and structural rehabilitation) on similar pavements and traffic conditions for the development of guidelines for determining when rigid pavement restoration or major rehabilitation is appropriate. The research should consider current methods of evaluating remaining structural life, long term pavement performance monitoring (serviceability vs. accumulated loading) and life-cycle cost analyses of the various rehabilitation techniques including their performance.

Current Activities

a. Research has been completed to estimate remaining structural life based on non-destructive deflection testing.

b. Ongoing and completed research provide syntheses of the current state-of-the-practice and cost performance data associated with a variety f rehabilitation techniques.

c. Suggested Key Words-restoration, rehabilitation, rigid pavements, performance, and life cycle cost.

Urgency

Considering current levels of funding expended on rigid pavement rehabilitation, this research is considered critical.

PROBLEM 77: Effect of Joints on the Response, Design and Performance of Rigid Pavements

Much of the distresses observed in rigid pavements initiates at a construction joint. The effect of various types of joints on the response, design and performance of rigid pavements has been a subject of extensive studies for more than half a century.

However, due to the lack or analytical methods, most of these studies were empirical in nature and the voluminous data collected were not analyzed theoretically. It is only recently that several pavement computer response models based on the finite element methods were developed for the analysis of jointed pavement slabs. To rationally evaluate the effect of joints on pavement response design and performance, a review of previous studies in light of these new response models is needed.

Objectives

The objectives of this research are:

a. To evaluate existing jointed pavement computer models and compare the computed stresses and deflections with experimental measurements.

b. To modify the models, if needed, so that strains, stresses and deflections in jointed slabs can be determined under various field conditions.

c. To establish design criteria for slabs and joints and predict their performance based on the computed strains, stresses and deflections.

Current Activities

A large volume of experimental data are available in literature; such as the well-publicized investigations by the U.S. Bureau of Public Roads in the 1930's, by the U.S. Corps of Engineers in the 1940's, and by the Maryland and the AASHTO road in the 1950's, as well as the studies currently undertaken by various Federal, State and private agencies. Several pavement computer models based on Winkler, Bousinesq and layered foundations are also available.

a. Suggested Key Words-Rigid pavements, joints, computer models, finite element method, design, performance and field measurements.

Urgency

The provision of adequate joints for rigid pavements has been a major problem since their inception. With the advent of high speed computers and the finite element

methods of analysis, it is now possible to develop a rational method for evaluating the effect of joints on the response, design and performance of rigid pavements. This problem is important not only for the design of new pavements, but also for the maintenance or rehabilitation of existing pavements. The ability to determine pavement response and predict pavement performance based on the existing conditions of slabs and joints will make possible the implementation of remedial measures at an appropriate time with considerable savings.

PROBLEM 78: Study of the Effects of Non-Uniform Foundation Support for Rigid Pavement Slabs

Distress in rigid pavement can be related to the non-uniformity of support for the slabs resulting from such phenomena as warping or curling of the slabs, localized weakening of the foundation materials due to moisture, freezing and thawing, differential subgrade movements and erosion of foundation material due to pumping action. Since most, if not all, current design procedures assume uniform foundation support, the non-uniformity that develops results in premature slab cracking and/or unacceptable roughness requiring excessive maintenance or early rehabilitation.

Objectives

The objectives of this research are to assess the effects of non-uniform foundation support on the response and performance of rigid pavements and to develop design methods that consider the effects of non-uniform support on slab response and select appropriate factors to produce a rigid pavement that will yield satisfactory performance for the desired traffic levels.

Current Activities

a. Highway research in progress has already been scanned in preparing this statement.

b. Suggested Key Words-rigid pavements, distress, foundation support, voids and joints.

c. Several projects are determining the performance of rigid pavements and assessing both their structural and functional conditions; however, little, if anything, is being done to determine how much of the adverse performance is attributable to non-uniform foundation support. In addition, only limited work has been accomplished to identify the sizes of voids inpavements and to introduce methodology which will recognize and account for non-uniform foundation support in design procedures.

Urgency

The study on non-uniform foundation support for rigid pavements is considered highly important to the development of design which will have higher probability of planned performance and thus savings of maintenance or rehabilitation resources.

PROBLEM 79: Validation of the Performance of Composite Design In Rigid Pavement Structures (with Special Application to Econocrete Composite Base Pavements)

For many areas of the nation where quality concrete aggregates have become scarce or depleted, economy and ecology considerations may dictate the use of lesser quality aggregates. These aggregates may be incorporated into an econocrete composite base structure upon which is placed a relatively thin bonded wearing course. Presently, no design procedure is available to permit design of a composite rigid pavement.

Objectives

The objectives of this research is to validate a rational design procedure for composite rigid pavements structures using econocrete composite sub-base containing lesser quality aggregate and a high quality, thin bonded wearing course. The focus of the research is correlation of actual full scale field performance of selected test sections with predicted performance based upon theoretical concepts.

Current Activities

a. Econocrete has found its widest use as a sub-base for rigid pavements or as abase for flexible pavements. It has also been used for pavement shoulders, walkways and light traffic roads. Layered system theory has been applied to provide a rational design procedure for composite pavements, but additional theoretical, laboratory and field work is still required to produce reliable predictions of performance.

b. Suggested Key Words-econocrete, composite rigid pavements and aggregates.

Urgency

This composite econocrete pavement system is a viable solution to pavement needs in areas deficient in quality

aggregates, offering, in many cases, economical, environmental and energy advantages.

PROBLEM 80: A Study of Subsealing as a Rehabilitation Technique for Portland Cement Concrete Pavement (PCCP)

The FHWA, industry and construction-related associations are currently promoting the use of cement/pozzolan materials to fill voids under PCCP's by subsealing, to restore "full slab support". It has been well established by previous research that most PCCP slab edges are in an upward curled or warped condition, to some extent, on a daily basis. Thus, "full slab support" is a condition that has seldom existed since the pavement was placed in service and, if reestablished when the slabs are curled, could possibly be detrimental. Also, subsealing experience indicates that there is no reliable methodology to determine the location of voids in the structural section, nor is there general agreement on the most appropriate type of material to use for PCCP subsealing.

Objectives

The primary objective of this research is to determine the effectiveness of subsealing as a means to extend the service life of PCCP. A secondary objective is to analyze the effect on future pavement performance of introducing a non-yielding grout into the voids between the PCCP and base.

Current Activities

a. Little or no research has been completed that addresses the desirability or likelihood of obtaining full PCCP support via "subsealing".

b. Some projects that were "subsealed" in 1982 are now exhibiting severe distress in the form of slab break-up.

c. The use of deflection and radar devices to locate voids prior to subsealing have met with mixed results.

d. Relatively small amounts of grout implacement are being accomplished on many projects involving PCCP subsealing.

e. Edgedrains placed as part of subsealing projects have since become plugged with a fine material that may be the subsealing grout that has been pulverized by deflecting slabs and then deposited in the drains by surface water infiltration.

f. Suggested Key Words: Rigid pavements, warping, curling, pumping, base support, cement, pozzolans, and injection.

Urgency

This study of PCCP subsealing is considered urgent due to the amount of this form of rehabilitation presently underway. The construction difficulties being encountered and, of even greater importance, the erratic results being obtained per subsequent inservice pavement performance, make it imperative that this technique be investigated to determine its effect on "rehabilitated" PCCP service life.

A2B05 Committee on Strength and Deformation Characteristics of Pavement Sections

PROBLEM 81: Development of Nondestructive Testing Equipment and Analytical Procedures for Improved Reliability in Pavement Layer Modulus Evaluation

The nondestructive testing (NDT) equipment currently employed for deflection basin measurements incorporate either low frequency cyclic or dynamic impact systems. These systems have been developed with the intent of providing a fast and reliable system for evaluation of the structural response and adequacy of pavements. In the evolutionary process of NDT equipment development, there has been considerable emphasis on providing load magnitudes that are similar to those produced by trucks and aircraft. However, the primary purpose is to obtain load-deflection data for the prediction of pavement layer moduli that can be used in mechanistic analyses for evaluation of pavement stresses and pavement rehabilitation needs (design).

In general, the NDT loading system uses either dual tires or wheels, a single plate, or two smaller plates positioned to simulate a truck's dual tire spacing. These loading configurations are so closely spaced that the pavement response as measured by deflection sensors is a single depressed basin which is more sensitive to the stiffness of lower pavement layers and subgrade than the upper layers (e.g., asphalt concrete and base course). Current methods for the back-calculation of moduli in three and four layer pavement systems often produce erroneous or highly variable results for E-1 or E-2 moduli, particularly when the initial estimate of moduli deviates excessively from actual layer moduli. It is not unusual in four layer back-calculation analyses to have exceptionally low base course moduli (E-2) and extremely high subbase moduli (E3) because of the NDT system's lack of sensitivity to upper layer stiffness. Also, the magnitude of load, sensor spacing and precision, pavement temperature relative to the modulus of the asphalt concrete, and excessive variability in deflections and/or layer thickness along a segment of pavement can contribute to the difficulties encountered in predicting reasonable values of layer moduli for subsequent stress on performance related analyses. Another important factor is the reduction in reliability as the number of layers increase in the iteration or back-calculation procedures for layer moduli evaluation. These problems may be alleviated by redesign of NDT loading and sensor configurations to provide improved deflection sensitivity of upper pavement layers (e.g., widely spaced dual loading to produce dual basins-doublebending). Secondly, improved analytical methods which would preferable provide reasonable estimates of layer moduli with or without additional back-calculation analyses. Therefore, research is needed to evaluate and optimize NDT load-sensor configurations and analytical methods for pavement layer moduli evaluation.

Objective

The primary objective of this research is to identify the optimum dual load spacing(s) and deflection sensor configuration(s) that will provide increased accuracy in the determination of layer moduli for pavement systems with four or more layers. Specific objectives include:

a. Evaluation of plate size (e.g., FWD) effects on deflection using direct measurements and analytical procedures.

b. Analytical evaluation to identify optimal load-sensor locations and development of equations and analytical procedures for prediction of layer moduli.

c. Construct or modify NDT equipment (e.g., FWD) conforming to the optimized load-sensor configuration and verify its operational capabilities and those of the developed analytical procedures (B) on existing pavements.

d. Provide complete documentation of the research including all applicable computer programs and analytical methods with complete instructions for their use in pavement evaluation studies.

Current Activities

a. Key Words: Nondestructive testing, load-sensor configuration, layer moduli evaluation.

b. Related Research Activities:

1. Analytical evaluation of the Dynaflect has resulted in the development of a sensor configuration utilizing double bending deflection response and direct prediction of the composite modulus (E-1,2) for asphalt concrete and base course, subbase modulus E-3, and subgrade modulus (E-4). Tests conducted on existing pavements were used to develop simple power law equations for layer moduli predictions that are as reliable as the more complex equations from the analytical study. However, the precision of the Dynaflect

measurement system is inadequate for stiff pavement systems (lowdeflections) primarily due to its extremely light loading capability. Experimental data and associated analytical studies of the FWD suggest that the diameter of the loading plate influences maximum deflection values on pavements with low moduli (high temperature) asphalt concrete and low stiffness pavements (2,4). The single plate loading does not appear to provide adequate sensitivity for reliable upper layer moduli evaluation except where modulus-thickness combinations produce every high stiffness in the base and/or asphalt concrete layers.

References

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c. Badu Tweneboah, K.,M. Tia and B.E. Ruth, "Procedures for Estimation of Asphalt Concrete Pavement Moduli at Institute Temperatures," Transportation Research Record 1121, Transportation Research Board, 1987, pp. 1-6.

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Urgency

The evaluation of pavements for structural adequacy and for assessment of future rehabilitation needs is highly dependent upon the adequacy of nondestructive testing procedures and analytical methods for layer moduli determinations. The development of improved and more reliable techniques for this purpose would provide highway engineers with a data base which would facilitate the use of mechanistic methods for rehabilitation design of pavement structures prior to the development of excessive distress or deterioration.

Cost: Estimated cost is $350,000.

PROBLEM 82: Determination of Strength Parameters of Unbound Granular Pavement Layers

Unbound granular pavement layers constitute the major structural component of many pavements around the world, especially in lower volume roads. Although many of these have provided appropriate levels of service for many years, the current traffic loads appear to be causing more rapid deterioration of the pavement structure than in the past. The current methods of determining the modulus of these layers including how the modulus changes with stress states in unbound granular layers do not appear to fully model the stress and strain states which develop within these layers.

Objectives

To develop a methodology for characterizing the modulus and how it changes with stress state within unbound granular layers.

Current Activities

a. Suggested Key Words: Pavement layers, modulus and granular materials.

b. The third symposium on use of unbound granular layers in roads held at the University of Nottingham in Nottingham, England in April 1989

Urgency

Most agencies use unbound granular layers in lower volume pavements. Some agencies use them in high volume pavements as well. The performance of these layers appears to be decreasing with the change in traffic loads. To determine the actual cause of the problems and develop logical approaches to address the problem, methodologies which define the potential permanent deformation of these layers are needed.

Cost: Estimated cost is $350,000.

PROBLEM 83: Determination of Permanent Deformation Parameters of Unbound Granular Pavement Layers

Unbound granular pavement layers constitute the major structural component of many pavements around the world, especially in lower volume roads. Although many of these have provided appropriate levels of service for many years, the current traffic loads appear to be

creating ruts within the pavement structure more rapidly than in the past. The current methods of characterizing the permanent deformation potential in unbound granular layers do not appear to fully model the stress and strain states which develop within these layers.

Objectives

To develop a methodology for characterizing the permanent deformation potential within granular layers and to model the expected deformation for given and to model the expected deformation for given support, loading and environmental conditions.

Current Activities

a. Suggested Key Words

Pavement Layers
Permanent Deformation
Granular Materials

b. The third symposium on use of unbound granular layers in roads will be held at the University of Nottingham England during April 1989. The U.S. Air Force is sponsoring research on rutting in flexible pavements on granular bases for airfield loads with high tire pressures.

Urgency

Most agencies use unbound granular layers in lower volume pavements. Some agencies use them in high volume pavements as well. The performance of these layers appear to be decreasing with the change in traffic loads. To determine the actual cause of the problems and develop logical approaches to address the problem, methodologies which define the potential permanent deformation of these layers are needed.

Estimated Cost: $350,000

Statement prepared by: R.E. Smith

A2B08 Committee on Vehicle Counting, Classification, and Weigh-in-Motion Systems

PROBLEM 84: Use of Weigh-in-Motion Data for Calculating ESAL's

Pavement thickness design equations are heavily dependent on axle loading estimates for the design life of each pavement section. Axle loading estimates are truck weight data that have been collected by each state and transformed into estimates of equivalent standard axle loads (ESAL's). The equations used to convert axle weight estimates to ESAL's were designed to use static axle weight measurements, not dynamic or in-motion weight estimates. However, weigh-in-motion (WIM) equipment is quickly becoming the standard means of collecting truck weight data in many states, and this new standard is causing concern because WIM data vary somewhat from static weight data.

Because a truck's axles bounce as the vehicle moves down the highway, axle weights reported by WIM equipment are more variable (i.e., they contain more heavy and light axles and fewer "middle" axles) than those same axles reported by static measurement. This wider distribution of axle weights causes a systematic overestimation of ESAL values because of the mathematical properties of the fourth power equation used to make the conversion. When translated into many pavements designs, this systematic overestimation will produce a serious over-design of pavements and a sub-optimal expenditure of highway funds.

Suggested Solution

Until the pavement design equations can be rewritten to assume WIM data as input to the design process, the conversion of axle weight data to ESAL estimates must be revised to reflect the changes taking place in the data collection methodology. Two potential solutions to this are readily apparent.

a. Develop a "packing" algorithm that takes WIM system calibration data (which provide a good measure of the relationship between static and WIM weight values at each WIM site) and adjusts the collected WIM data to more accurately represent the axle weight distribution that could be expected from weighing that same set of axles statically. This "packing" process would reduce the number of heavy and light axles, while providing an increase in the number of "middle" axle weights. The "middle" weights would be defined by the mean of the axle population.

b. Revise the equations used to convert axle weights to ESAL's so that they are slightly less sensitive to the increased number of heavy axles expected from WIM data.

PROBLEM 85: Increased Dynamic Forces on Rigid Pavements Due to Extreme Cold Weather

Rigid pavements on I-90 in Minnesota curled badly during the extreme cold temperatures experienced during the first week of February 1989. The curl was severe enough to cause shadows across the pavement caused by headlights during the pre-dawn hours. Trucks were traveling at a maximum of 55 mph, drivers were bouncing badly in the tractors, and trailer frames were oscillating at least 1.5 inches vertically due to relatively short slab lengths and severe curling caused by below zero temperatures at the surface and suspected much warmer temperatures at the bottom of the pavements. Trucks were observed to travel over the same pavement at 65 mph the previous week before the sever Alaskan cold air mass moved into this area.

How much of an increase in dynamic loading was caused by such severe oscillations? Does the type of suspension system increase or decrease the dynamic loading and to what degree? Are there mathematical models to determine the increased fatigue?

Suggested Solution

A piezo-WIM system has been installed in Iowa as a part of an FHWA demonstration study in cooperation with Minnesota. It may be possible to use that WIM site to measure dynamic loads during severe cold weather. The data might be analyzed by clock hour, statistical analyses of vehicle speed by each hour, variation in standard error of recorded data as a function of clock hour, etc.

Mathematical models may have been developed by truck manufacturers or by University of Michigan or others that might be used to quantify and/or verify the amount of increased dynamic loading (alias fatigue) as a function of oscillation of the truck/trailer frame and the suspension system.

PROBLEM 86: Frequency Signatures of Truck Suspension Systems

Data collected using a Golden River Weigh-In-Motion System were sorted by axle location on the truck. For a given axle location, particularly drive axles on the truck tractor, correlations of WIM to Static data indicated distinct groupings of data. The groupings may be a function of the type of suspension.If the suspension systems can be identified by variations in frequency and possibly amplitude while traveling over the WIM installation, adjustments to load equivalency factors can be made to increase accuracy of accumulated pavement fatigue.

PROBLEM 87: Tires on Drive Axles Apply Torque Forces to the Surface of the Pavement

A torque force applies a horizontal force resulting in shear within the pavement surface course. Shear forces due to tire torque forces result in distorted paint stripes at intersections. Braking forces push paint stripes forward and gripping forces push the stripes backwards.

Analyses of data collected with the Golden River System and at static truck scales provide correlations as functions of axle locations on the truck. For both four-tired single and eight-tired tandems, the slope of the correlation line is flatter for drive axles than for trailer axles. However, tire torque coupled with the vertical load component has to produce an equivalent force for drive axles that is greater than for trailer axles.

Suggested Solution

Install instrumentation on the pavement surface to record horizontal component of tire torque forces on the pavement caused by drive axles. Instrumentation should be installed on pavements having relatively flat grades and on steeper grades (36%) to determine horizontal forces to maintain constant speeds on level pavements, to climb up steeper grades, and braking forces on down grades and at approaches to intersections.

PROBLEM 88: None

Researches and data collection people have long feared that any use or connection of enforcement activities with a mainline weigh-in-motion system would severely bias the data. Weigh-in-motion is an excellent sorting tool for isolating overweight vehicles from the traffic stream.

Research is needed to quantify the magnitude and duration of the diversion of illegal and legal loads from a mainline route weigh-in-motion site when it is used in conjunction with weight enforcement activities. Certainly, random, intermittent, short duration enforcement activities should not introduce a long lasting bias into the data, but research is needed. If we can reduce the fears of the researchers, we can greatly increase the enforcement flexibility.

Suggested Solution

A test site or sites should be implemented at selected locations where potential bypass traffic can be monitored during several facets of data collection with the weigh-in-motion equipment. These would include:

a.Operations with active enforcement on the main line route only.

b. Operations with no enforcement activities underway.

c. Constant monitoring of a potential bypass route or routes during both the "A" and the "B" options.

The data results could then quantify the effects on the traffic by enforcement operations. These effects should include the changes in the traffic counts by vehicle type as well as vehicle weights.

PROBLEM 89: Effect of Flexibility on the Performance of Steel Bridges

The AASHTO Specification currently includes a limit on the flexibility of steel bridges. The maximum live-load deflection is limited to the span length divided by 800. This limit first appeared in the 1941 Edition. It is thought to have resulted from a recommendation made by the Bureau of Public Roads after a study of bridges that were reported to vibrate objectionally, as no doubt determined by subjective human response. Subsequent research by Wright and Walker suggested that limitations of bridge motion are needed only for bridges designed for pedestrian traffic or stationary vehicles. ASSHTO currently refers to Wright and Walker as an alternative method. However, specifications in other countries do not include these subjective limits. These bridges appear to perform well, not only with regard to vibrations, but also regarding longterm behavior.

Objectives

Perform a sound technical evaluation of the effect of flexibility on the performance of steel bridges, including vibrations and durability. Review design practices and experience in other countries. Develop recommendations for future specifications that will ensure satisfactory performance.

Current Activities

Work is being done at Texas A & M University on the effect of excessive deflection on deck deterioration.

Urgency

NCHRP is currently sponsoring the development of a draft LRFD Specification for bridges. Questions regarding flexibility should be answered before the new specification is completed.

Cost Estimate: $200,000.

PROBLEM 90: Methods of Rehabilitating and Repairing Concrete Box Girders and Other Structures, Where the Deck is Part of the Structural System

Continuous box girder bridges that need structural repairs, generally require flasework and/or support systems during repairs. These support systems must be placed so they do not interfere with traffic beneath the bridge.Expensive support systems often result which negates the usage of this type of structure.

Objectives

To develop economical support systems which allow rehabilitation and repairs to proceed with reasonable efficiency. Support systems which are devised from cable and truss designers may span roadways quite effectively.

Current Activities

Rehabilitation methods have been devised which utilize additional external prestress tendons. These tendons recover tensile properties but fail to compensate for concrete's compression strengths. Bonding steel plates or equal to compression flanges will recover these compressive strengths, which is where research methods and procedures are needed.

Urgency

Age of the concrete bridge girder systems now requires rehabilitation and repair methods. Optimum rehab costs will only be realized through research on new repair systems. A general cost estimate of $500,000 will be needed to study this topic.

PROBLEM 91: Use of Strut and Tie Model for Concrete Shear Design

The use of Strut and Tie Model for Shear Design is creeping into the concrete design codes. There are no established design procedures on the subject, especially for three-dimensional models. Designers spend unnecessary time discussing what they do not understand and know.

Objectives

Study and research the existing literature. Write out a summary and develop design examples and procedures. Prepare guidelines for when and how to use this design procedure.

Current Activities

The recently adopted AASHTO Guide Specification for Segmental Bridges recommends this method, but does not provide detailed instruction.

Urgency

A lot of energy and time will be used up if every agency tries to develop this expertise on their own. A project like this can help introduce this method. Use of the strut and tie model will result in safer, higher quality concrete structures as it provides a logical design for portions of the structure that are awkward to handle with traditional methods.

Cost: $100,000.

PROBLEM 92: Use of Precast, Prestressed Segmental Construction in Bridge Substructures

Precasting, prestressing and segmental construction in substructures has found success in other areas of heavy construction. Most DOT's do not have the experience necessary to confidently determine when these techniques are economical and then to design and specify such substructures utilizing these techniques.

Objectives

The research will perform a literature review to establish:

a. Substructure types where this technology would be appropriate.
b. Changes in design practices and details necessary when using these technologies.
c. Specifications necessary to assure an adequate product.

The researcher will then propose necessary changes or additions to bridge design criteria and construction specifications.

Current Activities: None.

Urgency

The economy of precasting has been shown by its wide use in the private sector. Precasting also give a superior product by placing concrete under controlled conditions. Prestressing is often associated with precasting but may have benefits of its own such as reducing column reinforcement congestion. Segmental construction can be very economical in remote locations. All of these technologies can reduce construction time.

Cost: $200,000.

PROBLEM 93: Optimization of Strands and Concrete Strengths of Precast Prestressed Concrete I Beams/Girders

Some existing standard AASHTO precast prestressed concrete I-girders are inefficient and unable to meet the designer's needs. New streamlines shapes are needed which achieve greater span lengths through more efficient flange sections. Common fabrication forms (Part, or in total) are being used for these new girders and need to be reviewed. Potential corrosion problems for these new girders exist at their ends (under leaking joints) and on their thin webs (from salt sprays).

Objectives

To determine the long range effect and trend of I-girder development. To optimize strand (steel or fiber) size and concrete strength and provide corrosion protection which will minimize future maintenance.

Current Activities

Present studies (PCA, etc...) that have been completed on this topic relate to bridges that have been constructed in the last 20 years.

Concrete strengths have been increased to optimize the increased strand sizes and strengths. Additionally, methods of further increasing the concrete strengths are presently being researched using fly ash, special aggregates, etc...Texas has developed a computer program which optimizes beam costs for simple supported precast, prestressed concrete beams.

Urgency

To develop an awareness for the latest technology and trends in precast, prestressed girder design. Also the research to optimize these shapes will enhance bridge design and maintenance.

PROBLEM 94: Placement and Types of Titanium Mesh for Cathodic Protection

Problem

Cathodic protection of bridge decks is quite costly using the existing materials and procedures. Use of layered materials and placement of costly strips to assure electrical circuitry has made cathodic protection undesirable.

Objectives

To determine the effective protection system using titanium mesh in the concrete. The titanium mesh substrate is placed in the concrete and sintered to a metal oxide catalyst. The evaluation procedure for measuring the mesh performance has to be completed in a controlled environment.

Current Activities

A bridge in Cincinnati, Ohio is being evaluated by the FHWA to measure the performance of the titanium mesh system. It is part of an 18 month FHWA study to measure performance of cathodic protection materials.

Urgency

Research on this project has medium priority. At the present time evaluation of the Ohio bridge should be included in additional research. Use of the mesh in substructure units needs to be investigated.

PROBLEM 95: Strengthening of Bridges using Non-Steel Tendons Such as Parafil or Fiberglass Tendons

Use of steel tendons in concrete beams has caused concerns as to corrosion and related problems. External strengthening of existing concrete beams requires non-corroding materials. A comprehensive research study should be undertaken to determine the feasibility of various different methods of rehabilitating bridges using parafil tendons, etc.

Objectives

To determine what synthetic materials are available to use in strengthening bridges. An evaluation of their

characteristics such as creep, deformation, elastic modulus, strain and tensile strengths should be made. Their performance and applications need to be determined as to how they work on short spans, bond development.

Current Activities

Research on strengthening bridges is being conducted in Iowa and at TRB at present. West Germany has developed a fiberglass tendon (polystal) that is being used on a bridge outside of Dusseldorf. England has developed a new material (parafil) which has about five times the strength of steel.

Urgency

Research on this topic has a high priority as to rehabilitation work. Use of new strand materials can greatly enhance existing bridges by external tensioning procedures. Lack of corrosion of these materials is the key to their successful use.

Cost: $400,000

A2C05 Committee on Dynamics and Field Testing of Bridges

PROBLEM 96: Instrumenting Existing Bridges for Load Rating-Methods and Analysis

As any bridge engineer knows, we are lagging behind in our efforts to replace or rehabilitate our nation's structurally deficient bridges. We are posting more bridges than ever before due to the inspection programs mandated by federal law. Currently, our posting analysis involves a "reverse design" effort. We apply modern and refined design and analysis techniques to these critical bridges that were designed and built for lighter loads with simple assumptions on expected structural behavior. Whenever a bridge engineer posts an existing bridge he does a balancing act between engineering judgement, application of sound engineering principles and the need to maximize the use of an old bridge without sacrificing the safety of the traveling public. Knowledge of how a critical bridge actually behaves under the current loads can enhance the bridge engineer's ability to rate the bridge for the maximum benefit of the traveling public. If these critical bridges are instrumental, the dynamic behavior of the bridges can then be monitored and an engineering analysis compatible with that behavior can be applied to rate these bridges.

Objectives

a. Determine cost effective methods of instrumenting various types of bridges for monitoring their behavior under loads. This could be accomplished through a literature survey and a questionnaire procedure involving state and local agencies responsible for bridge inspection and rating.

b. Recommend guidelines for interpreting data obtained through various instrumentation methods for use in differentiating analysis such as Limit State's Analysis for concrete bridges or Inelastic Rating Analysis of steel bridges.

Current Activities

Research in progress. Not determined.

Related Research Activities

TRB has sponsored projects in the area of strength evaluation of existing bridges which could be synthesized with this effort.

Urgency

With the ever increasing frequency of posting old deficient bridges due to our inability to replace them quickly, results from this project could help any bridge engineer to obtain the maximum benefit out of an old structure while he is struggling to replace a deficient structure.

Cost: $60,000-$80,000

Duration: Two years.

PROBLEM 97: Implementation of Non-Destructive Field Test Results in the Evaluation and Rating Process

Field tests have shown that the "real" load carrying capacity of a bridge is almost always much greater than that predicted by conventional evaluation analyses. This discrepancy is due in large part to conservative modeling assumptions concerning unknown conditions. Non-destructive field test permit many of these assumptions to be eliminated, because the bridge itself provides an exact model. There is a need for more knowledge concerning appropriate measurements and interpretation of the results. Is it possible to identify the critical failure mode? what limit state should be considered in old bridges, yielding or collapse? Once the strength has been determined, what are the appropriate load factors for rating?

Objectives

a. Develop non-destructive field test for bridges which identify damage and potential failure modes.

b. Evaluate failure modes for older bridges and establish criteria for unacceptable limit states.

c. Determine load factors for use in the bridge rating process.

Current Activities

a.Recent work has been completed which studied the available evidence for improving load capacity estimates by correlation with test data (NCHRP project 10-28 (8)). It is clear that available data is inadequate and new methods and tests are required which are based on more elegant non-destructive techniques than were used in the past.

b. Promising new technologies are being developed for existing structures by several agencies. Coordination of this effort is required to ensure that the needs of the rating engineer will be met. These may need further refinement before being sufficiently sensitive to be useful for bridge rating.

Urgency: Immediate

Cost: Not estimated.

Duration: 2 man-years.

PROBLEM 98: Integration of Field Testing in Bridge Rating

Many highway bridges are rated as structurally deficient yet may contain more capacity than allowed by present rating procedures. Bridge testing has evolved in recent years into routine and inexpensive operation. Accepted methods are needed for simplifying procedures for integrating the field tests with rating formulas.

Objectives

a. Summarize field testing methods and equipment required.
b. Determine how test data can be integrated into Bridge rating Formulas.
c. Preset examples of benefits and costs of field testing to improve bridge rating.

Current Activities

a. Key Words: Bridge, rating, safety and testing.
b. Activities of this nature have been reported by Ontario, Ohio, Pennsylvania, Maryland, North Carolina and other states. NCHRP 12-28 (13) Nondestructive Load Testing for Bridge Evaluation and Rating and NCHRP 12-23 Recommended Revisions to the AASHTO Manual of Maintenance Inspection of Bridges are both related activities.

Urgency

FHWA reports over 125,000 structurally deficient bridges with associate costs of tens of billions of dollars. Demonstrations have shown examples of benefits in improved rating from field testing which could avoid unnecessary posting or rehabilitation.

PROBLEM 99: Correlation of Deterioration Rates with Service Loads and Conditions

It may be that far too much emphasis is being placed on evaluation of the current ultimate strength. In rating a bridge, what is really needed is a prediction of both the strength and serviceability of the bridge just before the next inspection. This obviously requires some prediction of deterioration under future service conditions. Except for fatigue, very little is known about deterioration rates of bridges under service conditions.

Objectives

a. To determine those factors which influence deterioration in highway bridges under service loads and conditions.
b. Develop the net effect on load capacity when the effect of deterioration is included in the rating process.

Current Activities

a.Refined methods of evaluation of load capacity are being developed which involve both field testing and sophisticated analytical models.
b. No related work on the effect of deterioration is known at this time.

Urgency: Immediate.

Cost: Not estimated.

Duration: 3 man-years.

PROBLEM 100: Dynamic Load Design Criteria for Bridges

Using the available data (tests, measurements and analysis) to develop the dynamic load design criteria for bridges. Current AASHTO provisions relate dynamic load (impact) to span length only. On the other hand, recent studies indicate that the major factors affecting dynamic behavior are surface roughness, natural frequency of vibration of the bridge, and vehicle dynamics. There is a need to evaluate the effect of these three factors on structural performance. The developed design dynamic loads can be used in the LRFD variant of the AASHTO specifications.

Objective

To determine dynamic load on bridges for the design specification. This would involve an extensive literature

survey (U.S., Canadian and others), evaluation of WIM (weight-in-motion) data and other test results. Gaps in the available data will be identified and further research needs formulated.

The development will be based on dynamic analysis and test results. Probabilistic methods will be used to evaluate statistical parameters of extreme load conditions (combination of maximum static and dynamic effect). Resistance to short duration (dynamic) forces will also be evaluated.

Current Activities

a. Research in progress: WIM data is being accumulated by several states. Ontario MTC is presently involved in a bridge test program which includes dynamic testing.

Analytical dynamic models are being developed at several universities including the University of Michigan and abroad at the Technical University of Munich (Germany) and the Kyiushu University in Japan.

b. Related research activities: Development of dynamic load design criteria is closely related to the development of LRFD format for bridges (NCHRP Project 12-33).

Urgency

The developed design criteria can be used in the newly developed LRFD design criteria.

Cost: $150,000

Duration: 2 years, 2 man-years.

A2C06 Committee on Culverts and Hydraulic Structures

PROBLEM 101: Earth Loads on Culverts due to Backfill Compaction

Compaction of the backfill alongside a culvert wedges the backfill against the culvert and increases the earth load on the side of the culvert. Field measurements have shown that the deflections due to compaction can be as large as the deflections resulting from the weight of the fill. It is clear that compaction loads have a major influence on the deflections of and forces in culverts during construction. At present, however,there is no means of estimating earth loads due to compaction, nor any sound procedure for including their effects in analysis or design.

Objectives

a. Conduct literature search to collect available data on earth loads and earth pressures due to compaction.

b. Perform laboratory and field tests to supplement the available data and explore the effects of such factors as soil type, compaction method, compaction density, compaction water content and backfill depth on earth loads due to compaction.

c. Develop analytical procedures for simulating compaction and earth loads due to compaction in finite element analyses of soil-culvert interaction.

Current Activities

a.Suggested Key Word-Earth loads, culverts, backfill, compaction.

b. Other research in progress is unknown.Urgency

The effective utilization of the finite element method and other rational methods of culvert design depends on their accurate portrayal of field behavior. Accomplishment of this research will greatly improve the accuracy with which the actual behavior of culverts can be modelled analytically, and it will also provide a valuable background for interpretation of field measurements.

PROBLEM 102: Design Live Loads for Culverts

Current design specifications for culverts having a shallow depth of cover require that live loading be considered in the design and prescribe empirical procedures for distributing the static wheel loads through the soil to the exterior envelope of the culvert. These loading requirements do not appear to be consistent with the physical reality of the installation and/or the nature of the actual loading, and in many instances, these design procedures lead to appreciable increases in the required strength of the culvert which may not be necessary.

Objectives

a. Perform an experimental study of the nature and distribution of live loads throughout the vicinity of the culvert. These full-scale field measurements must be taken on a variety of culvert systems and installation types.

b. Using the field data and appropriate analytical models develop new analysis techniques and design recommendations for the response of culverts to the dynamic effects of live loads approaching and passing over a buried structure.

Current Activities

a. Suggested Key Words: analysis, culverts, design and live loads.

b. A project has been initiated in Canada by the Ontario Highway Department to measure the distribution of static concentrated loads through shallow fills over long span culverts.

Urgency

Refined methods have been developed recently for the analysis and design of soil-culvert interactive systems for the effects of loading imposed by the bedding and backfill. The empirical criteria for live loading has not been revised for years and these simplified methods appear to be inconsistent with our current understanding of load transmission. It is believed that the successful completion of this project will lead to truly rational live load criteria and result in more economical culvert installations.

PROBLEM 103: Life Cycle Costs of Culvert Structures—Lack of

Culvert designers and planners need an awareness of actual present value of life cycle costs for different

culvert structure installations. REquirements for service life of culverts exist in the planning process of some governmental agencies. These service life requirements are not properly utilized because of budgetary fluctuations and various constraints such as:

a. Opposition from material manufacturers based on uncertain results.
b. Annual/biannual funding programs.
c. Variable funds from gas taxes and excise taxes.
d. Political decisions at federal, state and local level.

Objectives

Develop a computer program which determines the life cycle costs of concrete, steel, etc.. culverts. The program should include but not be limited to the following factors:

a. Durability of culvert structures under erosive and corrosive environments.
b. Actual service life for each culvert material.
c. Guidelines for the design and construction of culvert structures.
d. Maintenance and repair costs over a common projected life span of the structures (50 years or older).
e. The optimum/minimum cost of each structure based on probability factors for inflation, interest rates and structural adequacy.

Current Activities

Studies of the durability and projected life cycles of culvert structures have been completed, but actual life cycle costs using probabilistic factors and variable return factors have not been successful. A literary search of available life cycle costs of culverts has not yielded any existing studies or papers.

Urgency

Because half or more of all structures being replaced on highways is a culvert, strong emphasis must be given to their life cycle costs. This research should be given high priority consideration.

PROBLEM 104: Durability of Drainage Structures

When an engineer designs a drainage system he must assume or be told by his client, what project design service life for which to design. Project design service life is defined as, "the time that the drainage system and its various components will be required to perform their function before major maintenance will be required." Since nothing man-made lasts forever, a finite period of time must be agreed upon that is both desirable and achievable. Having made that decision, he is then faced with the problem of choosing the material, or materials in the case of alternate bidding, that will satisfy the project design service life requirement, often referred to as the material service life. In order for the engineer to make an informed decision about the choice of materials to specify he must know or have a reliable source of knowledge about the past performance of the various drainage products/materials and combinations thereof, so that he can have confidence that his decision will ultimately satisfy the project design service life requirement.

Objectives

There should be reliable and readily usable information available for estimating the durability of the various products/materials being sold into the drainage structure market. This is the primary thrust of this research need i.e. how long will a drainage structure endure using a certain product/material under the specific environmental conditions of my project without the need for major maintenance? In order to have this reliable source of knowledge, we need a large research project that will:

a.Begin with a literature search of drainage structure (pipe) durability studies.
b. Correlate the data contained in these studies using a unified rating system, create a computerized data bank, and write a program for extracting selected data.
c. Plan and execute a field condition survey to verify the results of B and to fill gaps in the data.
d. Produce a durability of drainage products/materials design manual.

Current Activities

A number of State Highway Agencies are making limited field studies on specific materials. Some members of the drainage pipe industry are engaged in data collection on their own products.

Urgency

With the present interest in the application of life-cycle cost techniques to drainage structures, products and

materials selection, it is vital to have reliable durability guidelines for the proper application of these techniques.

Cost: General estimate of cost to accomplish. The estimated time for such a study is three to five years costing approximately $500,000.

PROBLEM 105: Long-Term Plastic Properties Affect Pipe Performance

Thermoplastic pipe materials (HDPE, PVC, ABS, etc.) are viscoelastic. Physical material properties change under stress, over time. They are affected by temperature and are strain rate sensitive. Advertised material properties are determinedly short-term tests, at fixed strain rates at laboratory temperature. Most current pipe designs consider only short-term material properties and often are based simply on pipe stiffness.

Objectives

Determine where long-term properties are applicable to the design or selection of plastic pipes and which service conditions or applications require consideration of properties other than short term.

Current Activities

Long-term tensile strength levels are used for pressure pipe designs. For gravity flow installations, Section 18 of the AASHTO Bridge Specification requires the use of a long-term modulus for buckling checks and allows the designer to determine if short of long-term properties are applicable to other portions of the design. Little research and some theorizing as to property affects is being done internationally.

Urgency

In view of the increased use and interest in larger diameter plastic pipes in highway applications, a complete evaluation is required.

Cost: Funding must cover both a theoretical evaluation and laboratory testing. Cost is estimated at $500,000 over a 2 year study period.

PROBLEM 106: Alternate to Three Edge Bearing Pipetesting Method

Neither AASHTO nor ASTM provide any guidance on acceptable designs and loads for large pipes (114" and up depending on pipe class). With the advent of Soil Structure Interaction designs, there is a trend to increase allowable loads on round pipe for cost reasons. Consequently, there is a need to develop a procedure for testing large pipes that is more representative of actual bedding conditions. In addition, it should eliminate the disparity that exists between testing methods for precast box culverts and those of reinforced round pipe culverts. Current state-of-the-art designs for box culverts or arch bridge structures are not required to pass any test equivalent to the standard three-edge bearing test for pipes. The three-edge bearing test was designed to compare the strength of one pipe to that of another and is not a true representation of actual field bedding conditions. The question exists: Should we test box culverts to the same degree, and, if not, why should round pipe be tested using the three-edge bearing test? Is a simplified combination design and test procedure practical that would suffice for both types of pipe structures?

Objectives

There is a need to develop testing methods that would be acceptable for both small precast box culverts and large round reinforced pipe culverts. They should be developed to allow independent agencies to evaluate these structures without undue concern over liabilities. An alternative could be a simplified combination test and design method suitable for small agencies and within personal computer capacity. It should correlate the design with anticipated bed loading and criteria used for precast box culverts. We should also evaluate the merit and limitations of a 0.01 inch crack design method.

Current Activities: None

Urgency

More and more large pipe is being used with a potential for greater liabilities for lack of authoritative (AASHTO, ASTM) information. A simplified methodology could resolve concerns and possible increase savings to small agencies that are presently reluctant to opt for large pipe due to the lack of design and testing information.

Cost: The estimated time frame would be a two-year study with research dollars approximating $75,000. Actual testing could add another $100,000. The total cost could approach $175,000.

PROBLEM 107: Plastic Pipe Creep and Relaxation Characteristics and Their Effect on Design

Current design procedure for plastic pipe does not adequately reflect the effects of time dependent properties of these materials on ultimate pipe performance. Thermoplastics and fiber reinforced materials exhibit a time dependent modulus of elasticity that result in stress relaxation under load. With the use of plastic pipe expanding in the transportation area by departments of transportation, airports and railroads; and with available size ranges increasing rapidly, this area must be studied and its finding made part of existing design procedures.

Objectives

a. Conduct a literature search to collect available data on pipe response to load as well as material properties.

b. 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. Determine size effects on test procedures.

c. Develop analytical procedures for predicting performance limits. Relate those performance characteristics to predicted soil reactions.

Current Activities

a. Suggested Key Words: Earth loads, live loads, backfill, culverts, compaction and plastic pipe.

b. Other Research in progress

1. 104′ Deep Burial Study on polyethylene pipe under Penn DOT Jurisdiction
2. Other research unknown.

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 procedures.

PROBLEM 108: Structural Behavior and Applications of Fiber Reinforced Plastic (FRP) Prestressing Systems

At least two forms (styles) of fiber reinforced plastic (FRP) prestressing systems are being developed at universities, and one system has been used for construction of a prestressed concrete bridge in Germany. Additional research is needed to study the transfer length and development lengths of these systems and to study the structural behavior of them in prestressed concrete members and as strengthening members for other types of bridges and bridge members.

Objectives

Develop structural design guidelines for fiber reinforced plastic (FRP) prestressing systems, through the conduct of laboratory tests and analysis.

Current Activities

At this time only one (limited) research study is being conducted on the structural behavior of a fiber reinforced plastic (FRP) prestressing system. Additional work is warranted.

Urgency

Research on this topic has a high priority. If such FRP prestressing systems can be developed, they may be a viable alternative for steel prestressing systems which usually must have an external protective coating for use in corrosive environments.

Cost: At least $300,000 will be needed to develop the needed data, but several smaller studies may be done to study various aspects of this topic area.

PROBLEM 109: Strengthening of Structures with Adhesively Bonded Fiber Reinforced Plastic (FRP) Plates

A few research studies throughout the world have show that it is possible to strengthen reinforced concrete beams with adhesively bonded fiber reinforced plastic plates (particularly graphite-epoxy plates) but there is very little knowledge or experience of this technology in the United States. A comprehensive research study is needed to evaluate this technology and conduct research to develop it in the U.S. Such plates are very strong, lightweight and not subject to corrosion.

Objectives

To evaluate the potential benefits of strengthening reinforced concrete beams with adhesively bonded fiber reinforced plastic plates; through a comprehensive literature review, laboratory tests, analysis and field test on concrete structures.

Current Activities

Related FRP research is underway in Switzerland and related research on structural adhesives is being sponsored by the Federal Highway Administration and the Ohio Department of Transportation.

Urgency

Research on this topic has a medium priority. However, if this concept can be developed it may be a viable technique for strengthening damaged or weak reinforced concrete bridge members.

Cost: At least $300,000 will be needed to conduct a comprehensive study of this topic.

PROBLEM 110: Structural Bond Behavior of Fiber Reinforced Plastic Rebars and Prestressing Systems

At least two forms (styles) of fiber reinforced plastic (FRP) reinforcing bars are being made, and used--without adequate structural bond behavior data or design equations. Although such bars have to date only been used in building and industrial applications, they do have potential application for highway structures in corrosive environments. Thus, it is important to develop structural bond data for FRP reinforcing bars and prestressing systems in concrete.

Objectives

Develop structural bond design guidelines for fiber reinforced plastic (FRP) reinforcing bars, and prestressing systems through the conduct of laboratory tests and analysis.

Current Activities

At this time only one (limited) research study is being conducted on the structural bond behavior of fiber reinforced plastic (FRP) reinforcing bars, under West Virginia DOH funding.

Urgency

Research on this topic has a medium priority. If such FRP rebars and prestressing systems can be developed, they may be a viable alternative for steel rebars for use in corrosive environments.

Cost: At least $300,000 will be needed to develop the needed data, but several smaller studies may be done to study various aspects of this topic area.

PROBLEM 111: Strength and Structural Behavior of Fiber Reinforced Plastic (FRP) Nuts and Bolts

FRP nuts and bolts are manufactured and used, for erection of FRP structural members. Although these are not currently used for highway structures, it is possible that they could be--if their structural proper ties were determined and if appropriate design guides were developed. Such bolts are not susceptible to corrosion, and their fatigue properties may be better than those of steel nuts and bolts. It may be necessary to use FRP nuts and bolts with structural adhesives.

Objectives

To evaluate the structural properties of fiber reinforced plastic (FRP) nuts and bolts; through a comprehensive review of current literature and practice and the conduct of appropriate laboratory structural tests of the nuts and bolts and bolted connections.

Current Activities

FRP nuts and bolts have been developed through an iterative manufacturing process, with minimal structural tests. Little, if any, formal structural research has been conducted on this topic.

Urgency

Research on this topic has a medium priority. However, if adequate design criteria were developed, FRP nuts and bolts may be appropriate for some types of highway construction.

Cost: At least $100,000 might be necessary to develop the required structural behavior data and to develop the design criteria.

A2E03 Committee on Mechanical Properties of Concrete

PROBLEM 112: Stress-Relieving Dowels and Tie Bars for Concrete Pavements

Dowels and tie bars are used at joints in slabs and pavements to provide load transfer from one slab to the other as vehicles drive over the concrete, and/or to tie the concrete joint together. It is common to place a pavement lane or slab with the dowels sticking out of the lane edge into the area where the second lane or slab will later be placed. By the time the adjacent concrete lane or slab is placed, the first one has usually contracted from temperature changes and drying shrinkage. When the second slab or lane adjacent to it shrinks-/contracts after it is placed, movement parallel to the joint is restricted by the dowels on tie bars. Very significant internal stresses can develop which are not part of design. Cracking is often observed but seldom noted and often it is attributed unknowingly to some other influence. This problem should be investigated through application of theory and mechanics, and through instrumentation of actual pavements. One way of eliminating these stresses is by using square dowels with a compressible material on the sides of the bars. The tops and bottoms of the bars would not include the compressible material. Total load transfer is provided across the joint but the slab is free to shrink and contract longitudinally.

Objective

To document the detrimental effect of dowels and tie bars when they restrain normal shrinkage contraction parallel to a joint, and to show how modified dowels and tie bars can eliminate this problem.

Current Activities

The problems of dowels and tie bars restraining movement in the direction where it is needed, has been discussed in Concrete Construction Magazine, World of Concrete Seminars on joints, and informally at ACI committees. Several designers have entertained the idea of using the modified bar with compressible material on one side. However, the problem and the effectiveness of the proposed solution have not yet been documented, nor is it addressed in standards on design methods.

Urgency

Thousands of miles of pavements and slabs routinely use dowels and tie bars each year. This includes airports, highways, parking areas, and industrial floors. Cracking near joints and corners as well as in the interiors of concrete slabs, is a major problem, with a continuing maintenance cost, leading to a reduced performance. Much of the stress which contributes to this cracking could be the result of dowel restraint which is not usually considered in design. A simple and economical modified dowel should be able to eliminate these stresses, thereby greatly improving performance and reducing lifetime costs. The need and benefits are immediate from both the practical application and theoretical standpoints.

Person Developing Problem

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PROBLEM 113: Skid Resistance of Roller Compacted Concrete Pavement (RCCP)

The primary advantage of using RCCP versus conventional concrete pavement is its lower construction cost. Savings of 15 to 30 percent have been realized. The degree of surface texture and smoothness achieved using this construction method has been less than that for conventional concrete pavements, limiting its present application to low-speed, heavy-duty pavements. With conventional concrete pavement, the final surface texture is provided by means of a burlap drag, broom, artificial turf, wire comb or grooving. Dragging with burlap leaves a fine sandy surface that is adequate for low-speed traffic. The wire comb provides the most skid resistant texture. Because of problems with aircraft, runways require saw-cut grooves. Roller compacted concrete cannot be textured with any of the above procedures except grooving and the texture is that obtained from a steel wheel and rubber-tired rollers.

Research should be directed to the collection of data on the skid resistance of RCC pavements with various experimental texturing methods and results compared to conventional PCC and asphaltic concrete pavements. The Mu-Meter and other methods can be used to determine pavement friction.

Objective

To develop data on the skid resistance of roller compacted concrete pavement to define the types and speeds of traffic that can safely use roller compacted concrete pavement.

Current Activities: None

Urgency

Roller compacted concrete is being used as an economical procedure in construction of pavement in many countries throughout the world. The restriction on its use because of its skid resistance should be known. The research is urgently needed so that safety requirements and design guidance may be available for types of pavements that could be constructed with this economical method.

Person Developing Problem

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PROBLEM 114: Field Performance of Low Viscosity Polymers as Concrete Crack "Sealer/Healers"

Much information is published about the prevention of cracks in concrete, but too often the construction plans go awry and cracks appear in the concrete. Numerous techniques have been applied to sealing and correcting the deficiency created by these cracks, the latest of which is the use of a family of low viscosity polymers that are designed to flow into the cracks. Although laboratory data are positive about the capabilities of this technique, little field information has been published regarding the ability of these materials to fill the cracks as well as their ability to bond to the crack walls after the concrete material has been in service.

Research should be conducted to determine the effective depths that are actually achieved in the field when using these materials. Cores should be taken of cracked concrete that has been treated, both horizontal and vertical surfaces. The actual depth of penetration of the sealer should be measured, and recorded along with the conditions at which it was installed. The type and viscosity of sealer should be noted. The cores should then be tested to determine bond strength at the filled crack.

Objective

To determine the effectiveness of this family of crack sealers so that those responsible for concrete repairs can make knowledgeable decisions regarding choice of materials and technique for crack repair.

Current Activities

There is no known activity that is evaluating the effectiveness of these sealer materials.

Urgency

Many of these materials are being used regularly to seal and repair concrete applications that are designed to repel water and water-borne chemicals. It is important that true performance characteristics be established for these sealant materials.

Person Developing Problem

L. A. Kuhlmann, The Dow Chemical Company

PROBLEM 115: Mechanical Properties of Highway Repair Concretes at Early Age

The age at which repaired 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. Data is needed on the mechanical properties of repair concrete at an early age 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 among the values obtained by these methods should be studied.

Objective

To develop guidelines for defining/evaluating the mechanical properties of typical highway repair concretes at ages from final set to 24 hours.

Current Activities

The ACI Committee on Hydraulic Cement (225) recently sponsored two sessions on the properties of concrete at early ages. However, highway departments need more information, particularly on mixtures used in pavement and bridge repair.

Urgency

The repair of concrete pavements and bridge decks has increased in recent years and is now a major part of the 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.

Person Developing Problem

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PROBLEM 116: Dielectric Properties of Concrete

The use of short-pulse radar for bridge and highway condition surveys has steadily increased in recent years. Short- pulse radar has found acceptance (as an alternative to the slower, more labor-intensive manual methods such as the chain drag soundings) in the detection of delaminations in bridge decks, voids under pavements, and debonding of overlays. The ASTM has recently introduced a new test method (ASTM-D-4748-87) for determining the thickness of bound pavement layers using short-pulse radar. Also, research is currently ongoing to investigate other potential uses of radar, such as determination of concrete strength, water-cement ratio, and curing condition.

The relative dielectric constant of the material influences (among other things) the speed of the transmitted electromagnetic wave, its reflection and attenuation properties, and the maximum penetration depth as well as the accuracy of the radar system. Research is needed to investigate the dielectric constant of concrete pavements and bridge decks; how the dielectric constant varies with type, age, moisture content, etc., of concrete; also how it varies from one location to another, and from top to bottom at a given location. Such information would assist in using radar for specific situations, allow improved test procedures to be developed, and generally effect improvements in radar data collection and interpretation.

Objective

To investigate the dielectric properties of concrete in bridge decks and highways, focusing specifically on the extent of variability in the relative dielectric constant and the factors which contribute to this variability.

Current Activities

Research into short-pulse radar is currently being conducted by SHRP (Contract C-101, MIT (for the New England Transportation Consortium), and several State highway agencies (e.g., California, Colorado, Massachusetts, and Virginia). Little, however, has been done in relation to dielectric properties of highway construction.

Urgency

The primary methods currently employed to detect delaminations in bridge decks and voids under pavements are: (1) the manual sounding technique using a chain, and (2) mechanical-tapping device known as the Delamtect. Both these methods are time consuming, require partial or complete closure of the bridge deck-/highway, and are not necessarily accurate. Because short-pulse radar has significant economic advantages, it has gained a foothold as an acceptable survey method. It has been estimated that if only 2500 bridge decks (i.e., 50 bridge decks per State) were surveyed with radar, instead of one of the primary methods, a savings of $1.2 million dollars would result. This research should lead to increased and optimal use

of short-pulse radar, making more accurate and economical surveys possible.

Person Developing Problem

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A2E05 Committee on Chemical Additions and Admixtures for Concrete

PROBLEM 117: Effect of Gradation and Amount of Aggregate on the Durability of Hydraulic Cement Concrete

Much research has been done on the resistance to cycles of freezing and thawing of hydraulic cement concretes in the presence of deicing salts. However, in certain pavements, excessive wear of the mortar phase has occurred. There is a need to evaluate the effect of the coarse aggregate-to-mortar-ratio on the longevity of concretes. More emphasis is needed on the importance of size, and gradation of the coarse aggregates to achieve maximum durability and abrasion resistance.

Objectives

1.To evaluate the effects of aggregate gradation and the coarse-aggregate-to-mortar ratio on the longevity of concrete. The concrete characteristics studies will include freeze-thaw resistance, abrasion resistance, resistance to chloride ion penetration, and sulfate resistance.

2. To develop guidelines for use in proportioning concrete mixture to attain optimum characteristics of the concrete to provide maximum longevity when placed in highways or bridges.

Current Activities

An investigation is currently underway in Texas to evaluate the effect of aggregate gradation on abrasion resistance of in-place concrete pavements. British standards have long included gradation and "proportioning for performance" criteria to improve concrete longevity. These criteria would be a starting point to develop needed guidelines for mixture proportions.

Urgency

Chemical and rheological behavior of concrete mixtures and their relation to long-term performance have been widely studied, but little has been done to evaluate and provide guidance on the size, shape, and grading of aggregates that relate to concrete longevity. Significant benefits would be realized through improved concrete performance.

PROBLEM 118: Durability Characteristics of Strength-Accelerated Hydraulic Cement Concrete Pavements

One of the techniques used to open pavement facilities to traffic earlier than usual is to increase the rate of strength gain of hydraulic cement concrete. Several alternatives for increasing strength gain are available, such as the use of Type III cement, increasing cement content, and using strength-accelerating admixtures. Accelerated strength gain is generally associated with increased heat generation within the concrete mass. Hence, durability of concrete mixtures will not only depend on mixture proportions and ingredient properties, but also on conditions such as initial temperature, heat generation and conduction, thickness, mass of the concrete slab, and the curing procedure.

Objectives

1. To evaluate the factors producing and controlling accelerated strength gain in hydraulic cement concrete and to assess the effect of such acceleration on the durability of the concrete inservice.

2. To develop construction specifications and guidelines for the quality control and acceptance of strength-accelerated hydraulic cement concrete pavement that are suitable for routine use by State highway agencies.

Current Activities

Information developed on several projects constructed in Iowa in the past two decades indicate successful use of strength acceleration. In 1988, the Federal Highway Administration monitored and participated in collecting data on a demonstration project in Dubuque, Iowa. In 1989, several other demonstration projects were scheduled in Michigan, Virginia, Pennsylvania, and Iowa. It is believed that the data obtained in these projects will form a data base for developing tentative specifications and guidelines.

Urgency

The highway network is faced with ever increasing traffic in which there is a need for minimum disruption to flow when pavement is repaired. This is especially true at critical locations such as bridge decks and approaches and access to residential and shopping areas. Strength-

accelerated concrete pavement is an effective way to fill this need.

PROBLEM 119: Evaluation and Improvement of Curing for Hydraulic Cement Concrete Used in Highways

Maintenance of satisfactory moisture content and temperature in concrete during early stages is necessary to assure the development of strength, durability, and dimensional stability. This process, known as "curing," is accomplished in a variety of ways using different materials. Test methods and specifications for evaluating the effectiveness of different procedures and materials for the range of specific conditions encountered in highway construction have not been fully established.

Objectives

1. To evaluate the relative effectiveness and applicability of existing materials and procedures for curing concrete.
2. To develop new materials, methods, and test procedures more closely related to performance requirements than those now available.
3. To develop criteria for judging the effectiveness of the curing procedure based on the properties of the concrete.

Background Information

ACI Standard Practice 308-81 for curing concrete recognizes that under some ambient conditions of temperature and humidity, curing can proceed properly without specific action. However, such conditions do not generally exist during highway construction; thus, specific measures must be taken to assure proper water retention and temperature maintenance for curing to proceed in the desired manner. This research need is especially applicable for liquid membrane-forming curing compounds designed to meet specific applications such as for tined and untined horizontal surfaces, vertical surfaces, and for quick-setting materials used where short-time lane closures are required.

Current Activities

A new proposed test (ASTM P198) has been prepared by ASTM to evaluate the effectiveness of materials for curing concrete. The practicality and usefulness of this test need to be evaluated. The precision of the current test ASTM C156 has been criticized.

Urgency

A lack of proper curing of field concrete results in lower strength and durability. Thus, unnecessary economic losses occur. Considering the wide use of concrete in the construction of highways, a quick response to this topic is needed to avoid continued economic losses.

A2F01 Committee on Rigid Pavement Construction and Rehabilitation

PROBLEM 120: Constructability of Drainage Systems

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 pavements system and were dubbed "bathtub" designs. Much has been learned about the detrimental effects of water to pavements systems; "D" cracking, pumping, 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 with 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 to meet the demand.

Objectives

The research objective would be to develop typical designs which would lead to ease of construction for contractors, while maintaining drainage effectiveness. Guidelines for drainable base materials, gradations and placement would be developed. The use of edge drains, perforated pipe of fin designs, would also be looked at in combination with permeable base layers. This would allow straddling the permeable base material for placement of the overlying pavement. The use of a monolithic drainable section, in which the base would be placed directly ahead of the concrete paving operation, would also be investigated. This information would then be made available to agencies and contractors for their use in development of new cross-sections and placement activities.

Current Activities

Permeable base layers have been designed and built by several agencies. There is at least one permeable base test section being studied by the State of Wisconsin. However, this effort is intended to monitor the effectiveness of varying permeable materials.

Urgency

Problems have arisen in construction with stability for the concrete paving equipment. Problems with clogging of the open-graded base have stemmed from placement on a fine-grained material. No known effort is underway to address construction related problems and develop accepted design criteria.

PROBLEM 121: Design Criteria for Joint Spacing

Concrete cracks. This fact is not disputed. Where appropriate construction is maintained, cracking can be attributed to concrete shrinkage, temperature gradients (curling), temperature movements and/or loading. At least the first three of these causes can be addressed, in part, through appropriate joint spacing. Virtually every agency uses different standards for joint spacing. In many instances these standards are based on old rule-of-thumb criteria, the derivation of which is not understood and often not known. As the volume of traffic on roadways increases, the need for improved pavement performance and low-maintenance also increases. Inhibiting crack development through appropriate joint spacing will lead to significant improvements for these critical needs.

Objectives

A study in this regard would review the literature to determine where current accepted joint spacing standards were derived. Research into the cause and effect of variables such as: shrinkage, curling and temperature would also be made to outline the relative effects of these variables. In addition, other variables such as concrete strength, slab support, ambient temperature, and relative humidity should also be researched. The results would provide a guidance procedure to be used in determining the joint spacing for a variety of materials, placement conditions and pavement types.

Current Activities

There is no known activity concerning this issue. In some cases agencies are not satisfied with their joint spacing criteria, but do not know on what basis to change it, because of lack of knowledge.

Urgency

Many miles of concrete pavement will be built in the future with the reconstruction of much of the interstate network. Use of the same joint spacing procedure as was used in the past, would lead to the same problems which were developed the first time. It would be beneficial to the agencies, the industry and the public to develop an accepted joint-spacing determination procedure based on well outlined facts.

PROBLEM 122: Recycled Portland Cement Concrete (PCC) Mix Designs

In today's rehabilitation of interstate and heavy traffic pavements, many concrete pavements have distressed past the point of economical repair through resurfacing and restoration. Recycling these pavements is the most economical alternative. Unfortunately, there is a lack of knowledge of the effects that old concrete has on the durability and long term performance. The effects of road salts, oils and other contamination, as well as, poor quality aggregates must be evaluated. Use of the old concrete matrix as an aggregate and/or recycled PCC as an aggregate in new pavements must also be researched.

Objectives

The objective is to establish the effect of recycled PCC on new concrete pavement durability and produce recommended mix designs for optimum use of recycled material in new pavements. This would be accomplished through literature review and further laboratory testing and evaluation.

Current Activities

Some agencies have recycled PCC pavements into base materials. Better use of the recycled material would be through use as aggregate in new pavement mixes, as a substitute for new raw materials.

Urgency

Since many miles of heavy traffic pavements require improvement through replacement with new concrete pavements, further knowledge of the effects of recycled materials on concrete durability would be beneficial. The most cost-effective alternatives for reconstruction could be made through the optimum use of the recycled concrete material.

PROBLEM 123: Guides and Specifications for "Fast Track" Construction of Concrete Pavements with Emphasis on Curing, Materials, Mix Designs and Opening to Traffic

For the last 50 years 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.

Objectives

The research objective would be to develop construction guides and specifications for "Fast Track" concrete that can be opened to traffic within hours after placement. Special emphasis should be placed on identification of appropriate materials, curing methods, mix designs, joint sealants and opening strength criteria. This information would then be made available to agencies and contractors for their use in pavement reconstruction and rehabilitation.

Current Activities

The concrete paving industry is making progress in developing "Fast Track" paving techniques; however, some agencies are apprehensive to apply Fast Track due to their lack of experience.

Urgency

Since much money is being allocated or about to be allocated to rehabilitate the interstate roadway system while under traffic, it would be beneficial to agencies and industry to develop "Fast Track" concrete paving. Equally as important is the need for strong, durable pavements to meet future traffic needs.

A2F02 Committee on Flexible Pavement Construction and Rehabilitation

PROBLEM 124: Construction of Large Stone Mixes

Recent increases in truck tire pressures and loads have resulted in an increase in rutting in asphalt pavements. Some states have begun using mixes with larger maximum size aggregate and in some cases higher stone content to produce asphalt mixes that are more resistant to rutting. These modified mix designs do show some improvement in mix properties but they cause problems during handling, placement, and compaction of asphalt mixes. Some of the problems that have been observed include segregation, tearing and pulling during placement, and inadequate compaction. Other problems include difficulty in mix design and quality control testing. Most states use 4 inch samples which are too small for these larger aggregate mixes.

Objectives

1. To identify all problems observed during construction and related laboratory testing of asphalt mixtures containing large stones (greater than 1").
2. To develop methods to be used during construction and testing to ensure that a high quality product is obtained.

Current Activities

1. Key Words: Large stone mixes, rutting, segregation, construction, laboratory testing.
2. Recent research on these topics has been conducted by a number of organizations. AAMAS which is a current NCHRP project is evaluating laboratory testing and mix design of asphalt mixes. The National Center for Asphalt Technology (NCAT) has looked at the use of larger maximum aggregate sizes in mixtures. The Asphalt Institute (AI) and NAPA have been involved in the construction of several projects where larger aggregate was used. Many states have performed work in the laboratory and in the field using these larger stone mixes.

Urgency

More and more projects are constructed each year with an increase in the maximum size of aggregate. It is imperative that the paving industry determine the best methods for testing and constructing these large stone mixes.

A2F04 Committee on Construction of Bridges and Structures

PROBLEM 125: Minimizing Cracking in Newly Constructed Bridge Decks.

It is not uncommon for newly constructed bridge decks to develop severe transverse cracking shortly after completion. Construction techniques, materials or conditions during construction may contribute to early severe cracking. In addition new technology has brought about development of wider finishing equipment, higher production concrete decking equipment and materials with new characteristics which might alter deck concrete behavior during placement or early curing stages.

Techniques, materials and conditions with high potential for causing deck cracking should be identified and methods of minimizing cracking should be evaluated.

Objectives

1.Review available literature on causes of early cracking in concrete decks and similar configurations of concrete.

2.Select a number of structures that displayed early severe deck cracking and identify common materials, methods or conditions that appear to have contributed to this cracking.

3.Catalogue measures that can be employed or should be avoided to reduce the potential for cracking for each type of probable cause.

Current Activities

1.Key words: Shrinkage, Curing, Flexural Cracking, Retarder, Plasticizer, Bridge Deck, Hydration.

2.Appears to be no comprehensive study being made of the problem at this time. Past research and small individual efforts likely to exist.

Urgency

The problem of cracking in new bridge decks now exists and the risk of occurrence is present on active construction. Corrections to recent sizeable occurrences of deck cracking have proven costly and questionable.

PROBLEM 126: Evaluation of Completion Time Incentive/Disincentive Clauses for Construction Contracts.

The increasing construction cost of transportation projects in general and the necessity of carrying traffic through construction has made completion of projects in as short a time as possible of paramount importance. Some transportation agencies have turned to incentive/disincentive clauses in construction contracts to promote early completion of projects. Such clauses generally pay a bonus for completion before a specified time and deduct liquidated damages for completion after a specified time. Calendar days are usually specified rather than working days. Are these incentive/disincentive clauses effective in promoting early completion of projects and what effect do they have on the total cost of construction projects including user costs? How are agencies using these specifications and, if they are effective, under what circumstances do they work best?

Objectives

1. To review existing specifications and procedures used by transportation agencies and evaluate their experience and success and failure with those specifications.
2. To evaluate the cost effect of incentive/disincentive clauses on the total project cost including user costs.
3. To propose possible specifications and guidelines for implementation and under what circumstances they are most effective.

Current Activities

1.Key words—Incentive/Disincentives, Contract Calendar Days, Working Days and Liquidated Damages.
2.Related research activities—No formal research or publications are known of at this time. Most transportation agencies have developed their own specifications and guidelines and evaluated their effectiveness on a project-by-project basis.

Urgency

Timely completion of transportation projects concerns both the agency that directly pays for and administers the project and the traveling public which uses the transportation system and pays for it through taxes and user fees. With the increasing cost of construction and the high cost of both direct and indirect delays, methods to promote timely completions need to be evaluated.

This problem statement was rated the highest priority of the nine research need statements submitted by the Construction Management Committee.

PROBLEM 127: Expert System for Contractor Qualifications

Qualification of contractors for publicly funded projects is a complex process utilizing both objective and subjective data. Necessarily, the process followed should have a rational and replicable procedure for weighting information about the potential contractors, depending on the specific characteristics of the project. Expert systems provide a potential tool which could be exploited to provide a fair, replicable, rational means of evaluating contractors for publicly funded projects. While a system applicable to all types of projects would be extensive, it is possible to develop a prototype system for a specific class of projects, such as resurfacing, bridges or grading.

Objectives

The objectives of such a project would be to:

1. Examine the process of qualification of contractors and determine an appropriate microcomputer-based expert system software shell to model the procedures used by experts.
2. With the help of experts from various transportation agencies, develop an expert system for qualification of contractors.
3. Test the system with actual project qualifying conditions to determine where modifications are needed, and enhance the system.

Current Activities

1.Key words—Construction, Qualification, Expert System.
2.Related research activities—Several studies have been conducted which have identified the process used to qualify contractors. The Penn State work has identified the procedures followed, and to some extent, the criteria used (six states). A study was conducted by Capt. Mark

Wright at the University of Kansas, which focused only on the criteria.

Urgency

Such a tool would sharpen the process of qualification and reduce the potential for disputes arising from disqualification of contractors.

This problem statement was rated second from the highest priority of the nine research need statements submitted by the Construction Management Committee.

PROBLEM 128: The Negative Impact of Dramatically Rising Liability Insurance Rates

Rapidly escalating insurance premium rates have dramatically impacted the construction industry. The problem continues to grow with a noticeable reduction in insurance companies that will submit bids and the conspicuous loss of competition. Jury awards for liability damage continue to be in high figures. The small contractor and potential contractor feel great pressure causing a loss of contractor growth in the industry.

Objectives

1.To determine true and accurate reasons for premium increases.

2.To determine near future expectations for costs.

3.To determine alternate methods for writing cost effective insurance.

4.To evaluate the feasibility of legislation that would limit risk.

Current Activities

1.Key words—Cost, Limited Risk.

2.Related research activities—The Associated General Contractors of America has done work on this subject. In addition, there has been information provided by insurance underwriters and AASHTO has probably done some general work on the subject. The State of New York is attempting a new insurance program but has not implemented the final plan.

Urgency

Affordable and practical insurance is basic to a healthy competitive bidding process. The problems generated by a runaway insurance industry affects all public construction expenditures. Research findings could be coordinated through the insurance industry and then, if accepted, be publicized nationwide. The true result of industry controls would be developed in future bid prices.

This problem statement was rated third from the highest priority of the nine research need statements submitted by the Construction Management Committee.

PROBLEM 129: Controlling Quality on Highway Projects Designed and or Managed by Consultants

The accelerated highway programs in the country have created the problem of a shortage of sufficient qualified highway personnel in Departments of Transportation for most states in planning, designing and construction management of highway projects. In many instances, contracts have been entered into with consultants to plan and design projects, and to do preliminary design, especially during peak load periods. Consultants have been used on complex or specialized designs requiring certain expertise that is not available internally. In a few instances, consultants have been used to design and manage construction projects especially on toxic soils. A major problem that arises with the use of consultants is with quality control, particularly during the design stages. The quality of the design produced by the various consultants do vary. Furthermore, inconsistencies in quality control, usage and coordination of consultants' work exist. The million-dollar question is "How does the federal or state agency know what it is getting from the consultant?"

Objectives

1.Review and synthesize the experience with the use of consultants and the approaches/methods in use at the federal and state levels to achieve desired quality control starting with design.

2.Investigate, identify and evaluate current practices in controlling quality in planning and design by certain selected states.

3.Determine factors and the primary elements for a comprehensive quality control program.

4.Undertake case studies of federal, selected states and consultants' design work to test and analyze the factors and elements identified in (3) above.

5.Explore the use of single consultants for planning, designing and construction management.

6.Develop knowledge base of data on variety of patterns or methods of engaging consultants and how to control quality in each pattern.

7.Develop procedure(s) that are used to effectively control the quality of consultants' work and at the same time eliminate the inconsistencies.

Current Activities

1.Key words—Construction, Consultants, Design, Project Control, Estimating, Management.
2.Related research activities—No current activity.

Urgency

The procedure(s) and the data base will (a) provide a more accurate method for controlling quality of consultants' work and (b) lead to expert systems in selecting and controlling consultants to achieve desired quality. There is a significant immediate and long term need for such procedure(s) and data base.

This problem statement was rated fourth from the highest priority of the nine research need statements submitted by the Construction Management Committee.

PROBLEM 130: Reference Schedules for Transportation Projects

Scheduling of transportation projects has been performed to varying degrees by state and local highway agencies. Clearly, there are advantages to having a schedule, however simple, for progress measurement and other administrative functions. Project schedules, if developed individually, require substantial time by someone within the agency. One possibility, due to the similarity between many transportation projects, is to develop a family of reference schedules for the range of projects normally encountered. These would then be modified to reflect the quantities, production rates, weather, and other major factors which would be unique for an individual project. In this way, a useful tool for project control could be developed with a minimum expenditure of effort.

Objectives

The objectives of the study would be:

1.To develop a series of 10 to 20 typical logic networks (controlling activities) for the normal range of transportation projects. These would be developed through interviews with major contractors.
2.To develop a range of production rates for the normal set of controlling activities. Again this would be accomplished through contact with contractors.
3.To develop an interactive software program and data disk to simplify the process.

Current Activities

1.Key words—Construction, Schedule, Project Control
2.Related research activities—Preliminary work was started at Purdue University in 1979. No current activity.

Urgency

Such a tool would enhance the productivity of the project engineer in performing normal administrative tasks, and would offer sounder project management of projects for the responsible agencies.

This problem statement was rated fifth from the highest priority of the nine research need statements submitted by the Construction Management Committee.

PROBLEM 131: Managing Removal or Relocation of Utilities in Rights of Way

Prior to any new construction or rehabilitation of highway projects, utilities that are affected by such work(s) have to be removed or relocated. However, at the present time, there are problems in planning, scheduling, coordinating and or controlling removal or relocation of utilities in the right of way. In many instances, construction projects are delayed, resulting in cost and or time overruns. These problems and their effects are agitating transportation personnel, especially those in the urban areas, to determine procedures that can be followed to effectively manage utility removal or relocation.

Objectives

1. Review and synthesize the current experience and practices by selected states in managing utility removal or relocation prior to construction using case study approaches.
2. Interview utility companies and organizations to determine their problems in meeting scheduled times for removing or relocating their facilities.
3. Determine factors that cause delays or non-compliance in removing or relocating utilities prior to construction.
4. Study the possibility of establishing utility "clearing house" or board to manage or coordinate utility removal or relocation; define the composition, duties, responsibilities and authorities of such a board.

5. Develop procedure (s) which can be followed to get utilities removed or replaced prior to construction.

Current Activities

1. Key words—Administration, Public Utilities, Relocation, Removal, Right of Way.
2. Related research activities—None.

Urgency

The procedure(s) will provide a more accurate and effective methods for FHWA; and most states in planning, scheduling, coordinating and or controlling utility relocation or removal. There is significant immediate and long-term need for such procedures.

This problem statement was rated sixth from the highest priority of the nine research need statements submitted by the Construction management Committee.

PROBLEM 132: Construction Projects with Constructibility Reviews

Criticism of design by construction contractors is not new nor are the associated change orders and claims which arise through errors, conflicts, and deletions in the design documentation. Because of the nature of the planning, design, and construction process by most transportation agencies, it can be expected that gaps in information development or transfer may appear between the specialty consultants and design and construction professionals. These gaps often prove costly to the agency, when through some form of systematic review, the design could be improved prior to the contracting process. This systematic review and evaluation process would be termed as "constructibility review." Such reviews are common in industrial projects and would appear to have applicability to transportation projects.

Objectives

The basic objectives would be:

1. A survey of the typical design deficiencies in transportation projects would be conducted and an appropriate scheme for categorizing these deficiencies would be developed.
2. A methodology for conducting constructibility reviews would be developed for various delivery processes employed by transportation agencies (external design, eternal design, and various combinations). These methodologies would be tested and evaluated and enhancements made.
3. A manual would be developed detailing the methodology for conducting constructibility reviews for transportation projects with examples.

Current Activities

1. Key words—Construction, Design, Quality, Constructibility Review.
2. Related research activities—Preliminary work for buildings was started at Heriot-Watt University with sponsorship from the Scottish Development Department and the Building Research Establishment of Scotland. Some work has been done by the University of Texas—Austin relating to the petrochemical process design. specific work related to transportation projects or other public-funded projects is not documented and thus, assumed to not exist.

Urgency

Clearly, problems with constructibility increase the cost of construction projects and thus reduce the dollars available for capital improvements to our transportation network. The benefits of such a study would be of an enormous magnitude, in terms of dollars, if through constructibility reviews, 5 percent of the change orders could be eliminated. This project would seem to have an assured, and immediate, payback with proper dissemination of the findings.

This problem statement was rated seventh from the highest priority of the nine research need statements submitted by the Construction management Committee.

PROBLEM 133: Developing Profilograph Control for Pavement Smoothness

The quality of newly constructed pavements dramatically effect pavement service life and public acceptance of the finished project. In addition, the paving industry needs to make every effort to renew pride in finished work and to work aggressively for better cost control. In the final analysis, the highway user must expect to receive the most substantial product that can be obtained from his highway user dollar. Pavement smoothness is basic to this problem.

Objectives

1. All types of profilograph equipment on the market today should be correlated from every perspective.

2. Realistic smoothness values should be established for incentive and disincentive specifications.

3. Smoothness values should be considered separately for urban and or isolated small locations.

4. Smoothness specifications should be developed for asphaltic surfaces.

5. A determination should be made regarding acceptable bump measurements and the specifications necessary for bump grinding and acceptance. Guidelines should be established to implement training of staff for testing and analyzing smoothness results. Quantified data should be developed to confirm service life extension versus smoothness ratings.

Current Activities

1. Key words—Service Life, User Comfort and Acceptance, Pride in Work.

2. Related research activities—Related work on this subject has been done by several states who have either implemented new specifications or are developing them. AASHTO has done committee work on the subject, but their total research is unknown at this time. In addition, the Federal highway Administration has been involved to some extent, and there are a few major paving contractors that have developed some experience and practical opinions on the subject. There may also be some correlation with the newly implemented Strategic Highway Research Program.

Urgency

Limited transportation funding requires better quality and longer service life. Results of this research would probably be regionalized to some extent and would be implemented by regions. It is conceivable that the Federal Highway Administration may in the near future mandate usage of such specifications when federal-aid is involved.

This problem statement was rated eight from the highest priority of the nine research need statements submitted by the Construction management Committee.

PROBLEM 134: Effective Human Resources Planning and Management

Two major problems facing the Federal Highway Administration 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 need 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 should 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 work loads in designing, construction and maintaining highways as well as managing finances, automation activities, human resources, etc.

3. Explore the statistical relationships of the various work load generators, developed in (2) above.

4. Review and evaluate the selected states DOT's personnel development and hiring practices to determine their effectiveness.

5. Investigate and identify human resources 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.

Current Activities

1. Key words—Design, Construction, Human Resources, Management, Planning, Resources.

2. Related research activities—None.

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 (a) forecasting human resource needs by FHWA and the states' divisions, districts and residencies, (b) budgeting, (c) coping with shifting demands in construction and maintenance, and (d) 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.

This problem statement was rated ninth form the highest priority of the nine research need statements submitted by the Construction Management Committee.

A2F07 Committee on Fabrication and Inspection of Metal Structures

PROBLEM 135: Interpretation of Acoustic Signals Recorded by Transducers Attached to Bridge Members

For acoustic monitoring to be useful in indicating bridge integrity, a way must be found to reliably interpret transducer signals in terms of the incremental fracture behavior and concomitant loss of load-carrying capacity of the bridge member.

Objectives

To establish correlations between acoustic signals and various types of microfailure events. The approach is to analyze the topography of conjugate fracture surfaces of specimens whose failure process was monitored by acoustic transducers. By using the data to reconstruct the microfailure details and correlating the microfailure time sequence with the acoustic signal sequence, we expect to be able to attribute particular signals to certain microfailure events, to estimate the size of the fractured area and hence to assess the reduction in the load-carrying capacity of a degrading bridge member.

Current Activities

1. Research in Progress—Although considerable effort is being devoted to understanding acoustic emissions spectra, little success has been achieved in relating AE signals to microfailure events occurring in the metal. The main limitation has been the lack of a way to observe microfailure events. A new concept that quantifies and compares topographies of conjugate fracture surfaces promises to provide the necessary microfailure data.

2. Suggested Key Words—Fracture Surface Topography Analysis, Acoustic Emission.

Urgency

If acoustic signals could be reliably interpreted in terms of microfailure events within stressed material, acoustic monitoring could become a practical way of detecting early signs of bridge failure, and could result in enhanced safety assurances.

PROBLEM 136: Determination of the Effects of Plasma Cutting on the Performance of Cut Edges

None of the relevant standards contain any guidance on the requirements for edge dressing of plasma cut edges, whether for subsequent welding or for free edges. Many different plasma cutting techniques are available and each will have a different effect on the quality and characteristics of the cut edge. There is only a very limited amount of published data on the characteristics of plasma cut edges, and less still concerning the performance o the edges when welded. Because of this general lack of data, at present edges are often required to be dressed back up to 3 mm from the plasma cut edge. This is sometimes to remove microcracks which have been observed in certain steels; however, this is often a blanket approach used for all plasma cut edges.

The problem is relevant to both the construction of new bridges and the repair of existing ones.

Therefore, there is a requirement to investigate the integrity and mechanical properties of welded joints made on as cut edges for typical grades of structural steels and for joint types relevant to those found in bridge construction. Free edges are also of interest, the fatigue performance of the edge being reliant on the surface quality of the cut, particularly its smoothness. This is of particular importance with respect to plasma cut holes and flange edges.

Objectives

The objectives are to generate quantitative data on the performance of plasma cut edges in common grades of structural steel. This would involve the welding and testing of joints made on dressed and undressed plasma cut edges. Mechanical and fatigue testing would be carried out, with mechanical testing by bend and tensile tests and hardness measurement. In addition, fatigue testing of specimens with as cut edges would be carried out.

Current Activities

1. Research in progress: A small-scale study is presently being carried out to determine the performance of plasma cut edges. However, this work is at an early stage, and of the four materials being studied, only one is a structural steel of a thickness relevant to bridge construction.

2. Suggested keywords: Plasma Cutting Welded Joints, Fatigue Strength.

Urgency

Fatigue failure and the repair of structures are very costly. Gains in productivity both in initial manufacture and repair can be achieved by use of the plasma cutting process which is both faster, and produces less distor tion, than traditional flame cutting. it is expected that cut quality can be improved in terms of the requirements for edge dressing by use of plasma cutting rather than traditional techniques.

A2H03 Committee on Mineral Aggregates

PROBLEM 137: Relationship Between Aggregate Characteristics and Field Performance of Base Courses

Information on the relationship between aggregate properties and field performance of untreated aggregate base course is generally lacking. The problem concerns base courses designed as structural layers in both flexible and rigid pavements as well as those designed as drainage layers. The optimum use of materials—considering cost, energy and resource conservation—for various levels of performance may not occur.

The entire realm of problems from defining the purpose of aggregate base course to developing realistic construction specifications should be studied and the technology brought up to date. Performance needs to be defined in terms of basic properties such as, but not limited to, permanent deformations over time as well as resistance to transient deflections. Physical and chemical aggregate properties such as density, gradation, durability, particle shape and texture, permeability and degradation under the effects of dynamic and repetitive loads must then be related to performance requirements. New tests for design and construction control may need to be developed which are more relevant, simpler and less costly than existing tests.

There is a lack of research on the influence of aggregate properties on thickness design. Future thickness design procedures, including provisions in the new AASHTO Guide for Design of Pavement Structures, will increasingly use mechanistic principles. Mathematical models now available may offer the means to analyze the effects of aggregate properties on thickness design, provided detailed characterization of the materials is known. Observation of field performance to verify mathematical predictions is also needed.

Objectives

a. Investigate and define purpose and performance requirements of aggregate base course in relation to present knowledge and needs.

b. Determine the effects and sensitivity of aggregate properties on modulus of resilience in mechanistic thickness design of base courses under various stress and environmental conditions. Verify laboratory and theoretical predictions with field observations.

c. Evaluate design criteria and, if necessary, develop new procedures and test methods to evaluate aggregate base materials for required performance.

d. Develop methods to evaluate costs and energy requirements of aggregate bases for various levels of performance and alternate materials.

e. Evaluate existing field control tests and, if necessary, develop new practical tests to ensure adequate performance of aggregate base.

Current Activities

a. Suggested key words: aggregate properties, base course, untreated aggregates, performance requirements, mechanistic design, modulus of resilience, construction control, testing, cost and energy.

b. There is no known comprehensive research on the problem. Several research studies in the United States and abroad have been completed, or are in progress, on various narrow specific aspects. An important reference is NCHRP Report 100, *Research Needs Relating to Performance of Aggregates in Highway Construction* (1970).

Urgency

The highway construction industry is facing increasing pressure to reduce material costs and improve efficiency. At the same time, sources of high quality aggregate are decreasing. Proper characterization of aggregate base course materials is essential if long-term performance at an optimum cost is to meet the needs of the highway user. Continued emphasis is needed to provide research direction.

PROBLEM 138: Criteria for the Use of Salvaged and Recycled Aggregate in Pavement Structures

In certain areas of the country, the supply of natural aggregates is limited, either through the depletion of economically available material or zoning restrictions on new quarry sites. This situation tends to exist in highly developed urban areas, where there often is the additional problem of proper disposal of wasted concrete. The combination of these two situations creates the incentive to incorporate the waste concrete as aggregate in new concrete, thus alleviating both problems. With increasing use of recycled concrete as aggregate in new concrete, the applicability of present aggregate tests to concrete salvaged from various structures and use and acceptance criteria for this material need to be established.

Objectives

It is known that recycled concrete has values which are higher than normally accepted for natural aggregates in such tests as absorption and L.A. Abrasion. Criteria need to be established as to what levels of test results are acceptable for recycled material, and also the applicability of certain test procedures. Criteria which need clarification include:

a. Gradation
b. Absorption (for both PCC and BCC)
c. Los Angeles Abrasion
d. Specific gravity
e. "D" cracking susceptibility
f. Alkali-aggregate reactivity
g. Freeze-thaw durability
h. Allowable contaminants:

1.Gypsum
2.Chlorides
3.Bitumen
4.Organics

Current Activities

a. Suggested key words: recycling, recycled aggregates, recycled concrete, aggregate testing, aggregate acceptance.

b. Many states have become involved in the recycling of PCC and have therefore investigated some of these criteria. The FHWA has also been active in this area through its Demonstration Project 47, Recycling Portland Cement Concrete Pavements. Criteria such as gradation, absorption, and abrasion have been addressed by several states and the behavior of recycled material examined. For these criteria, what is needed is establishment of generally acceptable levels. Other criteria listed under objectives are less well established in terms of the tests which are acceptable.

Urgency

As recycling of PCC into aggregates for new concrete becomes more widespread, it becomes increasingly important to be able to screen materials to determine those which will provide acceptable performance in the proposed application. To this end, appropriate test methods need to be selected and acceptable test results established.

PROBLEM 139: The Adverse Effect of Chlorides on Various Types of Aggregates

Premature failure of portland cement concrete (pcc) pavement due to rapid deterioration is a serious problem that is intensified with the shortage of highway funds. The durability of pcc in a particular environment is dependent on materials, design, construction and maintenance. Substantial research has been conducted and is in progress in regard to the D-cracking mode of rapid deterioration. Even though susceptible aggregates and some factors that affect the rate of deterioration have been identified, all failure mechanisms are not fully understood. The generally accepted failure mechanism of D-cracking is freezing and thawing.

Rapid failure of pcc may be due to freezing and thawing in conjunction with other factors such as chemical deterioration. Field reviews of pavements with identical materials, similar design and similar construction will often document the more rapid deterioration of roadways with greater de-icing salt application. It would appear that the salt accelerates the deterioration through either physical or chemical reaction, or both. A more thorough understanding of the rapid failure mode will result in improved design and reduced maintenance of pcc pavements.

Objectives

Determine the effect of chlorides on aggregates that contribute to the rapid deterioration of pcc pavement by the following:

a. An investigation and summary of past and current efforts in this area.

b. Determination of the effects of freezing and thawing in water, and freezing and thawing in chloride salt solutions as well as continuous soaking and wet/dry cycling in chloride salt solutions on various coarse aggregates.

c. Determination of the effects of these same conditions on concrete samples containing various coarse aggregates.

Current Activities

a. There are no known studies currently going on in this area. This work would be an extension of work reported by J.E. Gillott on pages 177-192, Volume II of the Quarterly Journal of Engineering Geology, 1978.

b. Suggested key words: aggregates, D-cracking, portland cement concrete, freeze thaw distress, chloride, salt influenced distress.

Urgency

D-cracking of concrete pavements continues to be a problem in obtaining necessary service life. Until the mechanisms involved in D-cracking are fully understood, permanent prevention of the problem is difficult to achieve.

A2J01 Committee on Soil-Portland Cement Stabilization

PROBLEM 140: Stabilization Characteristics of Waste/By-Product Materials-Compatibility and Leachate

A wide variety of waste/by-product materials are being produced in large quantities and at increasing rates by the industries in the U.S. and abroad. A partial list of such materials includes power plant ashes and sludges, incinerator residues, gypsums, refuse from mining operations, and slags. The disposal of these materials in a safe, economical and environmentally acceptable manner is of growing concern. The most desirable way of disposal is the utilization of these wastes in various engineering applications. Stabilization with cement (or other stabilizing agents) is required for acceptable performance in many higher types of uses such as highway pavements. It has been recognized that waste-/by-product materials very frequently possess physical, chemical and engineering properties that are significantly different than those of conventional aggregates and soils. This requires that they be properly and thoroughly characterized by appropriate tests prior to use. Two important questions arise relative to the stabilization of these materials: (a) compatibility of the stabilizing agent (e.g. cement) with the waste/by-product material; and (b) characteristic sand environmental acceptability of leachates from the stabilized materials.

Objectives

a. Research and construction literature should be investigated to compile information on the characterization and utilization of waste/by-product materials in general, and compatibility and leachate aspects in particular. Specific attention should be directed to sulfate-bearing materials (e.g. gypsums) relative to compatibility with different types of cements (C_3A content may be a significant factor). Focus relative to leachate aspects should be on the types and concentrations of trace elements and heavy metals.

b. Well-designed experimental research is needed to characterize and document the stabilization reactions, including long-term effects, between the waste-by-product materials and different types of cements. End properties of stabilized mixtures, i.e. strength, durability, volume stability and permeability, should also be investigated. Experimental research is also needed on characterizing leachates. Comparisons
should be made between the leachates from unstabilized and stabilized materials, and studies should be conducted on possible mechanisms, such as cementation of the elements to surface, chemical changes, encapsulation, etc., which may be responsible for improved (or worsened) leachate quality.

c. Laboratory studies should be supplemented with field trials for actual performance evaluation. Strength retardation and heaving problems, including long-term effects, and leachate quality should be monitored and documented.

Current Activities

A very limited activity is focused on the compatibility issue at the present time. Only a modest amount of research work is currently being conducted on the leachate characterization aspects of stabilized waste/by-product materials. There is no single source of information compiled on these subjects.

Urgency

There is great concern on the part of both the U.S. industry and public on the environmentally acceptable disposal of all types of wastes. There are also increasing pressures on the highway/ transportation agencies to utilize the wastes in their construction projects. These factors underscore the importance and urgency of this research.

A2J03 Committee on Lime and Lime-Fly Ash Stabilization

PROBLEM 141: Lime Columns or Deep Soil Mixing in Highway Embankment Rehabilitation, and Maintenance

The use of lime columns or deep soil mixing is a technique of in situ soil improvement involving the construction of vertical or inclined columns of improved soil by addition and mixing of lime, fly ash, cement, flue dust or other dry products. To date, use of the lime column method has been limited to Japan and the Scandinavian countries, and utilization of this soil improvement technique has received only limited attention from the construction industry in the U.S. and virtually none from the research community. Lime and cement fly ash mixtures are widely used in the highway industry to modify and stabilize near surface soils such as base courses and improved roadbed materials. The mechanisms of improvement (ion exchange, pozzolanic reaction and hydration reaction) are the same for deep soil mixing; however, little is known concerning the design methodology for the technique. While it is possible that these techniques can be successfully utilized without the development of such a design methodology, this type of stabilization does not have adequate research which could serve as a basis for design or construction guidelines.

Objectives

a. Research and construction literature-especially those generated in Europe and Japan-should be investigated to determine the extent of previous design methodology developments for lime columns as a method of in situ soil stabilization.

b. Current slope stability design procedures need to be reviewed and analyzed using lime columns to determine how improvement is calculated to determine factor of safety.

c. Current method of estimating foundation settlements should be reviewed in light of utilizing lime columns. It is reported that due to the increase in soil permeability of the columns drainage increased and consolidation times decreased.

d. Other applications for lime columns to solve various geotechnical problems should also be investigated.

e. Experimental field projects should be planned to verify the effectiveness of lime columns for embankment stabilization, rehabilitation of low volume roads and other appropriate applications, and to establish parameters for this technique such as maximum depth, soil types, etc.

Current Activities

Although previous lime column work in the U.S. is virtually nonexistent, there should be no technical reason why this method should not experience the same success here as it has experienced abroad.

It appears that no current ongoing research is being conducted which addresses the objectives listed above.

Urgency

This stabilization technique appears to have potential in the maintenance and rehabilitation of low volume roads. Many highway embankments located across flood plains are subjected to significant saturation levels during the wet season and have over a period of years become significantly distorted and need to be restored to their original template. However, restoration of the template without modifying the embankment materials would only temporarily solve the distortion problem. This technique should also have potential in new construction areas for reducing long term settlement of foundations and embankments and in improving stability of newly constructed embankments.

Since improved maintenance and rehabilitation procedures could result in lower costs and improved performance, especially for low volume roads and embankment stabilization, the proposed research should be a high priority item.

PROBLEM 142: Synthesis on the State-of-the-Practice of By-Product Reuse in the Construction of Transportation Facilities

The transportation industry is being, and will be more frequently in the future, called upon to incorporate industrial and mining by-products into the construction of transportation facilities. More and more frequently transportation facilities (roads and airports) are located through or in former waste disposal areas with the proviso that the transportation owner must reclaim or make environmentally harmless the whole waste area. Transportation agencies have been asked to incorporate mining by-products such as sulfate sludges, and coal mine refuse and others into or under the pavement

structure. During its Waste Utilization Program of the 1970's FHWA looked at incinerator ash, fused incinerator residue, highway litter, by-product sulfate, sewage sludge and others for highway applications. The results of this program indicated that many by-products have good potential for constructing transportation facilities. It appears that many transportation agencies have used or treated by-product materials in the development of their facilities. A synthesis of the State-of-the-Practice of by-product use and/or treatment is needed to identify existing technology for its design and use and gaps in the technology which need to be filled by future research.

Objectives

a. Research and construction literature should be investigated to determine the extent to which mining, industrial and domestic by-products have been used or treated to satisfy the construction needs of transportation facilities.

b. Identify laboratory and field test procedures to evaluate the various by-products for use as a construction material.

c. Develop a strategy for evaluating the cost effectiveness of by-product utilization based on a total picture that includes the cost of transportation, disposal, treatment and storage of the by-product.

Current Activities

There has been no formal program in by-product utilization by a transportation agency since 1980. The Environmental Protection Agency has sponsored research in fulfilling its charge to implement the Resource Conservation and Recovery Act of 1976. The Department of Energy has also sponsored research on the use of the by-products of energy production.

The construction and public works literature frequently contains articles on by-product treatment and utilization. Consulting engineers are frequently called upon to assist in by-product containment and utilization problems. It appears that there exists a considerable body of information available that needs to be synthesized to enhance sharing of the technology as well as identifying needed improvements.

Urgency

The value of land used to store various by-products and the costs associated with their transport and treatment to mitigate their detrimental impact to health and the environment strongly endorse the need for their reuse. States and smaller governmental entities must use all the resources available to solve their pressing problems i.e. the construction and maintenance of transportation facilities must help solve the problems of waste disposal. This is evidenced at the Federal level in that it is legislated that fly ash shall be used in the production of concrete. Similar legislation mandating the use of other by-products may be in the offing.

It is imperative that the construction industry develop the technology to utilize these by-products before their use is mandated.

PROBLEM 143: End of Construction Stability of Compacted Plastic Clay Embankments

Recently several states have experienced failure or severe bulging of embankments constructed using compacted plastic clay. Factors contributing to these failures include:

1. Laboratory compacted samples may not represent the field soil structure.
2. Laboratory tests performed on the finer fraction of well graded soils do not represent the behavior of the total sample.
3. Shear planes may be induced during the field compaction process.
4. Field control using only dry density and water content may not effectively control the soil's shear strength.

Objective

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.

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.

PROBLEM 144: Stability of Wide Embankments on Very Soft and Relatively Thin Cohesive Layers

The stability (bearing capacity) of embankments on very deep soft deposits can be 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. Available theoretical solutions based on idealized models from the theory of plasticity do not agree with each other, and they do not consider very flat side slopes nor layers of variable thicknesses. Common computerized slope stability programs are not applicable to this problem.

Objectives

Develop realistic solution to the problem using both classical and finite element techniques. Bound the problem for a range of embankment widths, side slopes, thicknesses of weak layers, and slopes of the underlying firm layers. Simple design charts covering the range of applicable variable should be developed.

Current Activities

Some research has been conducted on this problem as applied to reinforced embankments, but no definite solutions are available.

Urgency

The problem is urgent, especially for reinforced embankment, as an unreinforced bearing capacity analysis must be carried out prior to any reinforcement analysis and design. Expensive failures may be avoided.

PROBLEM 145: The Efficiency of Vertical Drians

It is generally assumed that vertical drains accelerate the process of consolidation and settlement. Research has never addressed the question of the amount of improvement that one can expect from using vertical drains over the rate without drains. It is generally agreed that the rate increases but does the increase justify the cost of the drains. It has been observed that the coefficient of consolidation backfigured from drains spaced close together is not as great as that calculated from wider spaced drains.

Objectives

To develop a logical process for determining the conditions for which the cost of the vertical drains is justified.

Current Activities

There is no effort underway to investigate this question.

Urgency

Until this question is addressed some projects will continue to waste money.

PROBLEM 146: 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. In order to maximize the effective use of available funds for road improvement projects, it is proposed that problems associated with the use of embankment for widening in areas of compressible soils be identified, and available as well as innovative methods of analysis and construction be researched, compiled, and detailed for reference purposes.

Objectives

To define and develop design and construction solutions for widening embankments over soft ground.

Current Activities

Currently, there is no in-depth analysis of the problem.

Urgency

This problem becomes more urgent with time as upgrading of the existing ROW becomes more frequent than new construction.

PROBLEM 147: Design Parameters for Prefabricated Vertical Drains

Installation of prefabricated vertical drains (PVD) is a soil displacement process. This process has been known to cause smear around sand drains in the past. The selection of the design parameters is further complicated by the fact that the shape of the PVD does not approximate the circular shape assumed in the theory. Proper design requires that the effect of smear be accounted for.

Objectives

To improve the ability to design PVD installations effectively.

Current Activities

Work has been done on finding an equivalent diameter of PVD drain but the question of smear has not been addressed.

Urgency

The determination of these parameters will insure more efficient design.

PROBLEM 148: Stabilization of Creeping or Marginally Safe Slope by In Situ Soil Reinforcement

Recent research efforts have concentrated on developing design methods, construction guidelines and applicability criteria for the construction of "top down" walls such as "Soil Nailed Walls" and "Tieback Walls" for permanent or temporary application on the transportation system. A larger need exists to develop effective methods of in-situ stabilization of creeping slopes or slopes that may be marginally stable or become marginally stable due to steepening to accommodate widening. The literature indicates potential successful applications using either closely spaced inclusions (nails) or large diameter piles or caissons. Methods of analysis used for these applications vary widely and no consensus emerges as to a "most rational" method. This is further complicated in that creeping slopes and marginally stable slopes require totally differing design approaches (see NCHRP-290).

Objectives

A need exists to develop a rational cost-effective methodology for the rehabilitation or stabilization of these slopes using closely spaced inclusions or large diameter inclusions. Specific areas of concern are classification of problems, development of design methods and monitoring schemes. The design must consider the driving forces and the capacity and orientation of inclusions.

Current Activities

General information in NCHRP-290.

Urgency

Priority 1-Retaining Wall Foundations. This research is urgent to permit proliferation of top down walls for landslide stabilization.

PROBLEM 149: Soil Structure Interaction as Identified for Use in Soil Nailing and In Situ Soil Reinforcement

A growing volume of work is being performed by specialty contractors using small diameter inclusions drilled and grouted into in situ soil masses to provide support reinforcement strengthening of an in situ soil mass. Soil nailing for retaining walls is only one example of the potential uses of this phenomenon. Other examples of in situ reinforcing in the U.S. have been for "Root Pile" or "Type A" INSERT wall structures used for landslide control and also inclusions used to reinforce a soil or rock zone overlying a mined or cavernous zone. Potential other uses include reinforcing the soil under surface structures that will be undermined by urban tunneling and for control of liquefiable soils under existing dams and other structures.

Objectives

The cost effectiveness of the in situ reinforcing solution is typically dependent on spacing top diameter ratios that are required to assure interaction among the inclusions, i.e., how close together must they be to insure that the reinforced zone will act as a unitary mass of reinforced soil. Paper studies as well as modeling will give a more economical refinement of the answers required. Field testing of a number of different configurations in different soil types would lead to definitive answers.

Current Activities: None

Urgency

Priority 2-Retaining Wall Foundations

PROBLEM 150: Evaluation of Slurry Wall Design Procedures

The use of slurry walls has been a relatively recent development in the construction of earth retention facilities. Their use in transportation facilities, however, has become increasingly common in many states in recent years. Largely because of the lack of experience and lack of research on slurry walls, current procedures for their design are highly empirical and approximate.

In transportation facilities, slurry walls are generally used for support of vertical excavations. They represent an alternative to other types excavation support such as soldier pile walls, which are typically more flexible than slurry walls. The design of slurry walls, as with other types of retaining structures, depends on the pressures exerted on the wall by the retained soil. The development of these pressures, however, is influenced strongly by the interaction of the soil and the wall. Available

design procedures for excavation support systems are based on the measured behavior or relatively flexible wall systems. The applicability of these procedures to the typically much stiffer slurry walls is uncertain. The uncertainty associated with these design procedures introduces conservatism at several steps in the design process. The cumulative effect of this conservatism is a final design which is often substantially overconservative, resulting in slurry walls which are thicker and more heavily reinforced than likely necessary.

Objectives

Research would include both analytical and experimental investigations of slurry wall behavior for the purpose of development of rational slurry wall design procedures.

The research would consist of analysis of full scale slurry wall behavior. This would include the extensive instrumentation and detailed measurement of the behavior of selected sections of a new slurry wall, in relatively poor soil conditions. The instrumentation system would be designed to measure deformations and stresses in the wall and in the soil in the vicinity of the wall. The response of the wall and soil would be interpreted in a soil/structure interaction analysis in order to evaluate the performance of the wall. The results of these analyses would be used to develop improved design procedures for slurry walls.

Current Activities

Non-substantial basic work covered in FHWA research publications RD 74-29/30.

Urgency

Priority 3-Retaining Wall Foundations

PROBLEM 151: Soil Nail Wall Design

Soil nail walls are a relatively new development for both temporary and permanent retaining systems. The system consists of unstressed ground anchors with shotcrete facing. The design is currently based on a limit equilibrium analysis which is generally considered to be inconsistent with the load transfer mechanism. This analysis results in an overconservative design with individual nails being designed for excessively high loads. This conservatism reduces the cost-attractiveness of soil nail walls over conventional tied-back walls and results in increased shoring costs.

Objectives

Research needs to be conducted to develop more cost effective design procedures. Examples of issues to be addressed are: the contribution of nail shear resistance to overall wall stability, actual earth pressures that develop on wall facing, wall deformation associated with construction, and determination of actual reinforcement stresses.

Current Activities

FHWA research contract DTFH-61-85-C-00-142 to develop a basic manual of practice for soil nailing will be completed in 199O. Also AASHTO-ARTBA-AGC Task Force 27 has completed a generic specification for soil nails in 1989.

Urgency

Priority 4-Retaining Wall Foundations

PROBLEM 152: Long Term Vertical Forces in Tiedback Soldier Piles

There is concern in the design of tiedback walls as to the ability of various soil profiles to carry the vertical forces developed from the tie back tensioning and the weight of the wall. Current practice varies from assuming that the friction between soil and steel can carry all the vertical force to assuming that none of the vertical force is transferred to the soil. This latter approach results in significant length of soldier piles below the elevation of the bottom of the final wall and the development of a drilled shaft system to carry the vertical force and the weight of wall.

Objectives

Determine mobilization of wall friction coefficient by instrumenting soldier piles of anchored walls. Relate mobilization of skin friction to development of increased lateral load due to negative wall friction angle.

Current Activities

FHWA proposed research DTFH61-89R-00038 addresses basic concepts of same objectives.

Urgency

Priority 5-Retaining Wall Foundations

PROBLEM 153: Seismic Response of Tied-Back Walls

Permanent tiedback walls are now being constructed in many states. However there is limited data on how these walls respond during an earthquake.

Objectives

There is no generally accepted method for seismic analysis of tiedback walls. To develop new design procedures, an understanding of the soil-structure interaction under seismic loading needs to be developed. The effects of surcharge, anchor locations, out-of-phase movement, wall stiffness, diaphragm wall embedment, potential reduction in anchor capacity, and other critical factors need to be evaluated. AASHTO criteria does not provide any specific guidelines. Some states are designing for seismic loads while others are not. Research is needed to develop an understanding of seismic soil-tiedback wall behavior, which would result in a design approach and procedures.

Current Activities

Washington State has recently published Phase I of Seismic Response of Tieback Retaining Walls which entails areas of needed research.

Urgency

Priority 6-Retaining Wall Foundations

PROBLEM 154: Permanent Geotextile Walls: Evaluation of Long-Term Durability and Strength of the Geotextile Layers

Geotextile walls have proven to be very cost effective wall options, often costing 50 percent less than any other wall types available. However, geotextile wall use for permanent installations have been limited due to the unknown long term performance of the geotextile reinforcing layers. Performance of the geotextile as a soil reinforcement layer within the wall is dependent on geotextile creep,durability, installation damage, and the synergy of these three factors.

Objectives

The long term performance of the geotextile layers must be determined before permanent geotextile walls can be used with confidence. A considerable amount of effort is already being expended to establish methods to predict long term creep as a function of ultimate geotextile tensile strength. Limited work has been performed, however, regarding the effect of durability factors, such as oxidation and hydrolysis, as well as the effect of installation damage, on long term geotextile strength. The synergy of these factors with stress and creep has also not been investigated.

New research should address long-term geotextile durability (i.e., oxidation and hydrolysis), construction damage, and the synergy of these factors with stress and creep.

Current Activities

The Geosynthetic Research Institute sponsored a seminar on Aging and Durability of Geotsynthetics in 1989. The AASHTO-ARBTA-AGC Task Force 25 has recently prepared generic specification for geosynthetics.

Urgency

Priority 7-Retaining Wall Foundations

PROBLEM 155: Soil Resistance Factors for Load-Resistance Factor Design of Foundations for Highway Structures

General criteria currently are being developed for the application of the Load Resistance Factor Design (LRFD) Method to the design of foundations for highway structures. This method requires resistance (ϕ) factors, which quantify the uncertainties in the soil properties used in LRFD. The development of ϕ factors for soil properties must consider uncertainties that are not usually considered for other structural materials. For example, while the strength of steel or concrete is determined from relatively standardized tests, the strength of soil is evaluated by numerous methods with different degrees of reliability, ranging from crude empirical correlations to relatively complex laboratory and in situ tests. Consequently, the ϕ factors for soil should vary with soil type and test method. Environmental effects and time dependent changes also should be considered.

Objective

The objective is to use probabilistic methods to develop appropriate soil resistance factors for typical soils and common test procedures. For some soil types, e.g., clean sands and saturated clays of low sensitivity, an adequate data base is likely to be available, especially for the more commonly used test methods. However, for other soils, particularly those of local and regional interest, or for more specialized testing methods additional experimental data will be needed. Resistance factors should be developed for both shear strength and deformation properties.

Current Activities

The framework for LRFD for highway structure foundations and some load and resistance factors currently are being developed under NCHRP Project 24-4. The project also is comparing results obtained from the proposed LRFD criteria and conventional working stress methods.

Urgency

Appropriate values of soil resistance factors will be essential to the implementation of LRFD methods for foundation design. However, the proposed research should utilize the frame work and criteria developed in NCHRP 24-4.

Priority 1-Shallow foundations

PROBLEM 156: Spread Footings Data Base

Large savings can be achieved by using spread footings rather than deep foundations. It has bene shown that the cost of spread footings varies from 15% to 65% of the cost of pile foundations. This advantage is often not taken because the engineer does not have the same confidence in a spread footing as he does in a pile foundation.

Objective

The objective is to increase the engineer's confidence in spread footings by documenting and then improving the accuracy of settlement predictions. This will require the collection of a data base of spread footings. Many pile load test data bases have been comparatively dismal. There is a need to develop a comprehensive data base and to use it to improve the precision of settlement predictions.

Current Activities: None

Urgency

Considering the potential cost savings involved with the use of spread footings, this research is considered to be extremely urgent.

Priority 2-Shallow foundations

PROBLEM 157: Non Destructive Testing of Spread Footings

Large savings can be achieved by using spread footings rather than deep foundations. It has been shown that the cost of spread footings varies from 15% to 65% of the cost of pile foundations. This advantage is often not taken because the engineer does not have the same confidence in a spread footing as he does in a pile foundation. A spread footing load test at a site would increase the engineer's confidence in the design; however, a load test is relatively expensive and will decrease the savings generated by using spread footings.

Objective

The method is aimed at increasing the engineer's confidence in a spread footing design with a test with relatively low cost. It is a dynamic load test performed by hitting the footings with a sledge hammer instrumented with a force transducer and recording the footing-soil response with two geophones placed on the footing. The stiffness of the footing-soil system can be determined from analyses of the force-time signal from the hammer and the velocity-time signal from the geophones. The stiffness may be used to evaluate the soundness of the footing (quality control) and to calculate the settlement under load (verification of design).

Current Activities: None

Urgency

Considering the potential cost savings involved with the use of spread footings, this research is considered to be extremely urgent.

Priority 3-Shallow foundations

PROBLEM 158: Determination of Pile-Driveability and Capacity from Sounding Rods and SPT Tests

In spite of extensive research efforts over the past several years, the prediction of pile-driveability and pile

capacity from subsurface investigation information remains to a considerable degree an art. Today, about one-third of all state highway departments are using dynamic devices such as the Pile-Driving Analyzer to estimate pile capacities and to study other aspects of pile-driving performance. It should be possible to use such devices to make measurements during Sounding Rod and SPT test to establish both static soil resistance and damping constants for pile-driving analysis. This approach has the advantage that an established and familiar test is still used and only additional, optional measurements are made.

Objectives

Data should be collected on Sounding Rod and SPT tests at sites where piles are driven and dynamically tested. These data should be analyzed and methods developed from improved pile length estimation, capacity prediction, and driveability analysis.

Current Activities

None-after a few field efforts by the University of Colorado and Pile Dynamics Inc.

Urgency

Priority 1-Deep Foundations. The use of SPT data to design bridge foundations is widespread. This research is essential to improve current procedures while utilizing existing exploration equipment.

PROBLEM 159: Development of Criteria for Predicting Load Transfer Between Drilled Shafts and Geomaterials Intermediate Between Soil and Rock

The use of drilled shaft foundations provides for increased economy in comparison with driven piles. Considerable research has been conducted into the mechanisms of load transfer of drilled shafts in classical geomaterials such as saturated clay, sand and massive rock. However, drilled shafts are often the most economical alternative to driven piles in hard soils to soft, weathered rock. Examples of such geomaterials are clay-shales and mudstones of the midwest and far west, conglomerates, and the hard residual clays of the piedmont region. Presently, design is very conservative in these geomaterials.

Objectives

Fundamental research should be conducted to assess the effects of construction on the properties of such geomaterials, particularly as they relate to properties indicated by standard testing methods (laboratory triaxial tests, standard penetration tests, static cone test, pressuremeter tests, dilatometer tests, etc.) This research should be done under as closely controlled conditions as possible (analytical or experimental) to avoid effects of random scatter that might arise by analyzing past load test records, and at least some carefully planned full-scale field test should be included in the program.

Current Activities

The Association of Drilled Shaft Contractors has privately sponsored several small research efforts in the past few years. FHWA is currently promoting increased use of drilled shafts nationally with a National Highway Institute course.

Urgency

Priority 2-Deep Foundations. Urgent that research begin now to provide improved criteria for state DOT's increased use of drilled shaft foundations.

PROBLEM 160: The Use of Non-Destructive Testing Methods to Evaluate Behavior Characteristics of Piles and Drilled Shafts

There are a number of situations in which the integrity of a driven pile or drilled shaft may be in doubt after construction. For example: (1) In drilled shafts intensive use of reinforcing steel may potentially prevent the outflow of concrete into the annular surface between the reinforcing steel and the soil, producing an important defect. Conventional, existing low-strain sonic, ultrasonic or gamma logging nondestructive testing methods cannot usually detect such defects. (2) In the slurry displacement method for installing drilled shafts, which is becoming increasingly popular due to low cost, cutting can potentially settle out of suspension in the slurry and become entrapped between the concrete and base of the shaft, making the shaft susceptible to large settlements before mobilizing its full end-bearing capacity. (3) Piles driven to potentially high toe bearing in rock may have defective toes due to structural failure. (4) In some environments scour may remove soil around piles or piers that may be needed to assure stability.

Appropriate means of integrity evaluation for these and similar conditions must be developed. Methods, such as mechanical impulse-response methods and geophysical methods, should be studied to determine such engineer-

ing properties as the initial tangents to head and toe load-displacement curves, from which internal integrity can be inferred, and mappings of the soil conditions around the pile, from which external integrity (e.g., scour damage) can be inferred. Having such methods available will increase the designer's confidence in the integrity of deep foundations in difficult subsurface profiles.

Current Activities

FHWA has begun a major research effort DTFH61-88-Z-00040 on conventional integrity testing of drilled shafts. Additional work will be required to refine specialized systems for production use.

Urgency

Priority 3-Deep Foundations

PROBLEM 161: Risk Assessment in the Design of Deep Foundations

There is presently a move in the transportation engineering community in the U.S. to convert design codes (for example, AASHTO) to a load and resistance factor basis, rather than an allowable stress basis. Doing so would have obvious benefits to the designers, since foundation design would be pursued along the same line as structural design.

To make a load and resistance factor design approach workable, careful research is needed into the precision of prediction of pile capacity and settlement with various design approaches, which will then lead to the establishment of realistic resistance factors. One product of such research should be a rational method for assessing risk, and the development of the seeds of a design philosophy that risk is a part of all foundation design in that designs should be developed to an acceptable level of risk and not to a level of perceived zero risk.

Current Activities

Research is presently underway to provide a framework for such a design process for bridge foundations. NCHRP Study 24-4 will result in a load factor approach for the AASHTO Bridge Specifications.

Urgency: Priority 4-Deep Foundations

PROBLEM 162: Long-Term Observations of Relative Settlements Between Pile Groups and Soil Surrounding Pile Groups

Current state-of-the-art design methods concentrate on determination of pile capacity and the establishment of design lengths that ensure little or no settlement of the foundation (for example, peremptory use of toe-bearing piles). This design perspective, in general, results in piles that are potentially too long, which increases foundation costs. In reality, the design of pile foundations is governed primarily by concern that settlement does not reach the tolerable settlement of the superstructure (as opposed to merely assuring adequate capacity), and it is highly desirable that the settlement aspect of the problem be given greater attention in the pile design process. The settlement problem is most significant when piles are installed in groups, or clusters.

It is therefore recommended that pile group foundations and the surrounding soil be instrumented and monitored over a long period of time. The instrumentation should be geared to measurement of deformation in the piles in relation to the settlement of the surrounding soil, and loads in the piles and their changes with time should also be monitored. Several diverse geologic profiles should be chosen for such monitoring, and both floating and toe-bearing pile groups should be studied.

Current Activities: None

Urgency: Priority 5-Deep Foundations.

PROBLEM 163: Use of Timber Piling in Bridge Foundations

Timber piles have a potential economic benefit over certain other types of piles in many bridge foundation applications. While state highway engineers generally do not specify timber piles at present, it is possible that economic pressure will increase to do so, since, unlike steel, timber piles are produced domestically. Past research into the behavior of timber piles, especially regarding allowable capacities, has been contradictory.

A comprehensive program of study is needed to evaluate both the allowable stresses in timber piles under varied conditions of installation and loading and the long-term behavior of timber piles under varied environmental conditions.

Current Activities

The American Wood Preservers Institute has previously sponsored small research efforts at the University of Colorado to determine allowable stress in timber piles.

Urgency

Priority 6-Deep Foundations.

PROBLEM 164: Group Action in Axially Loaded Drilled Shafts

An advantage of the use of drilled shafts is that one drilled shaft can be constructed as an alternate to using a group of driven piles. However, if extremely heavy loads are to be resisted or if there is a limitation on drilled shaft size (as for micropiles), it may be necessary to place drilled shafts in closely spaced groups. Significant research has been conducted recently into the behavior of groups of driven piles, at least relative to their short-term capacities and load-settlement behavior. No such parallel work has been done with drilled shafts. Furthermore, there is reason to believe that the response of groups of drilled shafts, especially in granular soils, will be very different from that of groups of driven piles, for which design criteria are available. This is because the action of drilling produces stress release in the soil surrounding drilled shafts already in place, and there is uncertainty regarding the effect of concreting on the reestablishment of effective stresses, which control the behavior of the shafts in the group. Since the use of drilled shaft groups is rapidly increasing, since the Federal Highway Administration is presently emphasizing drilled shafts as economical alternates to
driven piles, and since no design guidance whatsoever exists with regard to efficiency and settlement effects in drilled shaft groups, studies of this problem are particularly timely.

Objectives

Perform full scale tests on small diameter drilled shafts and develop a centrifuge and/or model shaft analysis to match the observed behavior. Extend the behavior aspects to larger shafts at variable spacings and lengths.

Current Activities: None.

Urgency

Priority 7-Deep Foundations.

PROBLEM 165: Corrosion of Driven Steel Piles

In the late 1950's and early 1960's the U.S. Bureau of Standards issued several publications concerning the corrosion of buried metals. The first report addressed the corrosion of metals buried entirely in disturbed soils. An approach to corrosion protection grew out of this study that involves soil resistivity, pH, dissolved chemicals in ground water and redox potential. Two subsequent studies concerning driven steel piles indicated that corrosion is not a serious problem when there is a substantial portion of the pile below the ground water table.

Objectives

Occasionally corrosion on driven piles is observed, and there are no applicable guidelines for checking a site to determine how much if any protection is required for steel piles. As a result protection is often recommended by corrosion engineers who are unfamiliar with the true conditions for driven steel piles producing solutions that are overly conservative and expensive.

Current Activities: None.

Urgency: Priority 8-Deep Foundations

A2K04 Committee on Subsurface Soil-Structure Interaction

PROBLEM 166: Long-Term Performance of Buried Conduit Systems

Buried conduit systems of all types are subject to a number of time-dependent phenomena which can adversely affect the long-term performance of these systems. Foundation and backfill soils are vulnerable to both consolidation and time-dependent deviatoric creep, and recent evidence suggests that granular backfills may suffer from inadequate durability in some cases. Conduits themselves are often formed of time-dependent materials, can be subject to material degradation, can suffer adverse shape changes due to repeated loading, consolidation and creep-induced deformations, and are often subject to corrosion, abrasion and fatigue under repeated live loads. Weather effects, including seasonal changes in both moisture and temperature, may also affect long-term soil/conduit behavior. Most of these time-dependent phenomena are currently poorly modelled, if at all, in analyses and design, and there is currently a lack of good field data regarding long-term performance of many types of conduit systems, and also a lack of data relating to potential retrofit of these systems. Exceptions are corrosion and invert abrasion, for which a fair amount of data already exists for some conduit types.

Objectives

Acquire field data relating to the long-term performance of various types of conduit systems, and to retrofits of these systems. Develop and implement analytical procedures for modelling time-dependent soil and conduit behavior; this is expected to require significant laboratory testing of both soils and conduits. Study backfill durability and conduit fatigue behavior under many repeated cycles of live loading. Incorporate long-term performance considerations in conduit design procedures. Provide information and guidelines relating to potential retrofit of these systems.

Current Activities

Research regarding long-term plastic properties for thermoplastic pipe materials is currently advocated under a separate research needs statement. Considerable research on corrosion and invert abrasion has been performed for some types of conduit systems, primarily under the auspices of Committee A2C06. All other problem areas addressed above remain largely unresolved.

Urgency

In view of the tremendous number of buried conduits currently installed, there is an urgent need to develop a basis for evaluation of their projected durability and longevity, and to develop potential retrofit techniques to extend their service life. There is also a similarly urgent need to incorporate long-term performance considerations in the design of future conduit installations.

PROBLEM 167: Plastic Pipe Material and Structural Characteristics and Their Effect on Design

Problem

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-sectional 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

a. Conduct a literature search to collect available data on pipe response to load as well as material properties.

b. Determine material properties applicable to the design or selection of non-pressure plastic pipes.

c. 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 parameters to reflect longitudinal flexibility, resistance to bending moment, and corrugation stability.

d. Conduct field tests with varying backfill conditions to determine acceptable limits of the parameters indicated in a, b, and c above.

e. Develop analytical procedures for predicting performance limits. Relate these performance characteristics to predicted soil reactions.

f. Recommend revisions to the materials and design specifications for profile and corrugated wall plastic pipe types.

Current Activities

a. Highway Research in Progress

1. Individual corporate profile and corrugation development.

2. Penn DOT and FHWA funded 104' Deep Burial Study on Polyethylene Pipe by Dr. Ernie Selig, University of Massachusetts.

3. Computer simulation using CANDE done by Dr. Mike Katona and funded by the corrugate Plastic Tubing Association.

b. Key Words-Ring Stiffness, Flexibility, Flexibility Factor, Bending Moment, Soil-Structure Interaction, Corrugation, Profile Wall, Corrugated Polyethylene Pipe, Plastic Pipe.

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 materials should reflect the actual distress and/or failure modes encountered in this type of installation.

PROBLEM 168: Buried Conduit Structural Backfill Envelope and Construction Effects

The structural backfill envelope is an important element in the performance of buried flexible conduits. Presently this zone is not designed, but rather constructed according to specifications indicating accept types of backfill materials, the minimum amount of compaction and the minimum envelope dimensions. Methods are not available for selecting values for these parameters which take into consideration pertinent project conditions. Furthermore placement and compaction operations affect the conduit deformations and moments, which are important to the performance. These factors are not presently a part of the design process.

Objective

Obtain a better understanding of construction effects through field investigations and determine means for incorporating these in design. Develop design criteria for the material, compaction and dimensional requirements of the structural backfill envelope which consider: frost, drainage, allowable deflection and shape change, buckling, thrust, and moment as a function of structure size/gage, structure shape, cover depth, water conditions, and nature of surrounding soil.

Current Activities

Some research has been done to address these issues, but the objectives have not yet been met. More field observations on placement and compaction effects are needed to represent a wide variety of construction alternatives. While all aspects of the structural backfill envelope design need some attention, the most critical are those relating to effects of soil property or behavior changes over a period of time after construction. Examples are soil creep, consolidation and property changes from moisture content changes. Means to incorporate the results of these studies into design practice must be established.

Urgency

The expected cost of future flexible conduit installations is very large. Especially important in relation to this research need is the potential extensive use of long span buried conduits as bridge replacement structures. The costs of these installations will be significantly affected by the results of the research.

A2K06 Committee on Subsurface Drainage

PROBLEM 169: 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, there 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:

a. Define the various types of free draining layers used in pavement systems.
b. Evaluate the total cost of construction of free draining pavement layers to include material costs.
c. Compare the performance of pavements on free draining layers with those on poor draining layers.
d. Quantitatively compare the cost vs. performance properties of pavements with free draining layers with those pavements without free draining layers.

Current Activities

Although the benefits of pavements subdrainage are well accepted, little has been done to quantitatively evaluate those benefits. Some of the current activities include:

a. Studies of subdrainage effectiveness on rigid pavement faulting by California DOT.
b. Studies of open graded base course gradation requirements by Pennsylvania, New Jersey, Illinois, and other DOT offices.
c. Studies of open graded base course performance in France by the Central Laboratories of the Ponts et Chaussees.
d. Numerous FHWA studies on the influence of subdrainage, pumping, and aggregate gradation on pavement performance.
e. 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 exist to quantitatively evaluate these systems. It is felt that this study will provide greater insight for the design of cost effective pavement drainage layers and to establish the value of drainage layers in pavement systems.

PROBLEM 170: 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 geosythetics 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.

Current Activities

a. 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.

b. Suggested key words geosynthetic, geotextile, geogrid, modelling, laboratory simulation, analytical modelling.

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. This procedure could be made more efficient with good fundamental research as indicated.

PROBLEM 171: Application of AASHTO Pavement Design Drainage Coefficents 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 a non-drained full depth pavements in areas of proper drainage because this one pavement is not penalized by a poor drainage coefficient.

Objective

The study objective is to determine the appropriate drainage coefficients to use with full depth bituminous pavements.

Current Activities: Unknown

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.

PROBLEM 172: 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 are:

a. Define the various types of free-draining layers used in pavement systems.

b. Determine the effects of gradations and material characteristics on the layer performance.

c. Determine the permeability criteria for each type of free-draining layer to ensure pavement performance.

d. Develop standardized laboratory procedure(s) to measure compliance with permeability criteria.

Current Activities

Some of the current activities include:

a. Studies by the California Department of Transportation

b. Studies of open-graded base course gradation requirements by Pennsylvania, Illinois, New Jersey, West Virginia, North Carolina, and Wisconsin.

c. Studies of open-graded base course performance by the Central Laboratories of the Ponts et Chaussees, France.

d. 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.

PROBLEM 173: Development of a Rapid Test Method to Determine In Situ Horizontal Permeability of Free Draining Bases (FDB)

With the promulgation of free draining bases in pavement design standards around the country, there arises the need to specify and determine the in-place horizonal permeability of these FDB materials, the desirable performance measure. Currently, in 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, these materials finished on grade are generally non-homogenous 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 DOT's 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.

Objective

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.

Urgency

The need for this test method is immediate since State DOT's are already specifying and using FDB's.

PROBLEM 174: Edge Drain Trench Compaction

Installation of longitudinal edge drains next to new or old pavements is becoming increasingly 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, at least in some cases, construction compaction was minimal or ineffective. Lack of compaction of the trench backfill leads to:

a. Settlement of the trench backfill.
b. 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:

a. Evaluate current construction practices in this area.
b. Propose and evaluate appropriate construction procedures to achieve high levels of trench backfill compaction.
c. Evaluate loss of pavement edge support due to trenching operations with both good and poor compaction procedures.

Current Activities

Past work has been performed on large utility trenches. No research activity into the area of narrow edge drain trenches is known.

Urgency

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.

PROBLEM 175: Detrimental Effects of Recycled Portland Cement Concrete as Subbase Material on Subsurface Drainage Systems

In the next several years, restoration, rehabilitation and reconstruction of our highways will be our major program effort. To accomplish this program, recycling, milling and crushing of old portland cement concrete 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 a cementitious material believed to leach out of the processed portland cement concrete. This leached material has plugged the installed subsurface drainage such that the free moisture becomes trapped in the pavement section causing early surface distress.

Objectives

The general objective is to continue the economical use of the recycled portland cement concrete in pavements. An economical pavement requires good long-term subsurface drainage characteristics. Therefore, a method needs to be developed to reduce the cementitious effect of the leachate from the recycled portland cement concrete.

Current Activities

At present, some States are investigating the reasons that underdrain systems have failed and have recognized the above problem to exist.

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.

PROBLEM 176: 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, on occasion, 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-difference icing. More specifically, the study must produce an analytical method (with real data in put and verified by field studies) to predict whether differential icing will occur.

Current Activities: None known.

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.

A2K07 Committee on Geosynthetics

Geotextiles within the Pavement Structure

PROBLEM 177: Effects of Using Fabrics for Waterproofing Asphalt Overlays

Reflection cracking field studies have shown the fabrics in overlays provide some benefit under certain conditions in delaying the formation of cracks in the asphalt overlay which are reflections of cracks which existed in the underlying pavement prior to the overlay. A number of highway agencies that have used fabrics in overlays claim success in delaying reflection cracking but also have expressed the view, based on very limited data, that even when the crack comes through the overlay, the fabric remains intact, and provides a waterproofing function. In 1972 and 1974, South Dakota conducted a field study of the waterproofing capability of fabric in which moisture contents of the underlying pavement structure were recorded periodically at various depths down to seven feet below the pavement surface. Results were favorable but not to the degree that an engineer can be assured that a certain fabric does act as a moisture barrier in a pavement overlay.

Objectives

The study should provide answers to the following questions:

a. What fabrics presently in use can be considered waterproof or rendered so with a proper tack coat?
b. What value does full width (out to out of shoulders) placement of fabric have on waterproofing the pavement particularly over Portland cement concrete?
c. If the fabric is truly waterproof, at what level in the overlay should the fabric be placed to provide maximum effective use?

Current Activities: None

Urgency

The possible waterproofing action of geotextiles used in overlays is frequently claimed to be an engineering benefit but little data exist demonstrating the validity of these claims. If a rational design method for paving fabric use is to be developed, it is urgent this problem be resolved.

PROBLEM 178: Paving Fabric Reinforcement

It has generally been recognized that a properly engineered and properly installed fabric system provides stress relieving and waterproofing functions within the pavement structure. Some advertising implies, however, that the fabric, in fact, reinforces an asphaltic concrete overlay.

Objectives

Determine if an engineered paving fabric does, in fact, serve as a structural member in a pavement system. If so, what physical properties (and minimum values) contribute to this feature?

Current Activities: None

Urgency

Urgency of this research need is high. If fabrics do, indeed, reinforce asphaltic concrete overlays, potential savings are great.

PROBLEM 179: Fabric Performance over PCC

Pavement rehabilitation often requires overlaying a Portland cement concrete (PCC) pavement with asphaltic concrete. Fabrics are frequently specified to act as a waterproof membrane over the old PCC pavement, and to retard reflection of the PCC construction joint up through the new overlay. Effectiveness of the fabric in this latter regard appears to be, among other things, a function of the degree of differential vertical deflection that may exist at the construction joint under load.

Objectives

Determine what magnitude of differential deflection can be tolerated without impairing stress relieving functions of the fabric. Or to put it another way, at what deflection levels should slab seating or stabilization be recommended prior to installation of a fabric membrane overlay?

Current Activities: None

Urgency

Urgency of this need is high. Asphaltic overlays of PCC pavements often incorporate geotextiles. This extra cost may be wasted if excessive vertical deflections are encountered.

PROBLEM 180: Paving Fabric Specifications

Agency specifications for paving grade fabrics have become mired by physical property requirements which appear unrelated to performance of the fabric within a pavement system. For example, fabric weight and fabric thickness may be important only to the extent that they contribute to tensile strength and asphalt retention characteristics of the finished membrane. If true, then weight and thickness, per se, may not be of fundamental importance to performance.

Objectives

Determine what fabric properties most directly relate to functional performance of an engineering fabric within a pavement system.

Current Activities: None

Urgency

Among the needs statements in this category, the urgency of developing specifications is moderately high.

PROBLEM 181: Effects of Recycling Asphalt Overlays Containing Fabrics

Recycling of our nation's pavements is a proven technology that continues to grow in use as we get back to saving the vast investment we have already made in our highway system. In the past 10 to 12 years, greater use has been made of synthetic fabrics in asphalt overlays, a technique for retarding reflection cracking. A recent report by FHWA identifies at least 19 fabric products in use experimentally and non-experimentally in asphalt overlays. Phillips Fiber Corporation financed a study by a Connecticut consulting firm on recycling of pavements using Petromat and no problems were reported.

However, the data are limited on the subject and success in every case is not assured, particularly with other fabrics.

Objectives

Determine the effects of geotextiles on recycling asphalt overlays. A study modeled somewhat after the Phillips Fibers Corporation study is recommended which will include all the more widely used fabrics of varying material and manufacturer.

Current Activities: None

Urgency

Compared to the other research needs statements regarding geotextiles, urgency of this need is relatively low.

Geotextiles in Reinforcing Applications

PROBLEM 182: Soil-Geotextile Interaction Behavior

The rapid increase in the use of geotextiles in transportation facilities is well-known. However, in many applications, particularly in reinforced retaining walls, embankments and roadways, the interaction mechanism of soils and geotextiles is not well understood. Both long term (creep) properties as well as dynamic properties require study.

Objectives

To conduct research into both the short term, including dynamic, and long term behavior of geotextiles in realistic soil-geotextile systems. Studies of soil-fabric friction, stress-strain behavior, and the creep response of geotextile are required. Ultimate objective is to develop realistic models for soil-geotextiles systems and to develop procedures for obtaining appropriate parameters for the design of these systems.

Current Activities

Some research is underway on these topics at a number of universities in the U.S., e.g., Oregon State, Purdue, Drexel.

Urgency

Very high priority. The continued economic and safe use of geotextiles is impeded by this lack of information.

PROBLEM 183: Evaluation of the Seam Strength of Reinforcing Geotextiles

In early geotextile reinforcement systems, adjacent sections of fabric were overlapped. Such a procedure was unsatisfactory when subgrade deformations were large, so field sewing was instituted. Limited evidence suggests that sewn seams have significantly (25-35%) less strength than the intact material. Yet designs are usually based on intact specimen tensile strengths.

Objectives

Set up a research program to:

a. Determine appropriate strength reduction factors for sewn seams
b. Develop alternate stronger seams

Current Activities: None

Urgency

High priority for safe construction of reinforced embankments on very soft foundations.

PROBLEM 184: Design of Low Deformation (Permanent) Roads Incorporating Geotextiles

Limited field experience has shown geotextiles to be of considerable benefit in permanent roads. However, design parameters are currently lacking. Design guidelines and validated evidence of advantages of using geotextiles in permanent roadway design are needed.

Objectives

Determine advantages of geotextiles in low deformation systems. Determine design parameters for different geotextile constructions in low deformation systems. Research should be carried out on soil systems of CBR less than 2. Effect of geotextiles when used with free draining subbase materials should also be examined.

Current Activities

Various geotextile producers offer design procedures for temporary and haul roads. NCHRP Project 10-33 examined the structural benefits of incorporating geotextile within the unbound layers of flexible pavement systems.

Urgency

This is an important area for the use of geotextiles in highway engineering.

PROBLEM 185: Use of Geotextiles and Geogrids in Bridge Abutments

A significant proportion of the cost of bridges and bridge replacement can be attributed to the abutments of especially short bridges. Geotextiles and geogrids can potentially reduce the costs of abutments while increasing their stability, especially where foundation conditions are poor.

Objectives

Develop design methodology and construction procedure for the use of geotextiles and geogrids in bridge abutments, especially in rehabilitation and replacement structures.

Current Activities

Geogrids have been used in England for the construction of the abutments of at least one bridge. Fabrics and grids have been used in earth retaining structures.

Urgency

High priority, as the need for the rehabilitation of county and local bridges is great.

Geotextiles for Drainage and Filtration

PROBLEM 186: Drainage/Filtration Performance of Soil-Geotextile Systems

Lack of apparatus and procedures for evaluating acceptable drainage/filtration performance of geotextiles with various soils.

Objectives

a. Select or develop the most appropriate apparatus and procedure(s) for simulating drainage/filtration behavior or a soil-fabric system.

A soil-fabric permeameter system that can yield permeability vs. time and gradient ratio measurement appears to be most appropriate for this evaluation. Short

term (1-7 days) and long term (2 weeks) behavior should be compared and analyzed to determine if performance can be predicted using a "quick test" (1 or 2 days) that would be appropriate for government agency and independent lab testing.

b. Determine the behavioral mechanisms of the soil-fabric system (e.g., bridging, filtercaking, clogging, etc). This should include identification of those parameters that affect or control the behavioral mechanisms.

c. Recommend apparatus, procedure, and relevant performance indices that should be used to predict field performance of soil-fabric systems. This recommendation should also include options for test conditions that could be selected to evaluate non-critical and critical field conditions.

d. The ultimate goal of this research need will be to establish guidelines for acceptable fabric performance, i.e., allowable limits for performance indices (e.g., maximum gradient ratio, maximum change in system permeability, etc). Guidelines should include recommendations for soil-fabric drain system design that will eliminate or reduce the chances of adverse behavioral mechanisms.

Current Activities

Previous work by Marks (University of Tennessee), Leflaive (French Textile Institute), Rollin (University of Montreal), and Haliburton (Oklahoma State University) have defined several mechanisms of soil-fabric interaction, however, conditions of testing vary greatly between researchers. Other smaller scale research efforts have been conducted by Koerner (Drexel), McGowan (Strathclyde), and other manufacturer sponsored programs.

The Corps of Engineers, Haliburton & Associates, Geotextile manufacturers, Drexel, and many others are currently using the gradient ratio test (or a variation of that test) for acceptance testing of geotextiles for critical drainage applications.

Urgency

Very high. The urgency of this research need is very great. There must be a concentrated effort to sort out the facts that reflect true performance mechanisms and significant engineering criteria.

The gradient ratio has been standardized by the Corps of Engineers and adopted by a number of government agencies and private engineers for evaluation and specifications of geotextiles. The validity of this test method must be evaluated before it becomes an accepted standard.

PROBLEM 187: Field Evaluation of Drainage Fabric Performance

User confidence in the long term performance of drainage fabrics is constrained because little diagnostic field data has been collected on a nationwide basis.

Objectives

a. Survey highway department and other government agencies throughout the United States regarding drainage fabric experience in order to locate those agencies who have used geotextiles extensively and can provide data on long term performance. Assess the response from these agencies relative to the successes and failures encountered in drain fabric use.

b. Exhume drainage sections in both "problem" and "successful" projects and assess the cause for their respective performance. This should include examination of the exhumed fabric, the drainage aggregate and pipe, and the protected soil for evidence of piping, clogging, or other adverse behavior.

c. Construct and monitor test sections under controlled conditions for performance monitoring. Test sections should be designed and constructed so as to eliminate or reduce variables that might lead to noncomparable results between sections.

Current Activities

Several state highway departments have exhumed drainage sections in the late 1970's. Conclusions from these projects have noted varied performance but no concrete definition for performance differences. There has been very little exploratory investigation into fabric protected drainage trenches other than watching outflow from collector pipes.

Urgency

The urgency of this research need is also very high. Drainage fabrics are rapidly becoming the conventional approach to protecting subsurface drainage structures. Although thousands of drainage structures have been installed with fabrics in the past 10 years, only fragmented documentation has been provided. It is time for a full scale evaluation of performance.

PROBLEM 188: Flow Capacity of Prefabricated Drainage Structures

Measurement of water flow capacity of prefabricated drainage structures (pds).

Objectives

a. Develop/select an acceptable test method for evaluating pds.

b. Measure flow capacity of commercially available prefabricated drainage structures under various hydraulic gradient conditions and confining pressures. Assess the performance expectations of "pds" products versus conventional aggregate filled drains...short and long term. Define the behavioral mechanisms that affect pds flow capabilities (e.g., system deformation, fabric deformation, etc).

c. Recommend use criteria for pds, including flow rate requirements for various applications (e.g., pavement edge drains, retaining walls, etc).

Current Activities

Healy & Long have published results of field evaluations for pds systems (1983). No significant testing has been reported since that time. Prefabricated drain manufacturers have developed their own flow testing equipment and procedures.

Urgency

Urgency is high because prefabricated drainage structures are growing in prominence and use in transportation related projects, i.e., behind retaining walls, bridges, abutments, cut off drains and embankments. Flow capacity evaluations are necessary to generate critical information required in drain system design.

PROBLEM 189: Performance of Geotextiles for Slope Erosion Control Applications

Evaluate the performance of geotextiles used in erosion control on armored slopes.

Objectives

Develop a soil-fabric test method(s) for evaluating geotextile performance in erosion control applications. The method should simulate erosion forces that act against an earth slope (e.g., wave action, surface runoff, seepage, etc) and evaluate the effects of various hydraulic and construction conditions on soil fabric armor system performance. The method should accommodate variable soil, hydraulic and materials parameters and identify the critical failure mechanisms.

Current Activities

The Corps of Engineers routinely uses the Gradient Ratio test to evaluate fabric performance potential in slope erosion control applications. This approach does not consider the varied hydraulic effects encountered in slope erosion control applications, i.e., wave actions and surface runoff.

Urgency

Urgency is moderate compared to other research needs within this category. There is a variety of geotextiles used for slope erosion control in transportation related facilities. The selection criteria for such fabrics are not based on evaluations that simulate field conditions. Such evaluation is necessary to aid in selection of effective erosion control fabrics.

PROBLEM 190: Transmissivity (In-Plane Flow) Behavior of Fabrics

Measurement of in-plane flow capacity (air and water) of fabrics when under simulated field use conditions.

Objectives

a. Develop/select an acceptable test method(s) for measuring air and water transmissivity of fabrics under variable soils and boundary conditions.

b. Recommend guidelines for testing (apparatus & procedure) including specific conditions for tests as they relate to the various applications anticipated.

Current Activities

No independent studies have been published on geotextile transmissivity. Fabric manufacturers have developed their own testing techniques for transmissivity.

Urgency

Urgency is relatively low among these problems. Fabric transmissivity is not a critical parameter for the majority of geotextile uses and transportation related structures. There are, however, numerous situations where in-plane flow capacity of a geotextile could be employed:

- Embankment drainage
- Subgrade drainage
- Vertical drainage
- Intceptor drains

A method for measuring transmissivity is a prerequisite to design and use of the in-plane flow capabilities of geotextiles.

Railroad Applications of Geotextiles

PROBLEM 191: Abrasion Testing of Geotextiles Used in Railroad Tracks

Geotextiles are subjected to severe abrasion when embedded in railroad track ballast, and there exists no accurate means of predicting the abrasive resistance of geotextiles.

Objectives

The contemplated test method should meet the following criteria:

- Be phenomenologically related to the track environment
- Produce quantifiable results predicting fabric longevity
- Be relatively inexpensive and swift

Current Activities

Currently available abrasive test methods (Taber, Rotary Drum, Queen's University Method) do not simulate or even roughly approximate the railroad environment. Furthermore, current results are highly subjective and inconclusive.

Urgency

The Taber test will probably continue to be used until a better test is developed, even though the Taber test results can be entirely misleading. Accordingly, development of a new test is very urgent.

PROBLEM 192: Depth of Placement of Geotextiles Used in Railroad Track Bedding

Accurate determination of the optimal depth of insertion of geotextiles in railroad beddings.

Objectives

Determination of the following geotextile/bedding parameters and their influence on the optimal depth of insertion:

- Geoxtile manufacturing process
- Geotextile mechanical properties
- Geotextile chemical composition
- Geotextile structural parameters
- Tie and ballast types and composition
- Track MGT and dynamic loading
- Subgrade composition and structure

Current Activities

Current activities are considered preliminary and barely indicative. One potential resource is the Caldwell Test Site data (AAR archives)-a wealth of raw data from the Southern Pacific/Monsanto test track.

Urgency

Recognizing that shallow placement may result in early disintegration of the geotextile and that deep placement is very expensive, the need for guidelines determining optimal depth of insertion below track is very urgent.

PROBLEM 193: Use of Geotextiles as Sub-Ballast Replacement/Reduction Medium

Determination of the quantitative benefits offered from the use of geotextiles as a sub-ballast replacement/reduction medium.

Objectives

To determine the possibility of using geotextiles as a sub-ballast replacement/reduction, i.e., the geotextile's ability to act as the following:

- Subgrade reinforcement
- Filtering medium
- Moisture barrier
- Particle separator
- Subgrade stabilizer
- Drainage medium

Current Activities

Current activities consist of a few individual uncoordinated tests being conducted by separate railroads.

Urgency

Should the geotextiles prove to be a proper substitute for sub-ballast, the savings would be huge. Accordingly, the need is very urgent.

PROBLEM 194: Determination of the Dynamic Loading Functions of Geotextiles

Determination of the effect of geotextiles on subgrade loads.

Objectives

To compute the effective loads acting on the subgrade, i.e., establish a method for determining the relationship between known static reactions and dynamic railroad loadings, and the effect(s) of geotextiles on both.

Current Activities

Current activities are nonexistent.

Urgency

The development of an analytical loading function would allow a specific determination of geotextile strength requirements. Thus, the need is urgent.

PROBLEM 195: Chemical Stability of Geotextiles Used on Railroad Applications

To quantify the detrimental effects of corrosive agents commonly found in a railroad environment on polymer-based geotextiles used in track beds.

Objectives

To determine the degradation, if any, of geotextiles in contact with diesel fuels and track defoliants and to establish reliable life expectancies.

Current Activities

Current research indicates some serious contradictions between studies carried out by manufacturers and independent study groups. A probability exists that early test data (from the 1950's) differ from current data because the polymers have changed.

Urgency

The determination of these results would obviate ongoing chemical compatibility arguments and ensure the availability of the widest possible range of polymers. The need is moderately urgent.

PROBLEM 196: Evaluation of Caldwell Test Site Data

Potentially one of the greatest available resources for the analysis of geotextiles in the track environment is currently not being used because of the lack of funding.

Objectives

Sort, collate and analyze the Caldwell data.

Current Activities

As previously mentioned, a wealth of raw data is available but is not being used.

Urgency

Urgency decreases with each passing year but the reduction of the data will still prove valuable.

Geotextiles in Extreme Environments

PROBLEM 197: Geotextiles in Arctic Environment Applications

Determining the actual behavior of geotextiles used in arctic environments.

Objectives

To develop reliable methods for the determination and assessment of geotextile properties and behavior in arctic environment including:

- Mechanical properties at very low temperatures
- Interstitial cutting and abrasion from ice
- External cutting and abrasion from ice
- Conformance to large scale subgrade heaves and settlements

Current Activities

Current activities are experimental on a trial-and-error basis.

Urgency

Recognizing the increasing use of geotextiles in the arctic, the need is very urgent.

A2L01 Committee on Exploration and Classification of Earth Materials

PROBLEM 198: Applications of the New Generation of Regional High Altitude Photography and Planned Higher Resolution Landsat Satellite for Exploration of Transportation Corridors

This new imagery used in 1982-1986 has thematic map capability for vegetation and geology with higher resolution than present. Their application for exploration for transportation corridors has not as yet been fully defined or described.

Objective

Although the capability of high resolution in high altitude photograph is well documented the higher resolution planned for the newer satellite imagery will have untested use in transportation planning and exploration. There should be research to coordinate the two new systems to maximize utilization of data. We have not seen any reports of ongoing research of this nature.

Current Activities

a. The TRIS data base for key words "High Altitude Photograph" and "landsat" was scanned in preparation of this statement.

b. Simulation studies have already been done over a variety of terrain types for other purposes (e.g., agricultural crop studies, soil erosion and land use), but not for transportation.

c. Suggested key words: Satellites, satellite program, high altitude photography, landsat.

Urgency

Any delay in planning research for these two new sources of data will be detrimental to continued state-of-the-art use of remote sensing by the transportation field.

PROBLEM 199: 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.

Current Activities

a. The TRIS data base for key words "legal," "exploration,". "classification," "earth" and "soil" was scanned in preparation of this statement.

b. There does not appear to be any coordinated effort to resolve this problem by the legal profession.

c. Suggested key words: Legal action, legal responsibility, liability.

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 200: Physical Properties of Soils Related to Geophysical Subsurface Exploration

The physical properties of conductivity, density and velocity of soils and bedrock are measured by geophysical techniques. The correlation of the measured physical properties with soil types and/or bedrock is one of the major components of the interpretation of geophysical data. The correlation between physical properties of soils and/or bedrock may vary from area to area; however, broad ranges of physical properties can be correlated with soil types and bedrock. Correlation data are available in numerous textbooks and articles, but a comprehensive study or library search of such data is not available.

Objectives

The physical properties of soils are affected by numerous factors and may vary from area to area. The proposed

study, which may take the form of a library search, would present the data in a systematic way. The data may be grouped as related to differing climatic and geographical regions, i.e., tropical, temperate, arctic, foothills, plains, etc. The objective of this study is to further the understanding and behavior of the physical properties of soils and bedrock under varying climatic and geologic conditions, which would lead to improved interpretation of the geophysical data.

Current Activities

a. The TRIS data base for key words "geophysical exploration, and "soil physical properties" was scanned in preparation of this statement.

b. 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.

c. Suggested key words: Geophysical exploration, geophysical measurements, soil physical properties, correlation, subsurface exploration.

Urgency

The need for a systematic study of physical properties is a long standing one. The availability of a set of data resulting from the proposed study would enhance many fold the value of geophysical surveys, thus improving their cost-effectiveness. The problem is considered urgent.

PROBLEM 201: Evaluation of Geophysical Methods and Instruments as Applied to Subsurface Exploration of 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. This problem may be subdivided as follows:

a. Analysis and comparison of geophysical methods and instruments as applicable to subsurface exploration.

b. Analysis and comparison of interpretive techniques with special emphasis on transportation applications.

Objectives

a. Determination of those geophysical methods most appropriate for transportation applications.

b. Evaluation of modern geophysical instruments in regard to their applications and limitations.

c. Examination of new interpretive techniques and comparison with established procedures.

Current Activities

a. Research for tunneling applications has been sponsored by Federal Highway Administration Material Division, Project 5-B-2. In addition, Atomic Energy Nuclear Waste Disposal Research has achieved significant advances in the past decade.

b. Suggested key words: Geophysics, subsurface exploration, depth to bedrock, physical properties.

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.

A2L05 Committee on Engineering Geology

PROBLEM 202: Design of Horizontal Drains in Soil or Rock

Recent equipment developments have caused a rapid expansion in the use of horizontal drains in all types of soil and rock. At present, there is no proven way of determining where and to what length and slope such drains should be drilled for optimum effect except where the geology is well enough known to permit seeking specific joints, faults, or strata.

There is no general way of predicting the shape or extent of the zone of influence of the drains. Drilled drains are expensive and can be useless or even detrimental if poorly located. Present placement methods may provide more drainage than is necessary. It is desirable to know the service life and have a better understanding of the behavior of these drains during the service life.

The design and construction of collector systems affects the ultimate performance of the entire drain installation. Types of materials and methods of handling the collected water need study.

Objectives

The objectives of this research are to answer the following questions:

a. With respect to soil and rock conditions:

1. What is the optimum location, spacing, slope and casing type for drains?
2. What is the zone of influence around the drains?
3. How should pipe size and slot size be determined?

b. How should performance be monitored?

c. How can the need for individual pipe or system maintenance be determined?

d. How can maintenance best be accomplished?

e. What are the characteristics and performance of various collector system designs?

f. What service life can be expected?

Current Activities

a. The TRIS base was surveyed using the key words "horizontal" and "drains."

b. A California Department of Transportation/Federal Highway Administration study titled "The Effectiveness of Horizontal Drains" was completed in 1979 but did not address design methods. Additional references are:

Kenney, T.C., Pazin, M., and W.C. Choi, "Design of Horizontal Drains for soil Slopes", Journal of the Geotechnical Engineering Division, ASCE, November, 1977.

Nonveiller, e., "Efficiency of Horizontal Drains on Slope Stability", Proceedings of the 10th International Conference on Soil Mechanics and Foundations Engineering, 1981.

Choi, e.C.C., "Seepage Around Horizontal Drains in Hill Slopes", Journal of Hydraulic Engineering, Division ASCE, October, 1983.

c. Suggested key words: Drain, subsurface drainage, horizontal drains, drain performance, drawdown.

Urgency

A large amount of horizontal drain work is being done, especially in the control of landslides. Criteria leading to successful installations and accurate estimates of bid quantities would be valuable to designers and construction engineers.

PROBLEM 203: Rock Fall Behavior—Field Studies

In mountainous areas, construction of new transportation facilities is starting to encroach 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. It is difficult to predict from present kinematic models 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.

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 one or more selected study areas.

• To develop empirical predictions of rock fall behavior based on the available records.

• To use the above data to delineate hazardous areas and provide guidance for selecting collection bench widths or protective ditch dimensions.

• To use the above data to calibrate kinematic models for use in making predictions of the hazards of rock falls in new areas.

Current Activities

a. At the present, there are two kinematic models available to calculate the path of falling rock—Cundell's dynamic block model, and Piteau's bouncing ball model. Existing field studies have been conducted by the Corps of Engineers and by graduate students at the University of British Columbia to collect comprehensive information on the slope angle of talus slopes. However, there is no data on the distance that rocks roll past the toe of the slope nor on the relationship between block size and distance travelled. Some preliminary data on this relationship has been collected by the firm of Golder Associates and could be available to the researchers.

In preparing this research needs statement, the TRIS data base has been surveyed using the key words rock falls, talus slopes, and rock slide hazards. No current research projects involving rock fall trajectory prediction were found. The California Department of Transportation has an active project relating to mitigation of rock fall hazards, but this appears oriented more toward restraint and catchment mechanisms.

Previous research on rock fall trajectory and slope design has been conducted by the Washington State Department of Transportation. The results, reported by A.M. Ritchie in Highway Research Record No. 17, should form a good starting point for the suggested project.

Two published papers may also supply information of use to the research. The first is a French monograph of the Groups d'Etudes des Falaises titled "Rock Falls on Roads—Mapping Methods" and available from the Transport and Road Research Laboratory. The monograph reports techniques of developing hazard risk assessment maps for rock falls along roads. The second paper is titled "A Simple Dynamic Model of Rock Falls: Some Theoretical Principles and Model and Field Experiments" by I.Statham and published by the International Colloquium on Physical Geomechanical Models—Bergamo, Italy, 1979. This document is also available through the Transport and Road Research Laboratory.

b. Suggested key words: Rock falls, roadway hazards.

Urgency

In some areas, there is undue restriction to transportation facility routing and other development because there are no guidelines as to the magnitude of the rock fall hazard zones. Conversely, there are other areas which are being developed that are within high risk zones of rock fall damage. Decisions involving many dollars are currently being made on the basis of inadequate or no data and these decisions later result in significant maintenance cost for the rights-of-way due to rock falls.

PROBLEM 204: Application of Geostatistical Methods to Improving 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 in probability 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 discreet boring points.

Objectives

a. Review existing geostatistical techniques to identify methods with potential applications for subsurface exploration interpretation.

b. By use of demonstration projects, evaluate limitations and suitability of the methods to specific geotechnical data needs, i.e., estimating material quantities and physical properties.

Current Activities

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., 1977. A Practical Interactive Program for Randomization Tests of Location. American Statistician, Vol. 31, 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 is increasing.

PROBLEM 205: Application of Photogrammetric Methods to Monitoring of Slopes

Interstate and modern highway construction has resulted in the creation of more and larger rock cuts. Natural weathering of the rock in these cuts tends to cause increasing rates of failure with time, and these failures have potential hazards to users. After failure, it is frequently impossible to reconstruct previous conditions; thus the precise cause of failure often cannot be determined.

Concurrently, agencies are faced with increasingly tight maintenance budgets. Efficient, inexpensive monitoring of slopes is needed to aid in maintenance planning. Many agencies have sophisticated photogrammetric groups for map production. These groups have the expertise to conduct terrestrial photogrammetric monitoring of rock slopes, but such work is rarely requested.

Objectives

a. To prepare a state-of-the-art summary on photo logging of rock slopes defining:

1. The geotechnical data required and constraints concerning data accuracy, repetitive coverage, etc...

2. Photogrammetric options and economics including alternative equipment and procedures

b. To prepare a review of cases where these techniques have been applied, and a critique of each application.

c. To undertake one or more demonstration projects.

d. To prepare a "guidebook of recommended practice" to assist engineers in applying the technique to future studies.

Current Activities

a. The TRIS data base was surveyed using the suggested key words.

b. Suggested key words: Photogrammetry, rock slopes, equipment, methods, slope stability

c. The use of terrestrial photogrammetry to study slope stability in open pit mines has been reported in the April 1971 "Photogrammetric Record", a publication of the Photogrammetric Society (England). More recent work in this area has been conducted by the Canadian Department of Energy, Mines and Resources, Mines Branch, Ottawa, Canada. No other current research projects were found by the TRIS search.

PROBLEM 206: Construction and Maintenance Methods for Horizontal Drains

Over the past several years, numerous techniques for drilling and installing horizontal drains have been developed by contractors; however, little information has been published or made available on the effectiveness of these techniques. Designers may not be aware of the extent of current technology and have difficulty preparing proper specifications. State DOT maintenance engineers are not acquainted with proper techniques for maintaining the drains in a fully functional manner.

Objectives

a. Prepare a state-of-the-art summary covering:

1. Equipment capabilities
2. Drilling methods and techniques
3. Borehole guidance procedures and capabilities
4. Hole stabilization techniques

b. Review existing installations to determine the geologic conditions, drilling techniques used, production rate achieved, costs, and problems encountered.

c. Survey requirements and needs for environmental controls.

d. Develop a demonstration project to evaluate newer techniques and equipment available and determine opportunities and limitations with respect to geologic materials and conditions.

e. Contact highway department in states having a history of horizontal drain use (e.g. California, Tennessee, North Carolina) to develop a manual of maintenance procedures.

Current Activities

a. The TRIS data base was surveyed for the key words "drilling equipment" and "horizontal drains."

b. Suggested key words: Drilling equipment, drilling methods, drilling machines, horizontal drains, subsurface drainage, and drainage practices.

c. No research covering this area was found in the literature survey. A study jointly sponsored by the California Department of Transportation and the Federal Highway Administration titled "The Effectiveness of Horizontal Drains" is a survey of existing installations. This survey may gather historical data on installation methods used.

Urgency

The use of horizontal drains is increasing, especially in the eastern half of the United States. Many new contractors are entering the field using methods and techniques which have not been available recently. Designers in preparing specifications for bid purposes are having difficulty properly specifying approaches and techniques to achieve the desired effect resulting in construction difficulties, improperly constructed drains, and in some cases, legal action by contractors.

A2L06 Committee on Environmental Factors Except Frost

PROBLEM 207: Placement Requirements for Volumetrically Active Embankments

The complexities of predicting and controlling settlement or swelling of fills is often overlooked when preparing specifications for compacted fill. Surface movements are most noticeable and critical adjacent to rigid structures such as bridge abutments and other instances where there is an interface between rigid structures and compacted fill. There are significant differential movements, however, in any zone where the depth of fill changes rapidly and the movements increase with increasing depths of fill. Volume changes can be caused by various environmental factors, however, changes in moisture content can lead to expansion, shrinkage or compression. Although these factors are generally well understood, there is presently no clearly defined criteria for the design of fills based on the classification of the fill materials and the susceptibility of the fills to volume change caused by various environmental factors.

Volume changes of compacted fills caused by swelling, compression or shrinkage are very significant adjacent to highway structures and are also a concern in the general building industry. Backfills around deep basement excavations which support utilities and site development features must perform at very low volume change to avoid serious problems.

Shrinkage cracking of embankments often leads to slope failures by allowing moisture direct access to the failure plane of a slope. Flexible pavements may experience severe levels of distress resulting from the existence of a shrinkage crack which creates a direct means for water to infiltrate the base and subbase layers as well as the subgrade.

A need exists to review standard specifications related to the construction of embankments and the preparation of subgrade in areas where these problems exist and to evaluate methods of avoiding the problems associated with embankment volume changes in critical areas. A series of case studies of recent projects in areas where these problems have been especially acute should be carried out as part of this effort.

Objectives

To determine specific requirements for moisture and compaction in methods of placement of embankment materials to minimize volume changes due to environmental causes.

Current Activities

Many examples of distress resulting from swelling clays can be described and methods of prevention and treatment have been studied on many occasions by state highway agencies and by various industries. Most have dealt with problems associated with differential swelling, however, rather than examining methods of reducing shrinkage or compression of embankment materials or effectively treating the consequences.

Urgency

Given that these problems are usually recurring and that the focus of most transportation agencies is on maintaining facilities rather than constructing new ones, this should perhaps be given the highest priority. It is suggested that monitoring of installations and long term behavior be undertaken with these items in mind.

PROBLEM 208: Development of Embankment Design and Repair Criteria Using Risk Analysis

At present, many highway departments use geometric requirements related to traffic safety to design highway fill embankments. Maintenance experience has found that using a single standard (based on traffic safety) across a state is inadequate because many slope failures have occurred. As a result, some states have spent substantial amounts of money on slope repairs and have sometimes adopted more conservative design criteria. One problem associated with this approach is the use of unwarranted conservatism in areas where the traffic safety-based guidelines may be adequate. In this case, it is possible for construction costs to outweigh any savings gained through reduced maintenance, thereby increasing costs overall. The goal of this research is to reduce overall costs associated with fill embankments by developing a management system for selection of the criteria used for design and maintenance of highway fill embankments. Criteria for slope design and repair can be selected using risk analysis methods that consider the functional requirements of highways, sizes and numbers of embankments, variations in soil properties, variation in weathering conditions, and expected cost of maintenance.

It is recognized that this approach will be best suited for fill embankments and not for cut slopes. The reason

for this is that the earth fill in the slope is usually compacted according to a standardized procedure. Thus, some degree of uniformity of soil properties may be anticipated. In contrast, cut slopes cannot achieve this degree of uniformity due to variations in stratigraphy and water table conditions.

Objectives

To develop a management system for the selection of criteria used for design and repair of highway fill embankments. This project should include the following tasks:

a. Task 1: Select, develop or modify methods for analysis of slope stability that use risk analysis methods to account for variation in soil properties, slope and weather conditions. These methods should allow a designer to calculate the probability of failure of an embankment of a specified slope given the variability of the properties of the soil and cross-section geometry

b. Task 2: Examine the strength of compacted fill embankments to assess the variability of soil properties compacted to different compaction criteria. This task should include efforts to assess the magnitude of weathering effects in areas with severe weather and poor quality soils. The purpose of this task is to obtain data for use with the methods of Task 1. This task should document how these statistical characterizations are made so that individual states can perform the similar statistical characterizations for their own needs. If possible, the researchers could verify the methods of Task 1 by comparing the estimated probabilities of failure of embankments with the historical maintenance records.

c. Task 3: Develop an economic analysis to estimate the life-cycle costs of new embankments and any potential repair methods used for maintenance on existing embankments. This economic analysis should include a desired level of risk based on the functional requirements of a highway (for example, urban interstate versus rural state highway), the costs of construction (including costs of right-of-way), and be able to estimate maintenance costs given the level of risk assumed.

Current Activities: None identified

Urgency

The goal of this research is to develop a system that will allow designers to select slope design criteria for each project that balance the concerns related to traffic safety, functional requirements, environmental and geological conditions, and economics. Thus, slopes could be designed and managed in a manner similar to the way pavements are designed and managed. The payoff of this project is two-fold. First, money can be saved on new construction by building embankments with acceptable levels of risk and expected maintenance costs, thereby avoiding unacceptable over-building or under-building. Secondly, maintenance funds can be best spent by selecting repair methods with the optimum economic efficiency.

PROBLEM 209: Determine Crack Occurrence in Expansive Soils and Their Effect on Field Behavior

Expansive clay soils change volume with changes on water content caused by natural or artificial environmental causes. In most cases, this volume change includes cycles of both swelling and shrinkage to such an extent that tension cracks occur in the soil mass. This network of horizontal and vertical cracks provide avenues for both wetting and drying to penetrate the soil mass further, activating volume change and crack propagation. These cracks also affect properties of the subgrade such as permeability, strength and compressibility.

Prediction of behavior in expansive soils is, therefore, significantly complicated by the existence of cracks and lack of knowledge of the specific nature of cracks in the subgrade. Determination of crack occurrence, size and depth, and establishment of the relationship between field behavior and the crack characteristics are essential to more adequate prediction of behavior of these problematic soils.

Objectives

Develop methodologies for the measurement and prediction of crack occurrence in expansive clay soil subgrades, and determine the effect of these cracks on the engineering properties of the subgrade used for transportation facility design.

Current Activities

Recent research efforts have primarily been directed at the measurement of suction changes in expansive clays. Suction measurement both in the field and in situ has been reviewed by Fredlund and Rahardjo in their paper, "State-of-Development in the Measurement of Soil Suction". Two covered areas representing semi-arid and arid environments with expansive clay soils have been

instrumented and monitored by W. Kent Wray. Use of suction changes along with relevant soil characteristics to predict equilibrium suction conditions and volume changes has been presented by McKeen, Fredlund, Lytton and others.

A model of the interaction of expansive clays with the environment that incorporates soil crack patterns was presented in a Ph.D. dissertation by Miguel Picornell. The importance of cracks in design of vertical moisture barriers for pavements on expansive soils has been studied by Mal Steinberg and Bill Isenhower of the Texas Department of Highways and Public Transportation and by Lytton and others at the Texas Transportation Institute. Preliminary efforts at measuring the depth of vertical cracks using nondestructive techniques was reported by Picornell and Lytton.

Urgency

Damage to transportation facilities caused by expansive clay soils probably measures in the hundreds of millions of dollars annually, at least part of which can be tied to the need for better methods to predict behavior of these materials.

Cost: General cost estimate over a minimum five-year period is $500,000.

A2M01 Committee on Railroad Track Structure System Design

PROBLEM 210: 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 non-destructive 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.

Current Activities

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 ideal conditions 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.

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 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

This 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 211: 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.

Current Activities

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 212: Method to Detect and Identify Wheel Tread Defects Caused by Impact Loadings

Track impact loadings caused by wheel defects have been measured by the AAR at FAST, by Salient Industries, and by others. The fact that track system components are adversely affected and their service life shortened is well documented. The amount and magnitude of this deteriorating practice is dependent upon many variable operating factors but is accelerating with the advent of a greater density of 100- and 125-ton cars traveling over the railroads of North America. Wheel defect standards are in existence and are being followed to a limited degree. This is now being accomplished using human car inspectors who primarily give the cars

a visual pass-by inspection at yards, terminals, and repair shops.

Objectives

To develop, test and install instrumentation and monitoring systems capable of locating unacceptable wheel defects, such as out-of-rounds, flat spots, built-up treads, and shells. Compliance with existing or future standards will then be more objective. Present evaluations are very subjective and permit a wide range regarding interpretation and compliance.

Current Activities

As previously stated, the AAR, AREA, and other research organizations have been and are studying the problem. Enough is known about the negative effects of wheel defects, but the major problem is locating them and enforcing correction.

Urgency

The problem will not go away by ignoring it or taking a passive attitude toward obtaining real time/accurate data and then enforcing compliance based on these data. The railroad industry needs a better, more reliable and more accurate method of measuring car wheels on the move and one that is not subjected to the opinion of human interpretation.

PROBLEM 213: 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

To 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.

Current Activities

The AAR at the FAST facilities are conducting tests regarding the various types of rail available. Many railroads have done likewise and 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 desireable. A matrix incorporating the best features from all of the knowledgeable sources to express the most economical and practical selection of rail section, type, and laying sites, would result in a lower overall capital expenditure for most roads, would produce greater rail service life, and would reduce/simplify rail and rail-related products inventories.

PROBLEM 214: 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 pre-established specifications and standards.

Current Activities

To date, a number of Class I and shortline/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 215: 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 branchline abandonment emerged—creation of shortline 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, yet using traditional gross-ton-mile measures, 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.

Current Activities

As of January 1989, CN was reported to be studying fatigue life.

Urgency

Urgency is moderate. Substantial public and private funds are expended upon purchase and rehabilitation of branchlines each year. Improved understanding of future rail life will allow rational funding decisions.

A2M02 Committee on Electrification and Train Control Systems for Guided Ground Transportation Systems

PROBLEM 216: 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 systems. 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.

Current Activities

a. The TRB Committee A2M02 has an active subcommittee dealing with electrification cost differences.

b. The TRB Committee A2M02 has formal presentations related to comparison cost issues at its semiannual meetings.

c. Suggested key words: Railroad electrification, cost comparisons, electrification costs, overhead catenary power supply distribution, and alternative system capacities and styles.

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 217: 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

a. 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.

b. To encourage development and application of compatible train control equipment when new systems are installed in previously unequipped or "dark" territory.

c. To establish major reduction of the cost impact on electrification projects related to incompatibility of train control systems with high voltage AC electrification.

Current Activities

a. Several alternative methods of conversion for noncompatible train control systems have been applied to recent projects and studies by system suppliers and consultants.

b. Many new train control 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.

c. Introduction of track-side fiber-optic cable circuits is making a major contribution to reduced cost of conversion for noncompatible train control systems.

d. The TRB Committee A2M02 has formal presentations on compatible train control systems at its semi-

annual 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:

a. To provide better technical and cost data input for ongoing rail electrification studies.

b. 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.

c. To mitigate and eventually eliminate a major deterrent to authorization of electrification on North American rail systems.

A2MO3 Committee on Intermodal Freight Terminal Design and Operations

PROBLEM 218: Develop New Generation Intermodal Lift Equipment that is More Flexible, Less Costly, and Less Heavy than the Current Technology

Present generation lift equipment exerts 90-120 psi wheel load, requiring very stable ground conditions at the least, and usually heavy duty paving for sustained operations. Purchase costs generally run $400-800,000 per unit. Very few devices are flexible enough to efficiently handle the range of new intermodal equipment, such as, double-stack containers, Dallas Smith trailers, etc. There is also no clearinghouse between lift equipment manufacturers, trailer and container manufacturers, and users, to facilitate some degree of coordination and standardization.

Objectives

Assist equipment manufacturers in the design and development of a new technology of lift equipment that is more flexible, less costly, and requiring less surface stabilization and paving. Develop perhaps two basic units—one for smaller volume ramps (50,000 TAL and under) and one for larger volume ramps (over 50,000 TAL).

Current Activities

a. Lack of coordinated effort, standardization. No clearinghouse exists between lift equipment manufacturers, users, and trailer-container manufacturers. As a result, standardization is virtually non-existent. Yet the efficiency of interstate intermodal transportation requires a degree of standardization—each group is functioning pretty much in a vacuum, responding to ad hoc crisis as a particular type of trailer or container comes on line and lift equipment has to be modified to handle it.

b. All lift equipment manufacturers are engaged in research and design efforts, but the effectiveness and relevancy is diminished by the lack of a clearinghouse outlined above, and the absence of more clearly defined standards. There is also a natural reticence on the part of lift equipment manufacturers to cooperate in R&D efforts.

Urgency

This problem is increasingly impacting the network efficiency of the nationwide intermodal system, which is a basic requirement for national economic efficiency, including defense.

PROBLEM 219: "Footing" or "Paving" to Support Rubber-Tire Lifting Equipment

Do existing methods of designing paving (using load repetitions, coverage, and equivalents) apply to supporting heavy wheel loads that cover larger areas and remain in one location oscillating for several minutes between movements?

Objectives

Determine the thickness of foundation including structural section and underlying soil and rock to be included in the economical design for support in common classifications of materials. Include medium dense sand, medium dense silt, medium stiff silty clay, and soft clay.

Current Activities

a. Key words are: "Depth of investigation required" and "depth of design required".

b. Observations of existing facilities, good records of sections and subgrade materials, spacing of joints and cracks vs. widths and thicknesses, load tests with pressure cells, piezometers, etc.

Urgency

Normal development as demand for rubber-tire equipment changes.

PROBLEM 220: Intermodal Cargo Container Transfer Equipment for Low Volume Operations

The movement toward large mechanized hub terminal operations, along with the development of the double-stack container car, has led to rapid growth in domestic container use and improved high-volume transfer handling equipment capable of sustained, reliable operation. At the same time, growth of shortline and regional railroads has occurred as major carriers sold off low-volume branchlines and redundant routes in merged systems. The shortlines typically provide feeder and distribution functions between the major carriers and

relatively low-volume shippers. To permit the economical expansion of intermodal containerization throughout the whole railroad network, and to further exploit the use of cargo containers, there is a need to develop simple, low-cost, container transfer handling equipment suitable for use at shipper sidings, team tracks or small, low-volume terminal facilities.

Objectives

Determine the minimum performance characteristics and functional requirements for low volume container transfer handling equipment suitable for use by shortline and regional railroads as well as shippers.

Current Activities

a. There is a continuing proliferation of sizes in cargo containers although the standardization of the location of lifting points remains generally intact at this time.

b. Previous efforts to develop transfer handling equipment for this low-volume, often only periodic use, has mainly been a foreign venture and resulted in relatively complicated devices designed to both load and transport the containers as opposed to simply transferring from rail to chassis or rail to ground, or loading dock or dolly.

Urgency

This problem is limiting the potential for full exploitation of domestic containerization to areas beyond heavy-density operations associated only with major rail routes. A solution holds the potential for improved utilization of container carrying vehicles by freeing them up during loading/unloading operations.

PROBLEM 221: 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.

Current Activities

The testing at 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 222: 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.

Current Activities

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 223: 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 reprofiling throughout the useful rail life cycle. Also, development of a grinding train deployment program with enough flexibility to accommodate urgent backlogged grinding locations.

Current Activities

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 grinding will likely produce a significant economic benefit.

PROBLEM 224: 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 underutilized.

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.

Current Activities

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 225: 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.

Current Activities

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 226: 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 at each storage location on a transit property.

Current Activities

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 mini-computer 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 took in the transit industry.

PROBLEM 227: 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 failures.

Current Activities

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 228: 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.

Current Activities

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 229: High-Speed Rail Technical, Operational and Economic Information Bank

The present activity in the field of high-speed rail (HSR) in the United States centers around feasibility and preliminary design studies for several intercity corridors. The next step may involve design of a high-speed railroad and the selection of railroad systems and equipment. Technical and operational information necessary to complete feasibility and preliminary design studies and to begin design and equipment selection are not easily accessible and reside principally with HSR suppliers and operators in Europe and Japan. There is a need for some agency to develop a catalogue of available information that is accessible to those who need it.

Objectives

The objective of this proposed activity is to develop and continually update a catalogue of the available technical, operational and economic information necessary for feasibility and preliminary HSR studies and for HSR system and equipment design and selection. The catalogue should indicate the type of available information and its source.

Current Activities

a. Consultants working on HSR feasibility studies and preliminary design studies are obtaining information from HSR suppliers and operators.

b. TRB Committee A2M05 has an active program under its Subcommittee for Identification and Classification of Technology Study Requirements, addressing such information requirements and its availability.

c. The FRA has completed several studies associated with HSR projects which have generated information of the type required.

Urgency

The resulting bibliography of technical, operational and economic information will be necessary for the continued domestic assessment of proposed HSR projects. The catalog will reduce the cost of feasibility studies and preliminary and final design of such systems for domestic use.

PROBLEM 230: High-Speed Rail Safety

Present activity in the field of high-speed rail (HSR) in the United States centers around feasibility and preliminary design studies for several intercity corridors. The next step will probably entail the design of a high-speed railroad system including the selection of sub-systems and equipment. As in all domestic rail passenger and freight operations, safety is of paramount concern. Some of the accepted safety regulations and standards that have evolved through years of conventional railroad operations may require modification in their application to HSR systems.

Objectives

The objective of this proposed research activity is the development of a bank of information and expert opinion that regulatory agencies can consult in the development of standards and regulations to govern the safety of HSR design and operation.

Current Activities

TRB Committee A2M05 and the High Speed Rail Association have each established sub-committees to attempt to determine the safety criteria used by foreign HSR systems and to compare them with current conventional domestic railroad safety standards.

Urgency

Many technical, operational and economic issues in the preliminary and final design of HSR systems will require the application of appropriate safety standards. Should regulations establishing such standards be developed after the designs have been completed, the expenditure to correct safety deficiencies could be large.

PROBLEM 231: Study and Research of Wheel-Rail Effects from 220 to 400 M.P.H.

An alternative to air travel is needed in corridors in the 100-750 mile range due to airport and airway overcrowding and the lack of space in which to build new airports. Wheel-rail vehicles powered by traction motors are a

proven technology at speeds up to 220 mph and have the potential for even higher speeds with extension of existing technology.

Objectives

Research of wheel-rail effects at speeds from 220-400 mph including, in addition to traction motor propulsion, systems using linear induction drive with wheel/rail support.

Current Activities

Revenue passenger-carrying trains now operate at speeds up to 186 mph, and test speeds over 300 mph have been achieved.

Urgency

The development of wheel-rail transportation systems speed-competitive with sub-sonic jet aircraft (considering terminal-to-terminal time) would require much less land area to satisfy present and future demands for which planning must begin at once.

Cost

The eventual cost is estimated at $20-$50 million dependent on the availability of test apparatus capable of higher speeds to develop designs for speeds up to 400 mph for prototype construction. Planning for the type of tests and equipment required could be started for under $500,000. Domestic verification of foreign test results of speeds up to 300 mph would be much less costly.