

TRANSPORTATION RESEARCH
CIRCULAR

Number 464

October 1996

Research Problem Statements

**Design and Construction of
Transportation Facilities**

RESEARCH PROBLEM STATEMENTS

DESIGN AND CONSTRUCTION OF TRANSPORTATION FACILITIES

Michael G. Katona, Chair, Group 2 Council
Frederick D. Hejl, Secretary

John J. Ahlskog
David B. Beal
Albert J. Bush, III
Charles T. Edson
David H. Fasser
Donn E. Hancher

Prithvi S. Kandhal
Vernon J. Marks
Robert J. McCown
Verne C. McGuffey
Raymond K. Moore
H. Celik Ozyildirim

Harold R. Paul
Albert J. Reinshmidt
Hayes E. Ross, Jr.
Larry A. Scofield
Michael M. Sprinkel
Mehmet T. Tumay

Transportation Research Board Staff

D. W. (Bill) Dearasaugh
G. P. Jayaprakash
Elaine King
Amelia G. Johnson
James P. Douglas

GENERAL NOTE:

This Circular supersedes *Circular 417*, November 1993.

Subscriber Categories

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

Transportation Research Board
National Research Council
2101 Constitution Avenue, NW
Washington, DC 20418

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

FOREWORD

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

The 173 problem statements in this circular represent a composite of efforts by 40 of the group's committees. They should not be considered an all inclusive recognition of research needs within the scope of Group 2's activities. Since many of the statements may touch upon the scopes of several other elements of TRB, the circular is being distributed to a wide range of interest areas.

RATING PRIORITIES

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

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

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

RESEARCH PROBLEM STATEMENTS

Section Designation	General Subject	Number of Problem Statements
A	General Design—Geometrics and Safety	9
B	Pavement Design and Performance	2
C	Structures—Bridges, Culverts, and Tunnels	15
D	Asphalt Concrete Mixes	18
E	Concrete Mixtures and Usage	10
F	Construction and Rehabilitation	23
J	Geomaterials Stabilization and Aggregates	8
K	Soil Mechanics	42
L	Geology and Properties of Earth Materials	26
M	Railway Systems	20

CONTENTS

Committee Designation	Problem Number	Problem Statement Title	Page
A2A01	1	Optimal Data Model for a Transportation Locational Data Acquisition and Management System	13
	2	Automatic Feature Extraction from Digital Imagery	14
	3	Utilization of Digital Imagery in Transportation Corridor Management	15
	4	Use of GPS, GIS and CCD Camera Technology as Controlling Devices and Techniques for the Use of Robotics to Control Construction Equipment in the Cleanup of Hazardous Waste Areas	16
A2A02	5	Access Control Limits along Roads Intersecting with Arterial Routes	17
	6	Design and Operation of Temporary Entrance and Exit Ramps in Major Freeway Reconstruction Projects	17
	7	Median Selection and Design Guidelines	18
	8	The Effectiveness of Passing Lanes and Other Geometric Improvements for Improving Service on Rural Two-Lane Highways	19
	9	The Effect of Median Width and Slope on Frequency of Cross-Median Accidents on Rural Roadways	20
A2A03		Research Problem Statements for this Committee Are Designated for Publication in a Separate Transportation Research Circular.	21
A2B01	10	Effects of Proper Maintenance Versus Capital Expenditures for Aviation Pavements	22
A2B04	11	An Examination of Potential Model Forms and Algorithms— Mechanistic and Others—for Pavement Rehabilitation Design	23
A2C01	12	Effect of Increasing Truck Size and Weight on Bridge Life	24
A2C02	13	Effect of Live Load Deflection on Steel Bridge Elements	25
	14	Effect of Skewed Supports on Bridge Design and Behavior	25
	15	Effect of Shrinkage of the Concrete Slab on the Deflections of Steel Plate Girder Bridges	26
	16	Develop Methods to Continuously Monitor Bridges and Predict Where Failure Will Occur	26
	17	Behavior and Design of Steel Box Sections for Combined Bending and Axial Loading	27
	18	Corrosion Control	27
	19	Design Issues for Bridge Bearings for Steel Bridges	27
A2C03	20	Connection Between Simple-span Precast Concrete Girders Made Continuous	29

Committee Designation	Problem Number	Problem Statement Title	Page
	21	Design and Construction of Adjacent Precast Concrete Box Girder Bridges	29
	22	Development Length of Prestressing Strand in Normal and Lightweight High Performance Concretes	30
	23	Design and Evaluation of Prestressed Concrete Bridge Girders for Fatigue	31
	24	Thickness of Bridge Deck Slab Supported by Concrete/Steel Stringers	32
	25	Fiber Reinforced Concrete for Seismic Bridge Connections in Concrete Bridges	33
A2C05	26	Testing and Evaluation of the Effect of Superstructure Flexibility on Bridge Deck Deterioration	34
A2D01	27	Direct Quantitative Chemical Analysis of Petroleum Asphalts for Amphoteric Compounds	35
A2D02	28	Justification for "Forbidden Zone" in SHRP Superpave™ Aggregate Gradation Specification	36
	29	Aggregate Morphology Needed for SMA/Gap-Graded Rut Resistant Asphalt Mixtures	36
	30	Gradations Needed for SMA/Open-Graded Asphalt Mixtures	37
	31	Aggregate Distribution in Asphalt Concrete Mixtures Related to Pavement Performance	37
	32	Polymer Modified Asphalt Concrete	38
	33	Comparison of Various Modifiers to Asphalt Cements	38
	34	CRM in Slurry Seals and Membranes	39
	35	CRM Fiber as Geotextile in HMA, Membranes or SMA; Fiber as Geotextiles in Asphalt Cements	39
A2D03	36	Effect of Aggregate Properties on Mix Performance and Design	41
	37	Confirm the Superpave™ Performance Models with Modified Asphalts	41
	38	Maintaining the Permeability of Open-Graded Bituminous Courses	42
	39	Accelerated Laboratory Testing of Asphalt Paving Mixtures to Predict Pavement Friction	42
	40	Life Cycle Cost Analysis of Surface Treatments	43
A2D04	41	Characterization of Novel Asphalt Aggregate Mixtures Based on Performance for Pavement Structural Design	45
A2D05	42	High Traffic Asphalt Concrete Intersections	47
	43	A Qualitative Analysis of Segregation in Asphalt Concrete	47

Committee Designation	Problem Number	Problem Statement Title	Page
	44	Superpave™ Level 1 Mechanical Property Test	48
A2E03	45	Effects of Early-age Temperatures on Cracking Aspects of High Performance Concrete	49
A2E05	46	Durability of Rapid Setting Repair Concretes	50
	47	Relation of Concrete Composition to Curing Requirements	50
	48	High-Reactivity Metakaolin for High Performance Concrete	51
	49	Effect of Viscosity-Enhancing Admixtures on Engineering Properties and Durability of Concrete	52
	50	Self-Curing Concrete	53
	51	Application of Incinerator and Waste-to-Energy Ashes	53
	52	Silica Fume Research Needs in Transportation	54
	53	Evaluating Latex-Modification of Concrete to Mitigate Alkali-Silica Reactivity	55
	54	Prevention of Cement/Admixture Incompatibility Problems	56
A2F03	55	Material Acceptance Using Quality Control Testing Verified by Agency Quality Assurance and IAST	57
	56	Quality Characteristics of Pavements for Use in Performance-Related Specifications	57
	57	Optimal Acceptance Procedures for Statistical Construction Specifications	58
	58	Forecasting Life-cycle Cost of Quality Levels	58
	59	Incentive/Disincentive Specifications Related to Performance Specifications	59
	60	Economic Assessment of Lot and Sublot Sizes in Relation to QC/QA Specifications	59
	61	Redefining the Role of Independent Assurance Sampling and Testing in a Quality Control/Quality Assurance Specification	60
A2F04	62	Corrosion of High Strength Steel Tendons in Prestressed Concrete Bridges	61
	63	Economics of Modern Timber Bridges in the United States	61
	64	Determining Cable Band Bolt Tensions on In-Service Main Cable Systems (Suspension Bridges)	62
	65	Development of a Multi-Sensor Bridge Monitoring System	62
	66	Life Cycle Cost-Based Engineer's Estimates for Bridges	63
	67	New Method for Connecting Field Splices for Bridges	63

Committee Designation	Problem Number	Problem Statement Title	Page
A2F05	68	Management of Partnering Effectiveness	65
	69	Optimum Deployment of Inspection Resources	65
	70	The Impact of Inspection on Highway Construction Projects	65
	71	Baseline and Benchmarking for Construction Management Functions	66
	72	The Role of Construction Management for Design-Build Projects	66
	73	Assessment of Sensor Technologies to QC/QA of Construction Operations	67
	A2F06	74	The Impact of "Specifications" on the Selection of Construction Equipment and Methods
A2F07	75	The Preliminary Investigation and Recommendation of New Steel/Fiber Reinforced Plastic Hybrids	69
A2F09	76	Application of Biotechnology to Roadway Landscaping	70
	77	Integrating Real Time Construction Site Data with Multimedia Database Managers	70
A2J01	78	Sulfate Induced Heave Problems—Identification and Control	71
	79	Resilient Modulus Testing Protocol for Cementitious Stabilized Base and Subbase Materials for Pavement Construction	72
	80	Testing Protocols and Mix Design Procedures for Flowable Fill	73
A2J02	81	Stabilization of Volatile Organic Compounds Which are Residuals of Certain Used Solvents	74
	82	Utilization of By-Product Gypsum for Highway Construction	74
	83	Low-Volume Road Performance Enhancement Strategies Using Stabilization Additives	76
A2J03	84	Evaluation of the Effects Of Aggregate Fines on the Performance of Hot Mix Asphalt Concrete	77
	85	Increased Use of Fines in Portland Cement Concrete	78
A2K01	86	Methods to Assess Costs-Benefits of Instrumentation in Design and Construction	79
	87	Remote Landslide Monitoring System	80
	88	Determining the Pitting Corrosion of Steel Elements in Soil	81
A2K03	89	Capacity of Foundations and MSE Retaining Wall Systems During Earthquakes	83
	90	Artificial Intelligence in the Design and Construction of Foundations for Transportation Structures	83

Committee Designation	Problem Number	Problem Statement Title	Page
	91	Improved Use of Nondestructive Evaluation Methods to Evaluate Loading Behavior of Deep Foundations	84
	92	Design Methods for Pile Groups to Resist Dynamic Lateral Loads	84
	93	Expedient Static Loading Tests for Piles and Drilled Shafts	84
	94	Loading Test Database for Deep Foundations	85
	95	Evaluation of Augered Piles for Load Bearing in Highway Structures	85
	96	Corrosion of Driven Steel Piles	86
	97	Feasibility of and Design Methods for Load-Bearing Sheet Pile Abutments	86
A2K04	98	Thermoplastic Pipe Design Procedure	87
	99	Criteria for Flowable Fill in Backfill	88
	100	Representation of Live Load on Two Dimensional Buried Structure Analysis Models	89
	101	The Design of Backfill Envelopes for Underground Structures	90
	102	Measurement of Earth Pressures Acting on Existing Lateral Retaining Structures	91
	103	Long-Term Performance of Buried Conduit Systems	92
	104	Case History Evaluation of Trenchless Construction Procedures	93
A2K05	105	Characterization of Soil Parameters Using Computational Neural Networks (CNNs)	95
	106	Frost Effects in Native Backfills of Earth Reinforcement Structures	95
	107	Thaw Weakening and Permanent Deformations in Base and Subgrade Soils	96
A2K06	108	Geocomposite Edge Drain Installation Concerns	97
	109	Methods to Mitigate Precipitate Potential of Subbase Aggregates	98
	110	Application of AASHTO Pavement Design Drainage Coefficients to the Design of Full Depth Asphalt Cement Pavements	98
	111	Development of a Laboratory Procedure to Measure Performance of Free-Draining Pavement Layers	99
	112	Development of a Rapid Test Method to Determine In-Situ Horizontal Permeability of Unbound Materials	100
	113	Prediction of Differential Icing or Frosting Due to Thermal Properties of Pavement Structural Material	100
	114	Stability of Open-Graded Base Courses	101

Committee Designation	Problem Number	Problem Statement Title	Page
	115	Determination of Geotextile Subsurface Drainage Characteristics Through Measurement of Largest Pore Opening and Pore Size Distribution of Geotextiles	101
A2K07	116	Sensors to Monitor the Load in Geosynthetic Reinforcement	104
	117	Life Cycle Prediction and Cost Improvement Model for Use of Geosynthetic Separators and Reinforcement in Roads	104
	118	Geotextile Separators for Open-Graded Bases	105
	119	Identification and Cost Benefit of Methods Used to Reduce Reflection Cracking in Asphalt Overlays	105
	120	Evaluate Geomembranes to Control Expansive Soils on Transportation Facilities	106
	121	Determination of Factors of Safety for Installation Damage	106
	122	Marginal Soil Used in Retaining Walls	107
	123	Soil Geosynthetic Interaction	107
	124	The Effect of Cold Temperature Environments on the Performance of Geosynthetics	108
	125	Determination of the Effectiveness of Geogrids in Strengthening Pavement Sections	108
	126	Performance Prediction For Geotextiles Based on Quality Control Information	109
	127	Use of Geotextiles and Geogrids in Bridge Abutments	110
A2L01	128	Identifying and Conserving Productive Agricultural Land in Engineering Construction	111
A2L02	129	Pavement Water Condition and Effects on Soil and Aggregate Behavior	112
	130	Synthesize Quality Assurance Tests and Installation Practices for Use of Recycled Materials	112
	131	Soil-Geosynthetic Interaction Behavior	113
	132	In-Situ Measurement and Interpretation of Soil Properties—Knowledge Based Expert System Development	114
	133	Unified Approach to Interpretation of In-Situ Testing	114
	134	Evaluation of Soils after Treatment by Ground Improvement Techniques	115
	135	Prediction of Axial Capacity of Friction Piles by In-Situ Techniques	115
	136	In-Situ Determination of Granular Soil Fabric	116
	137	Engineering Characterization and Design Methodologies for Weak Rock as a Transitional Material Between Soil and Strong Rock	117

Committee Designation	Problem Number	Problem Statement Title	Page
A2L03	138	Bioremediation for Transportation Industry Clean-Ups	118
	139	Contaminant Effects on Soil Properties	119
A2L04	140	Effectiveness of Load Restrictions	120
	141	Mechanistic Design of Pavements in Seasonal Frost and Permafrost Areas	120
	142	Changes in Pavement Stiffness Induced by Frost Action	121
	143	Measurement of Moisture Content and/or Moisture Suction in Soils	122
	144	Design of Pavements for Resistance to Freeze-Thaw Damage	122
A2L05	145	Rock-Fall Processes and Mitigation	125
	146	Rock Slope Rating Procedure Including Life Cycle of Rock Reinforcement	125
	147	Application of Geostatistical Methods to Improving the Interpretation of Subsurface Data	126
	148	Applications and Limitations of Probabilistic Methods in Evaluating Risks Associated with Natural Processes	126
	149	Earthquake Ground Motion at Bridge Sites	127
	150	Earthquake-Induced Ground Displacement and Damage Potential	127
	151	Short- and Long-Term Remedial Solutions for Geologic Conditions on Low-Volume Roads	128
	152	Risk Analysis Based on Existing Department of Transportation Earth Science Data	128
A2L06	153	Mechanistic Modeling of Unsaturated Geomaterials in Pavement Systems	130
A2M03	154	Financing and Improving Highway Access to U.S. Intermodal Cargo Hubs	131
A2M04	155	Recommended Strategies for Third Rail De-Icing	133
	156	Vibration Mitigation Alternatives to Floating Slab	133
	157	Track Design in the Transition Area Between Direct Fixation and Ballasted Track	133
	158	Economic Analysis of Premium Special Work Usage on Transit	134
A2M05	159	Safe Egress from High-Speed Ground Transportation (HSGT) Systems under Emergency Conditions	135
	160	High Speed Rail and Maglev Vehicle Interiors	135
	161	Overall HSGT System Safety Risk Analysis	135
	162	Track Geometry, Inspection, and Maintenance Practices	136

Committee Designation	Problem Number	Problem Statement Title	Page
	163	Intercity Passenger Transportation Life Cycle Cost/Benefit Analysis	137
A2M06	164	Identifying and Modifying the Influence of Subgrade on Track Maintenance Requirements	139
	165	Improved Non-Destructive Evaluation of In-Place Condition of Track Components	139
	166	Development of Predictive Track Maintenance Models which Utilize Field Data	140
	167	Mechanisms of Ballast Deterioration and Methods of Predicting Ballast Life	141
	168	Determine When to Clean or Replace Ballast	141
	169	Effects of Heavy Axle Loads on Bridge Maintenance and Life	142
	170	Improved Understanding of Rail Performance and Behavior	142
	171	Effects of Seasonal Frost Action in Railway Subgrades on the Maintenance of Track Geometry	143
	172	Mitigation of Rail-head Fatigue by In-Situ Resurfacing of the Rail-Head	144
	173	Determining the Impact of Performance Variability on Construction Schedule and Cost	145

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

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

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

Objective

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

Related Work

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

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

- New data collection technologies that can be expected to impact GIS-T are currently being adopted by DOTs. They include automation of engineering surveys, real-time telemetry of traffic counts, and various aspects of imaging (including video) for bridge inventory. Some agencies with GIS-T experience see the need for institutional change in the management of data collection and maintenance (Ibid., page 7).

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

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

Urgency

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

Cost

\$200,000

User Community

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

Implementation

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

Effectiveness

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

PROBLEM 2: AUTOMATIC FEATURE EXTRACTION FROM DIGITAL IMAGERY

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

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

Objective

The proposed research would result in the capability of automatically extracting a well-defined set of

transportation-related features from aerial and/or terrestrial imagery.

Key Words

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

Related Work

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

Urgency

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

Cost

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

User Community

FHWA, AASHTO

Implementation

The implementation of this research would be carried out at the state (DOT) level. Users who are involved with digital imagery would receive documented software and published algorithms to use during the compilation of aerial and terrestrial images. As time goes on, more and more of the mapping community will be using digital imagery, and hence this work will become more and more relevant.

Effectiveness

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

¹ References:

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

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

PROBLEM 3: UTILIZATION OF DIGITAL IMAGERY IN TRANSPORTATION CORRIDOR MANAGEMENT

Transportation system managers increasingly need tools that let them collect, display, and use visual images for corridor planning, design, construction, operation, and maintenance. In the past photographic images such as aerial photography and vehicle based photologs have partially served this purpose, but have been costly to produce and generally limited to specific applications such as for map production in stereoplotters. In recent years cost effective techniques have been developed in a number of areas to produce digital imagery through direct digital collection such as with video cameras, through digitization of photographic images such as continuous tone scanning or through digital data collection from visual imagery as in digital terrain modelling on a stereoplotter. Most of these techniques have been developed independently. Research now needs to be done to see how the various sources and methods of visual digital information can be integrated to aid in transportation corridor management.

Objective

The proposed research will evaluate all the methods and techniques for obtaining, displaying, and using

visual imagery and then recommend ways to integrate them to form essentially a solid model of the transportation corridor to be used in planning, design, construction, operation and/or maintenance.

Key Words

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

Related Work

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

Urgency

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

Cost

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

User Community

FHWA, AASHTO, ASPRS

Implementation

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

Effectiveness

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

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

Global Positioning Systems(GPS), Geographic Information Systems(GIS) and Charged Couple Device(CCD) cameras have become sophisticated tools in depicting real estate and its particular characteristics. The CCD can also be the eyes of the construction equipment and along with real time positioning using GPS cleanup of sites could be accomplished with minimum human exposure to the effects of the waste.

Objectives

1. To perform necessary literature search;
2. To develop alternative strategies for pack-aging the technologies;

3. To develop minimum requirements for each technology for this use;

4. To develop list of software requirements that need developing; and

5. To prepare a proposal for the most promising technology package that would allow for final development of a system package.

Key Words

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

Related Work

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

Urgency

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

Cost

Research in the problem area is relatively inexpensive, especially when the returns in savings are high. This project should be completed in less than a year and be operational within two years, a quick payoff!

1. Literature Search, \$35,000
2. System investigations, \$55,000
3. Testing with cooperative manufacturers, \$100,000
4. Technology transfer via manufacturers, \$55,000

Total Cost: \$245,000.

A2A02 COMMITTEE ON GEOMETRIC DESIGN

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

PROBLEM 5: ACCESS CONTROL LIMITS ALONG ROADS INTERSECTING WITH ARTERIAL ROUTES

Discount superstores and outlet shopping malls are rapidly developing along suburban arterials and at freeway interchanges with high volume traffic generation causing congestion and accidents. Access streets to such shopping areas attract satellite food and convenience stores with high volume driveways that interfere with entering traffic and traffic operations along the main arterial routes.

Objective

A synthesis of existing research, a state and local agency survey, and some case studies of site development along arterials will provide information for problem awareness and necessary improvements. Design guidelines for extension of arterial access control along intersecting streets into commercial, industrial and residential development shall be developed which will be suitable for incorporation into the AASHTO "Policy on Geometric Design for Highways and Streets". Analysis should address the costs of right of way and business damages due to the change to limited access. Access control for nearby traffic signals and turn lanes along intersecting streets will be determined for entering and exiting traffic conditions.

Key Words

Control of access, access management

Related Work

Most research is systems planning oriented or directed at access control along the arterial route, not the intersecting roads. Proceedings from the Federal Highway Administration Access Management Conference in Vail, Colorado (1993) should be consulted. NCHRP 3-52 also addresses driveway permits and arterials vs crossroads.

Cost

\$500,000

Urgency

High

User Community

The primary user of this problem and the related solutions is the AASHTO community.

Implementation

Results can best be implemented by inclusion in the "Policy on Geometric Design for Highways and Streets"

Effectiveness

A national policy in a recognized AASHTO publication based on valid research would help state and local highway agencies develop street design and subdivision policies for managing access and to resist political "pressure" from developers. Both the highway user and the site development would benefit by better access management to reduce traffic congestion and air pollution.

PROBLEM 6: DESIGN AND OPERATION OF TEMPORARY ENTRANCE AND EXIT RAMP IN MAJOR FREEWAY RECONSTRUCTION PROJECTS

In order to maintain access to the freeway within the constraints of the available right-of-way and construction phasing, less than ideal standards are sometimes used to design and operate temporary entrance and exit ramps in work zones. Often, this results in unusual ramp designs which include sharp reverse curves, significant merge or departure angles, and the shortening or elimination of acceleration, deceleration lanes. Typical ramp designs can often result in large speed differentials between mainline and entering traffic and may require special traffic control to aid in operations. There is a need to develop guidelines that would promote uniform design and operations of entrance and exit ramps for major freeway reconstruction projects.

Objectives

The research would address the following tasks:

1. Catalog existing standards and specifications for designing and operating temporary entrance and exit ramps in major freeway reconstruction projects.
2. Conduct field studies to establish relationships between ramp design and traffic operations.
3. Identify appropriate traffic control strategies for promoting the safe and efficient movement of traffic on temporary ramps.
4. Develop guidelines for designing and operating temporary entrance and exit ramps for major freeway reconstruction projects.
5. Separate guidelines in terms of urban or rural setting.

Key Words

Entrance ramps, exit ramps, geometric design

Related Work

None known.

Cost

\$300,000

Urgency

High

User Community

The results are of value to AASHTO members and FHWA.

Implementation

The results should be implemented in the form of a design manual for use by state and private design agencies.

Effectiveness

Guidelines would promote the consistent and uniform design and application of traffic control for temporary entrance and exit ramps in freeway reconstruction projects. In addition to improving traffic safety and reducing driver confusion, the consistent ramp design

and application of traffic control would improve traffic flow and capacity at reconstruction areas. Results may include relative information on the safety and operations at ramp merge points.

PROBLEM 7: MEDIAN SELECTION AND DESIGN GUIDELINES

The rehabilitation and enhancement of existing urban highways and streets involves making the best use of existing right of ways. Medians are considered as ways to positively separate opposing directional traffic and provide refuge areas for vehicles and pedestrians. Guidelines are needed as to assist the designer in the selection of:

- A. Median surface type (paved, turf, or barrier wall).
- B. Appropriate width to meet safety needs associated with traffic and pedestrians use of the facility.
- C. Height of median treatment (depressed, flush, raised, or wall).
- D. Geometric design of access points and cross over points.

Research is required to address safety, environment, long-term and short-term economic impacts, area land use, impact on wetlands, and highway functional issues associated with each of the selection factors.

Median widths vary between states with one state using 44-foot-wide raised medians in 55 mph zones. Guidelines for application of narrow width medians and associated openings need to be developed. Grass medians used with curb and gutter are usually less expensive to construct as compared to raised concrete medians. Maintenance of grass medians is a factor; however, in most cases does not offset significant savings expected from the use of the grass medians. Guidelines on the application of various surface types and the associated trade off implications are needed.

Objectives

To develop guidelines for the selection of:

- A. Median surface type (paved, turf, or barrier wall).
- B. Appropriate median width to meet safety needs associated with traffic (speed and volume) and pedestrian use of the facility.
- C. Height of median treatment (depressed, flush, raised, or wall).
- D. Geometric design of median access points.
- E. Benefit/cost ratios that address right-of-way costs.

Key Words

Medians, median access control

Related Work

NCHRP 3-49, NCHRP 17-14, NCHRP 15-14(2), FHWA Yellow Book, and Roadside Safety Manual

Cost

\$400,000

Urgency

High

User Community

The project should be considered by AASHTO, and FHWA.

Implementation

Findings can be provided in the way of a NHI course workshop or design manual to be distributed through the AASHTO organization to public and private designers.

Effectiveness

Findings of the study will enable designers to develop designs appropriate for the site conditions. Better designs with appropriate median width, surface and traffic access points will transform into construction savings more aesthetically pleasing designs.

PROBLEM 8: THE EFFECTIVENESS OF PASSING LANES AND OTHER GEOMETRIC IMPROVEMENTS FOR IMPROVING SERVICE ON RURAL TWO-LANE HIGHWAYS

There are many two-lane highways in various states where vehicle platooning is a problem. It may be due to low passing sight distance or heavy oncoming traffic. Solving the problem with a four-lane highway may not be cost-effective in many instances. Lower cost alternatives include periodic passing lanes and other geometric improvements. This allows opportunities for vehicle in platoons to pass slower moving vehicles without the expense of four continuous lanes. The effectiveness of these passing lanes should be evaluated to determine the circumstances where they might be more cost-effective.

Geometric improvements are also needed at isolated horizontal curves that have been shown to be the cause of many fatal accidents, especially if the curve is at the bottom of a downgrade.

Objectives

Determine the important differences, including speed, platooning delays, and accident rates between existing conditions and improved geometrics for a sample of highway sections. Determine the cost-effectiveness of passing lanes and make recommendations on the circumstances when they should be considered. Make recommendations on use of spot geometric improvements.

Key Words

Passing lanes, rural highways, two-lane highways

Related Work

None known

Cost

\$300,000

Urgency

High

User Community

This effort should be considered by AASHTO and FHWA due to its relationship to both design and safety.

Implementation

The results should provide both a tabular or graphic cost comparison and possibly examples of improved design guides that could be distributed by AASHTO or FHWA to state and private design agencies.

Effectiveness

The results of the research will provide valuable information when relatively low-cost alternatives are being examined for improving two-lane rural highways. This will improve the effectiveness of expenditures on those highways.

PROBLEM 9: THE EFFECT OF MEDIAN WIDTH AND SLOPE ON FREQUENCY OF CROSS-MEDIAN ACCIDENTS ON RURAL ROADWAYS

It has become common practice to flatten the foreslopes of existing depressed medians on rural divided roadways. This practice is justified as a safety improvement assuming that the flatter slopes will allow recovery and reduce the potential for the errant vehicle to overturn. This assumption is well accepted and supported for foreslopes on the outside of the roadway.

For medians that are relatively narrow, but beyond the width where a continuous median barrier is warranted, these flatter slopes may increase the potential for cross-median accidents. Cross-median accidents involve two or more vehicles travelling in opposite directions and are caused by a vehicle crossing the median.

Objectives

The proposed research would build upon the findings in NCHRP Project 17-11, "Recovery-Area Distance Relationships for Highway Roadsides". First, the research should consider the recovery-area distance relationships identified in Project 17-11 for single-vehicle, run-off-the-road accidents and validate that they are not affected by differences in operating speed, driver behavior, or maneuvers common to vehicles operating in the passing lane(s) of a divided roadway. Specific guidance on applying the recovery area relationships to medians should be developed, if proven necessary.

Second, current warrants for continuous median barriers should be investigated and verified.

Third, the proposed research should consider the effects of median slopes and widths, in combination, on accident frequency and severity for all accident types. Flatter median slopes may reduce the severity of single vehicle accidents at the expense of increasing the frequency and severity of cross-median accidents. By analyzing accident data from roadways of differing median widths and slopes, the research should identify the effects of the flatter median slopes on overall roadway safety and provide guidelines for the design of median slopes. Guidelines for improving the safety of

existing medians by flattening relatively steep slopes should also be developed.

Key Words

Median design, median safety, rural medians

Related Work

This project was considered at the second stage of the NCHRP list (number 95-G-18) for FY 1995 and was not funded.

Cost

\$300,000 (3 years)

Urgency

High

User Community

This research can best be directed at AASHTO and the NCHRP process for research.

Implementation

The results can best be implemented through a research circular that illustrates the relationships in tabular form. Followup design guides can be included in future AASHTO "Green Book" editions.

Effectiveness

Flatter median foreslopes are being constructed with the intent of reducing the severity of single-vehicle accidents while the effect on overall roadway safety is not clear. A better understanding of the effects of flatter median slopes may yield a safer roadway and save lives.

A2A03 COMMITTEE ON HYDROLOGY, HYDRAULICS, AND WATER QUALITY

RESEARCH PROBLEM STATEMENTS FOR THIS COMMITTEE ARE DESIGNATED FOR PUBLICATION IN A SEPARATE TRANSPORTATION RESEARCH CIRCULAR.

A2B01 COMMITTEE ON PAVEMENT MANAGEMENT SYSTEMS

PROBLEM 10: EFFECTS OF PROPER MAINTENANCE VERSUS CAPITAL EXPENDITURES FOR AVIATION PAVEMENTS

Although the Federal Aviation Administration (FAA) has recognized the importance of Pavement Management Systems (PMS) and the need for airport pavement maintenance, they have not declared maintenance an eligible item for funding. Little research has been done in the area of airport pavement maintenance and its cost-effectiveness for the reduction in capital outlay over a period of years. Maintenance funding has been shown in at least one state (Virginia) to significantly reduce the dollars for capital outlay on pavement reconstruction and rehabilitation while enhancing the overall condition of the system. When pavement management systems and maintenance funding are used together effectively, they can reduce expenditures for major rehabilitation of pavements and extend the useful life of those pavements while maintaining higher pavement condition indices. Research is needed to investigate the maintenance of pavements and its overall effect on pavement reconstruction, rehabilitation, funding, and safety.

Objective

To identify and quantify the effects of providing proper pavement maintenance in a timely manner to reduce capital outlay expenditures for aviation pavements and increase safety.

Related Work

There are currently no research projects of this nature relating to aviation pavements. A related TRB paper was published in 1995 for a single state (Virginia).

Urgency

This research should be started as soon as possible due to Congress' review of the Airport Improvement Program (AIP) and its reauthorization. Any findings of this research could be implemented through AIP legislation if necessary.

Cost

The total cost for this research is estimated at \$350,000, and would be completed in 12 to 18 months.

User Community

The users would be the FAA, state aviation departments, local airport governing bodies, and all users of the aviation system.

Implementation

Research findings would be submitted to the FAA, state aviation departments, and local airport sponsors for incorporation into their aviation funding programs.

A2B04 COMMITTEE ON PAVEMENT REHABILITATION

PROBLEM 11: AN EXAMINATION OF POTENTIAL MODEL FORMS AND ALGORITHMS—MECHANISTIC AND OTHERS—FOR PAVEMENT REHABILITATION DESIGN

There has been considerable rhetoric in recent years about the need to develop mechanistic pavement design procedures. While improved design of new pavements is important, there are far more deteriorated pavements being rehabilitated each day, and it is not feasible to develop mechanistic-empirical models for rehabilitated pavements as it is new pavements. This difference stems primarily from two distinct differences between new pavement design and pavement rehabilitation design. For new pavements the materials are much more uniform or consistent and continuous. They lend themselves to simpler mechanistic characterization. The mechanistic characterization of cracked, rutted, eroded, stripped, "D" cracked, etc. materials is much more difficult. Second, the number of rehabilitation types and therefore models needed is much larger. Instead of two or three types of new PCC pavements and two or three types of new AC pavements, there is the matrix of new pavements times the many possible stages of deterioration encountered for each type. Third, some existing pavements have a very poor original design that must be overcome.

Objectives

It is proposed that (1) a list of pavement rehabilitation types be generated, (2) a list of performance model

types (mechanistic-empirical calibrated from pavement data, mechanistic calibrated by expert opinion, historical statistical, etc.) and algorithms be generated, (3) an evaluation of the advantages and disadvantages of each rehabilitation type be conducted, and (4) selection of the model types that are most likely to succeed in any short term (next five years) development effort. Selection should be made by an experienced panel of pavement researchers from academia, consultants, and transportation agency professionals.

Urgency

The AASHTO Joint Task Force is proposing a crash effort of developing a new Pavement Design Guide by the Year 2002 that will be based on mechanistic-empirical formulations. This proposed effort is needed to assure that the undertaking is one of Ready! Aim! Fire!, and not Ready! Fire! Aim! Rehabilitation design is much more complex than new pavement design and it is essential that a concerted effort be initiated as soon as possible to support the AASHTO Joint Task Force effort.

Cost

The estimated cost is \$300,000 over 2 years.

A2C01 COMMITTEE ON GENERAL STRUCTURES

PROBLEM 12: EFFECT OF INCREASING TRUCK SIZE AND WEIGHT ON BRIDGE LIFE

It is generally recognized that trucks produce the majority of damage to highway pavements and bridges. In fact, TRB Special Reports 225 and 227, *Truck Weight Limits: Issues and Options* and *New Trucks for Greater Productivity and Less Road Wear: An Evaluation of the Turner Proposal*, both note that one truck may impose as much damage to a bridge as more than 1,000 automobiles. A truck's gross weight and axle weights, then, directly affect the wear and tear incurred by, and as a result the useful life of, highway bridge superstructures. Such damage typically occurs in the bridge deck and in the main superstructure elements including floor beams and girders, diaphragms, and joints and bearings.

Deck damage is widely recognized, and a number of research efforts have been initiated in an attempt to develop improved deck designs and deck construction materials. Another important concern of bridge owners today, however, is the amount of unseen fatigue damage caused by the ever increasingly heavy population of vehicles they must carry. Many of the connection details used in the fabrication and construction of steel bridge girders in service today are particularly prone to fatigue failures directly related to cyclic traffic loadings. Although steel girder bridges may have been theoretically designed for a service life of up to 75 years, their actual life may be considerably less, depending on the specific connection details used and the size and frequency of heavy truck loads. Repetitive fatigue loading stresses cause cracking in these steel members, and may severely limit the safe and economic use of a bridge.

Over the past 20 years, many of the details most susceptible to fatigue cracking have been identified, as well as the approximate traffic levels at which fatigue failures can be initiated. However, no comprehensive study has been conducted to quantify how the increase in the legal truck weights over time has affected the distribution and frequency of heavy truck loads. These increases have likely reduced the remaining life of fatigue-prone structural and connection details. Bridge owners critically need this information to determine the effects of increasing truck weights to better manage their existing bridges.

Objective

The objective of the proposed research is to develop a methodology which describes the historical increases in truck weights and volumes over time and provides guidance on predicting such increases in the future. The methodology would then be extended to provide information applicable to existing classes of bridges to assess their remaining fatigue life for present load levels. The research would also assess the change in bridge life that would result from incremental increases in truck weight limits.

The corresponding reduction in bridge life could then be used as a determinate in cost/benefit studies on truck weight limits, and may also be used in managing a State's bridge inventory by providing guidance on when to schedule more detailed or more frequent inspections for fracture critical bridges.

Urgency

According to Federal NBI data, more than 40 percent of the country's bridge inventory is either structurally deficient or functionally obsolete. For structurally deficient bridges, the greatest percentage are classified as such due to deterioration of the deck or main superstructure elements, in many cases caused by damage incurred by truck loading. For functionally obsolete bridges, a large number are so classified since they can no longer provide unrestricted access for the truck weights currently found on the National Highway System, as they were designed when trucks were smaller and carried less load.

The increases in truck weight over the past 50 years is a direct contributor to this large number of structurally deficient and functionally obsolete bridges, and future truck weight increases are likely to impact the National Highway System even more seriously. The proposed research will provide the tools necessary for evaluating the impact of truck weights and weight increases on structural performance, safety, and economics.

A2C02 COMMITTEE ON STEEL BRIDGES

PROBLEM 13: EFFECT OF LIVE LOAD DEFLECTION ON STEEL BRIDGE ELEMENTS

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

Objective

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

Related Work

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

Urgency

This is rated as an urgent project. It is urgent, because it may affect many bridges, and considerable saving could be achieved if the requirement can be modified.

Cost

Estimated \$150,000 and an 18-month period.

PROBLEM 14: EFFECT OF SKEWED SUPPORTS ON BRIDGE DESIGN AND BEHAVIOR

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

- It is known that the load distribution between girders is different for skewed bridges than for right bridges, and rules are needed to account for this.

- Temperature effects and movements affect skewed bridges differently than right bridges, and integral construction is typically not used on severely skewed bridges. Models are needed to better account for this and to determine if and when integral construction can be employed.

- Bracing and restraint requirements are different for skewed bridges. Guidelines are needed for diaphragm arrangement.

- Determination of when skew must be considered, when it can be neglected, and how it affects the economy and performance of the bridge.

Objective

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

Related Work

There are no broad activities in this area.

Urgency

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

Cost

Estimated \$350,000 over a 3-year period.

PROBLEM 15: EFFECT OF SHRINKAGE OF THE CONCRETE SLAB ON THE DEFLECTIONS OF STEEL PLATE GIRDER BRIDGES

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

Objective

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

Related Work

None.

Urgency

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

Cost

Estimated \$250,000 over a 2-year period.

PROBLEM 16: DEVELOP METHODS TO CONTINUOUSLY MONITOR BRIDGES AND PREDICT WHERE FAILURE WILL OCCUR

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

Objective

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

Related Work

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

Urgency

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

Cost

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

PROBLEM 17: BEHAVIOR AND DESIGN OF STEEL BOX SECTIONS FOR COMBINED BENDING AND AXIAL LOADING

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

Objective

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

Related Work

None.

Urgency

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

Cost

Estimated \$125,000 over a 2-year period for the initial state study.

PROBLEM 18: CORROSION CONTROL

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

this project should make full and practical usage of the past research.

Objective

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

Related Work

Field study information has already been performed with industry support. Two reports were prepared from this work:

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

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

Urgency

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

Cost

Estimated \$250,000 and a 2 year period.

PROBLEM 19: DESIGN ISSUES FOR BRIDGE BEARINGS FOR STEEL BRIDGES

Many issues regarding the design and placement of bridge bearings are unique to steel bridges. Steel bridges often deflect and more than other bridge types. Steel bridges are often larger bridges with more complex geometry, and these place greater demands upon the bearing or special orientation of placement. Some construction specifications require placement of bearings on steel shim stacks, erection of the

superstructure, and then grouting under the base plates. Modern multi-rotational bearing systems are often damaged by this sequence because the base plate or masonry plates are too flexible to support the applied load without continuous support. Voids in the grout have also occurred with this sequence, and this has also contributed to damage to pot bearings. Research is needed to define construction methods which allow adjustments during the construction process while assuring the adequacy and acceptability of the finished product. Requirements for bearing inspection, access for inspection, design to support construction load without physical damage or plastic deformation, and capability for bearing replacement should also be included.

Objective

Research is needed to address the wide range of specific issues related to bearings in steel bridges. A

large portion of the problems associated with bridges in service are caused by or related to improper performance of the bearings. This could lead to potential savings in the first cost and maintenance of the bridge.

Related Work

None.

Urgency

Moderate.

Cost

Estimated \$125,000 for a 2-year study.

A2C03 COMMITTEE ON CONCRETE BRIDGES

PROBLEM 20: CONNECTION BETWEEN SIMPLE-SPAN PRECAST CONCRETE GIRDERS MADE CONTINUOUS

Data contained in the National Bridge Inventory indicate that close to 50 percent of bridges built in the 1990's in the U.S. are prestressed concrete. One third of these bridges are girder type structures. Experience has shown that jointless bridges require less maintenance and are much more durable than simple span bridges with joints. Therefore, many states make precast, prestressed girder bridges continuous using a simple, conventionally reinforced connection between girders over the piers. Bridges constructed using this system have been in service for many years in a number of states and have performed well. Current trends are to use these girders for longer spans and with larger girder spacings. Further, optimized girder cross-sections have been developed and adopted by many states. A number of different details are being used for the positive moment connection, including mild reinforcement and extended prestressing strand. Research verifying the effectiveness of such connections is very limited and there are concerns that some current details may not be capable of performing as intended. Methods for the design of these connections need to be developed considering current practice.

Objective

Experimentally determine the behavior and strength of various simple details for connecting precast, prestressed concrete girders to achieve continuity. These would include the use of mild reinforcing steel and prestressing strand to tie the bottom flanges of adjacent girders. Based on an analysis of the data collected, design recommendations would be developed.

Key Words

Precast concrete, prestressed concrete, girders, continuity, connections, design, serviceability, strength.

Related Work

NCHRP Report 322, completed in 1989, summarizes the findings of a major analytical study on the design of simple-span precast, prestressed concrete girders

made continuous. Limited tests related to this type of structure were performed in the early 1960's by PCA and in 1977 by Salmons and McCrate.

Urgency

Given that about one-sixth of bridges build in recent years use this type of construction and that elimination of joints reduces maintenance costs and extends the service life of bridges, there is a need to build durable bridges incorporating rational and efficient details.

Cost

Estimated cost of \$300,000.

User Community

FHWA, AASHTO, local agencies and private design consultants would have interest in this project.

Implementation

This research project would result in the development of design recommendations to be submitted for incorporation in the AASHTO Specifications.

Effectiveness

This project would provide engineers the necessary design provisions to effectively use precast, prestressed concrete girders made continuous using the simple conventionally reinforced connection over the piers. More widespread use of this type of construction would make more efficient use of the limited taxpayers funds available for maintenance and construction of highway bridges.

PROBLEM 21: DESIGN AND CONSTRUCTION OF ADJACENT PRECAST CONCRETE BOX GIRDER BRIDGES

The National Bridge Inventory data indicate that close to 50 percent of bridges built in the 1990's in the U.S. are prestressed concrete. One sixth of these bridges are box girder type structures. In most of these bridges, many of which are on the secondary road system, the box girders are placed adjacent to each

other. Bridges of this type have become a popular and economical solution in many areas because they can be constructed rapidly since deck forming is eliminated. Adjacent box girders are generally connected by grout placed in a key between units and usually with some type of transverse tie. In some cases, no topping is applied to the structure while in others, either a non-composite topping or a composite structural slab is added. Bridges constructed using this system have been in service for many years in a number of states and have generally performed well. However, a recurring problem in some areas is that cracks form in the wearing surface or the grouted joints between adjacent units. These cracks allow water and other materials to penetrate through the joints. In some cases, this results in significant deterioration of the structure. A number of different types of grout key configurations, grouts, and transverse tie systems are currently being used. In some cases, designers implement costly details or procedures that are not justified by experimental or analytical data. Research verifying the performance of connections between adjacent box girders is very limited, and it is clear that some current details are not performing as intended. Methods for the design of these connections need to be developed considering current practice.

Objective

Experimentally and analytically determine the behavior of various details, materials, and procedures for connecting adjacent precast, prestressed concrete box girders. These would include grout key configurations, types of grouts, and all aspects of the transverse tie system. Based on an analysis of the data collected, design recommendations would be developed.

Key Words

Precast concrete, prestressed concrete, box girders, connections, design, serviceability.

Related Work

Possibly some research at Lehigh University in the 1960's. Also report FHWA/RD-82/106.

Urgency

Given that about one-sixth of bridges built in recent years use this type of construction and that prevention or control of cracking in the joints between box girders will reduce maintenance costs and extend the service

life of bridges, it is highly recommended that this proposed study be conducted to extend the service life of these economical structures.

Cost

Estimated cost of \$300,000.

User Community

FHWA, AASHTO, local agencies and private design consultants would have interest in this project.

Implementation

This research project would result in the development of design recommendations to be submitted for incorporation in the AASHTO Design and Construction Specifications.

Effectiveness

This project would provide engineers rational and reasonable provisions for the design of adjacent box girder bridges. Improved design details and procedures for this widely-used type of construction would make more efficient use of the limited taxpayers funds available for maintenance and construction of highway bridges.

PROBLEM 22: DEVELOPMENT LENGTH OF PRESTRESSING STRAND IN NORMAL AND LIGHTWEIGHT HIGH PERFORMANCE CONCRETES

The potential economic benefits of using high-strength/high performance concrete in highway bridge girders include longer span lengths and wider girder spacings. These benefits stem from the higher allowable stresses as a result of the higher concrete compressive strength. However, in order to attain these higher stress levels, larger prestressing forces must be provided. The prestressing force that can be applied to a girder cross-section is limited by a number of factors including strand size, strand grade, concrete cover, strand spacing and anchorage zone confinement reinforcement requirements.

The potential economic benefit of using lightweight high performance concrete in highway bridge structures is a reduction in the self weight of the superstructure. This, in turn, reduces the size of girders and sub-structure members. This is particularly important for bridge deck replacement

when a higher live load capability may also be required.

The equation for development lengths in the AASHTO Standard Specifications for Highway Bridges was developed for conventional strength, normal weight concretes. This equation has received a lot of attention in recent years and several revisions have been suggested. Some recent research has also indicated that development length of strand in lightweight concrete members is longer than that in normal weight concrete members. However, review of the literature indicates a lack of information about development length for normal weight concretes with compressive strengths in excess of 70 MPa and lightweight concretes at all strength levels.

Objective

To determine transfer and development lengths of prestressing strand in high-strength, normal weight concrete and lightweight concrete. The major parameters of the investigation are strand size, strand spacing, strand strength, concrete cover, concrete strength and concrete density.

Key Words

Development length, high-strength concrete, lightweight concrete, prestressed concrete, strand, transfer length.

Related Work

1. An Analysis of Transfer and Development Lengths for Pretensioned Concrete Structures, Report No. FHWA-RD-94-049, December 1994.
2. Optimized Sections for High-Strength Concrete Bridge Girders. Report to be published by FHWA.
3. On-going research at FHWA for concrete with compressive strengths up to 70 MPa.
4. On-going demonstration projects with high-strength concrete in Texas.
5. On-going research at the University of Minnesota.

Urgency

To effectively utilize higher strength, normal weight concretes in prestressed concrete girders, larger prestressing forces must be applied to the cross section. This can be accomplished through the use of smaller strand spacings, larger strand sizes or higher strength strands. However, before this can be done, information is needed about transfer and development lengths in high-strength concrete. Information about development length in lightweight concrete is also

needed. Unless this information is provided, the advantages of using high performance concrete in bridges will never be fully realized.

Cost

The estimated cost for this research is \$400,000 to \$500,000 over 3 years.

User Community

AASHTO and bridge designers.

Implementation

Results of the research can be used directly in the AASHTO Standard Specifications for Highway Bridges.

Effectiveness

Several investigations have indicated that the maximum useful concrete compressive strength for prestressed girders is in the range of 60 to 80 Mpa because of limitations in the amount of prestressing force that can be applied to a cross section. However, the limitations can be decreased through the use of larger strand sizes, closer spacing or higher grade strands. The proposed research will provide needed design information that will lead to longer span bridges and lighter, more economical structures.

PROBLEM 23: DESIGN AND EVALUATION OF PRESTRESSED CONCRETE BRIDGE GIRDERS FOR FATIGUE

Since the 1950s, the use of prestressed concrete in bridge construction has steadily increased. It is now incorporated in nearly half of the new bridge projects undertaken each year in the United States. The current AASHTO Specifications for Highway Bridges do not provide guidance for fatigue of prestressed concrete bridge girders. A limited number of fatigue tests on prestressed concrete girders have been conducted, resulting in some fatigue fractures of strands. These experiments have centered on girders made with normal strength concrete, with constant amplitude loading, and have not taken into account the cyclic creep of the concrete which is present at high frequency testing. Girders actually experience variable amplitude loading and are being designed with higher strength concretes.

Research is needed to evaluate the fatigue life of full-size girders constructed with both normal and high-strength concretes. The research results should lead to design provisions for fatigue, and guidelines for

the determination of remaining fatigue life of existing prestressed concrete bridges.

Objective

The objectives of this research are the following: (a) to evaluate the fatigue life of full-size prestressed concrete bridge girders constructed with normal [35 MPa (5,000 psi)] and high [69 MPa (10,000 psi)] strength concretes under actual bridge loadings; (b) to develop design provisions to protect against fatigue failures; (c) to develop guidelines for the determination of remaining fatigue life of existing bridges with prestressed concrete girders.

The objectives will be accomplished through a literature search, analysis of bridge loadings, fatigue testing of full-size girders, development of design provisions and guidelines, and preparation of a report.

Key Words

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

Related Work

■Russell, B.W. and Burns, N.H., "Static and Fatigue Behavior of Pretensioned Composite Bridge Cylinders Made with High Strength Concrete," Journal of the Precast/Prestressed Concrete Institute, Vol. 38, No. 3, May/June 1993, pp. 116-128.

■Bruce, R.N., Russell, H.G., Roller, J.J., and Marlin, B.T., "Feasibility Evaluation of Utilizing High-Strength Concrete in Design and Construction of Highway Bridge Structures," Final Report - Louisiana Transportation Research Center, Baton Rouge, LA, 1994.

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

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

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

Urgency

This project deserves high priority for research because of the rapid growth in construction of prestressed

concrete bridges, the lack of current design provisions for fatigue, and the lack of means of determining remaining fatigue life of existing prestressed concrete bridges.

Cost

Approximately \$500,000 over three years.

User Community

FHWA, AASHTO and other transportation agencies.

Implementation

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

Effectiveness

Results of the research can be effectively implemented through the AASHTO Specifications and will avoid fatigue problems similar to those that have occurred in steel bridges.

PROBLEM 24: THICKNESS OF BRIDGE DECK SLAB SUPPORTED BY CONCRETE/STEEL STRINGERS

With increased emphasis on optimization, the spacing of concrete and steel stringers has been on the increase. One of the areas of emphasis needs to be the thickness of the bridge deck since this is usually the largest load on the stringer. Therefore, there is a great push to keep the deck as thin as possible which in turn leads to more flexible slabs. This in turn may reduce the life expectancy of the bridge deck and in effect increasing the cost of the superstructure.

Objective

The objective of this research is to study the current AASHTO design criteria and provide some rational means to set the thickness of bridge decks supported by concrete/steel stringers.

Key Words

Deck slab, slab.

Related Work

Aware of none.

Urgency

With increased strengths of concrete and larger strand diameters, the spacing of prestressed beams/girders is continually increasing. Therefore, to obtain the maximum benefits, the thickness of the deck slab also needs to be optimized.

Cost

It is estimated that the cost would be \$350,000.

User Community

AASHTO and FHWA

Implementation

Implementation of a rational method would take advantage of optimization and provide for cost-effective and long-term bridge decks.

Effectiveness

More cost-effective bridges will result.

PROBLEM 25: FIBER REINFORCED CONCRETE FOR SEISMIC BRIDGE CONNECTIONS IN CONCRETE BRIDGES

Rigid connections between elements of bridge structures such as column to superstructure or column to footing require toughness, ductility, and strength to withstand seismic response. Present methods rely upon conventional mild steel reinforcement, and in high seismic areas constructibility controls the amount of reinforcement which can be placed in confined spaces. Many existing bridges have deficient connection details, and guidelines for new designs and retrofits do not give alternatives to conventional reinforcement.

Objective

Investigate the feasibility of fiber-reinforced concrete for connections between elements of concrete bridges.

If determined more practical and cost-effective than current practice, develop guidelines for design and construction.

Key Words

Concrete bridges, seismic design, fiber reinforced concrete, structure connections.

Related Work

Recent studies and testing in California have investigated stresses in bridge connections and have developed estimates of reinforcement required for reliable performance. Fiber reinforced concrete has been developed and used in connections between elements of concrete framed buildings.

Urgency

Bridge construction and cost in seismic areas has become more complex and costly subsequent to Loma Prieta and Northridge earthquakes. Practical solutions for improving bridge seismic safety are needed.

Cost

Large scale testing will be necessary to confirm analytical designs and validate structural behavior. A budget of \$300,000 or more may be needed.

User Community

Bridge design engineers, other structural design engineers, code writing bodies, structural researchers.

Implementation

It is anticipated that results would be used immediately by professionals engaged in seismic design of bridges in high risk areas such as California.

Effectiveness

Safer new bridge structures, and more cost effective construction will result from this research.

A2C05 COMMITTEE ON DYNAMICS AND FIELD TESTING OF BRIDGES

PROBLEM 26: TESTING AND EVALUATION OF THE EFFECT OF SUPERSTRUCTURE FLEXIBILITY ON BRIDGE DECK DETERIORATION

One of the biggest problems facing the bridge engineering community is the deterioration of existing bridge decks. At the same time, new bridges are being built with longer spans and larger girder spacings. Sophisticated (computerized) analytical tools and load distribution factors based on more refined bridge analysis are being used to accurately determine the design loads for individual members. Furthermore, the thickness of bridge decks is being minimized to reduce superstructure design loads. The overall result is that bridge superstructures designed today are more slender, and hence, more flexible than ever before. For a long time, it was believed that superstructure flexibility had no effect on bridge deck deterioration. Recent field research and observations suggest that superstructure flexibility plays an important role in bridge deck deterioration. These observations are equally true for bridges built with steel, reinforced concrete or prestressed concrete girders.

Objectives

The objectives of this project are to evaluate the effect of superstructure and deck flexibility on bridge deck deterioration, identify parameters that accelerate this deterioration, and develop design criteria to ensure more durable bridge decks.

Key Words

Bridges, concrete, decks, durability, dynamics, fatigue, girders, steel, stiffness, testing.

Related Work

Effect of superstructure flexibility on bridge deck deterioration is discussed in:

1. NCHRP Report 297: *Evaluation of Bridge Deck Protective Strategies*;
2. Transportation Research Record 1118 Bridge Needs, Design, and Performance;

3. International Bridge Conference paper No. 92-38; and

4. May 1994 issue of *Concrete Products*.

Urgency

Replacement of bridge decks is costly, disrupts traffic, inconveniences the public, and affects the welfare and economy of the community. Recent FHWA statistics indicate that 90 percent of the total surface area of highway bridge decks in the United States is made of concrete. Deterioration of bridge decks is, certainly, one of the largest problems plaguing bridge engineering. Given the scarcity of reconstruction and rehabilitation funds, it is imperative to build durable decks while maintaining an optimum design. Consideration of this problem deserves the highest priority.

Cost

The estimated cost for this project is \$650,000.

User Community

Results of this study will benefit all bridge owners including FHWA, AASHTO, and local agencies by providing cost-effective durable bridge decks while taking advantage of optimization.

Implementation

This investigation should result in recommended provisions for immediate adoption in the AASHTO Standard Specifications for Highway Bridges and the AASHTO LRFD Bridge Design Specifications.

Effectiveness

Optimization of design and construction of durable decks will extend the service life of bridge structures, reduce the life-cycle costs of the structures, decrease inconvenience to the public and enhance the economy and welfare of taxpayers.

A2D01 COMMITTEE ON CHARACTERISTICS OF BITUMINOUS MATERIALS

PROBLEM 27: DIRECT QUANTITATIVE CHEMICAL ANALYSIS OF PETROLEUM ASPHALTS FOR AMPHOTERIC COMPOUNDS

It is known that amphoteric compounds, more specifically, compounds containing both acidic and basic chemical functions in the same molecule, exert a disproportionate influence on the viscosity and elastic modulus of asphalts. Addition or removal of small quantities of amphoteric has a major effect on physical properties. There are new mathematical models that predict the physical properties of an altered (modified) asphalt. They can be used to tailor asphalts systematically, but require the concentrations of all combinations of amphoteric in asphalt as well as those to be added.

However, amphoteric must be isolated from simple acids and bases to determine their acid and base strengths and concentrations and the isolation process, by ion exchange chromatography (IEC), is both slow and expensive.

Objective

The objective is to develop a rapid method which can be used to analyze strengths and concentrations of acidic and basic functions of amphoteric in whole asphalts.

Related Work

A. There is no research in progress that specifically addresses this problem.

B. The related research involves development of a potentiometric titration method, which has been completed, and which is usable but requires isolation of amphoteric by IEC.

Development of mathematical models to predict (and hence prescribe alteration systematically) physical properties from chemical information is related, but requires the subject information.

Urgency

The urgency of this area, together with other modification methodology application, is inverse to the acceptance of the SHRP binder specifications. The more rapidly the tighter specifications (SHRP specs) are adopted the more rapidly the information will be needed for modification of major volumes of marginally out-of-spec asphalts to specification grade binders.

Cost

The estimated cost of this research is \$400,000 over two years.

A2D02 COMMITTEE ON CHARACTERISTICS OF NONBITUMINOUS COMPONENTS OF BITUMINOUS PAVING MIXTURES

PROBLEM 28: JUSTIFICATION FOR "FORBIDDEN ZONE" IN SHRP SUPERPAVE™ AGGREGATE GRADATION SPECIFICATION

SHRP research on asphalt pavements primarily targeted the properties of asphalt cement and their effects on pavement performance. Little funding was devoted to the study of the aggregate's contribution to pavement performance. Yet, near the end of the studies SHRP researchers were required to produce an aggregate gradation specification. This specification was developed with no new experimentation to support or verify its formulation. It includes a "restricted or forbidden zone" for certain percentages of specific aggregate particle sizes.

Many experienced engineers agree that, in some instances, the forbidden zone may not be applicable. For example, when aggregate particle sizes in the restricted zone are angular, it is highly probable that high quality, rut-resistant, non-tender mixtures can be produced even though the grading line passes through the restricted zone.

Objective

Testing needs to be performed to determine whether the restricted zone is needed to produce suitable asphalt mixtures that are neither tender during construction nor rut during normal service. If the need for the restricted zone is verified for specific conditions of fine aggregate angularity, then work needs to be performed to quantify the degree of angularity required for the aggregate particles that render the restricted zone no longer valid.

The study should include full-scale rutting testing (wheel tracking) of various mixtures with aggregate gradations in and out of the restricted zone.

Related Work

NCHRP Project 9-7, "Field Procedures and Equipment to Implement SHRP Asphalt Specifications," may be placing pavements with aggregate gradations in and around the forbidden zone; however, the mission does not specifically address verification of the restricted zone in the SHRP specification.

NCHRP Project 4-19, "Aggregate Tests Related to Asphalt Concrete Performance in Pavements," will evaluate existing aggregate test and develop new ones where needed but there is no specific objective to investigate the restricted zone in the SHRP specification.

Urgency

If the restricted zone is an inappropriate specification, it may preclude the placement of suitable quality, cost-effective asphalt pavements in many locations around the country. Specific conditions under which it may apply need to be identified. If it is not relevant, it needs to be removed from the SHRP Superpave™ mixture design procedure.

Cost

The estimated cost is approximately \$150,000 over 24 months.

PROBLEM 29: AGGREGATE MORPHOLOGY NEEDED FOR SMA/GAP-GRADED RUT RESISTANT ASPHALT MIXTURES

The United States is importing European asphalt mix technology to produce rut resistant mixes. These mixes require high quality aggregates. A test/procedure is needed to identify aggregates of different rock types that are acceptable for use since generic specifications tend to eliminate many rock types that have proven service records.

Objective

An aggregate specification by rock type (morphology) for SMA/gap-graded mixtures for areas that allow and do not allow studded snow tires.

Related Work

None.

Urgency

Many areas of the United States do not have access to European quality SMA aggregates. The United States does have aggregates that have produced long-lasting pavements without meeting SMA specifications. The SMA/gap-graded gradations appear to be very effective in eliminating rutting on high volume pavements. This research is needed so that more rut-resistant pavements can be placed using good quality local aggregates.

Cost

The estimated cost is approximately \$100,000 to 200,000 for the period of 12 to 24 months.

PROBLEM 30: GRADATIONS NEEDED FOR SMA/OPEN-GRADED ASPHALT MIXTURES

Dust of fracture fines are piling up at a tremendous rate each year at aggregate suppliers. Agencies want rut resistant asphalt mixes. Research has indicated that rock dust (dust of fracture can stiffen and reduce the low temperature cracking). The problem is how to design asphalt mixtures that maximize the amount of coarse aggregate for the structure and the amount of fines to provide enhanced mix properties. Mixes may need different ratios of coarse aggregate to fines based on maximum aggregate size and percentage.

Objective

Rut resistant mix design procedure to maximize use of coarse aggregate and fines in SMA/open-graded rut resistant mixtures.

Related Work

Work done by Texas DOT on Coarse Matrix High Binder (CMHB) asphalt mixtures.

Urgency

Asphalt mix specifications are requiring clean one-size aggregate with polymer modified asphalt. These types of mixtures help create an over abundance of rock fines versus clay fines. These rock fines can be utilized with or without polymers to modify asphalt. The rock fines can be used as fillers to reduce or eliminate the amount of polymer needed to obtain specific mix properties resulting in more economical rut and crack resistant mixes.

Cost

The estimated cost is \$100,000 over 24 months.

PROBLEM 31: AGGREGATE DISTRIBUTION IN ASPHALT CONCRETE MIXTURES RELATED TO PAVEMENT PERFORMANCE

Asphalt concrete (AC) is a strongly heterogeneous material which consists of asphalt cement voids, fine particles, sands and coarse aggregates. Literature review reveals that the investigations of AC have

mainly concentrated on the macroscopic behavior of the material based on the assumption that the mixture is homogeneous. It has been recognized that aggregates and their distribution play a key role on the stability and bearing capacity of AC. Due to the extreme difficulty associated with the quantitative measurement of aggregate distribution in AC, however, there is a very limited knowledge and investigation on the characteristics of aggregate distribution in the mixtures and their influences on AC performance.

Objectives

1. To develop a procedure and algorithms for the quantitative measurement of coarse aggregate distribution and orientation in AC mixtures.

2. To develop a simple technique to predict the aggregate gradation and shape used in AC for quality control of field and laboratory compaction.

3. To establish quantitatively the characteristics of aggregate distribution in different types of AC currently used in United States and Canada such as HMA, SMA and LSM, etc.

4. To establish relationships between aggregate distribution and AC performance in pavements.

Related Work

Last year, the submitter and his colleagues at the National Research Council of Canada performed a preliminary investigation on the application of digital image processing to quantitative study aggregate distribution in AC. A report was submitted to TRB Committee A2D02 for the 1995 TRB Annual Meeting and was recommended for publication in a Transportation Research Record. Other activity in the related area is a study funded by SHRP (88-A-IIR-13) on microscopical analysis of voids in AC mixtures, which was carried out by Danish Road Institute. This study was redirected by SHRP (A-003A) to the University of California at Berkeley in analyzing homogeneity of air voids in rolling wheel and gyratory compacted AC samples.

Urgency

Realistic prediction of AC performance necessitates consideration of the heterogeneous nature of the mixtures, in particular, the aggregate distribution. In a majority of current methods and models for AC performance prediction and evaluation, however, the composite material is almost always assumed to be homogeneous and its heterogeneous properties are largely ignored. Furthermore, there is no quantitative knowledge on aggregate distribution in AC mixtures, in particular, the differences of aggregate distribution in HMA, SMA and LSM. Such new knowledge and

techniques will improve AC mix design, compaction quality and pavement performance.

Cost

The estimated cost is \$200,000 over approximately 24 months.

PROBLEM 32: POLYMER MODIFIED ASPHALT CONCRETE

Current research efforts are being directed towards a fundamental evaluation of polymer modified asphalt cements and will only include a limited number of field test sections. A full-scale laboratory and field study is needed to evaluate the applicability of both the SHRP binder and mixture specifications to the performance of polymer modified asphalt concrete.

Objective

1. Evaluate the current SHRP binder specification requirements with polymer modified asphalt cements.
2. Evaluate the SHRP mixture compaction and test methods with polymer modified asphalt concrete.
3. Validate the results of both laboratory studies with field test sections. At least three field test sections should be placed; the selection of the field sites should be made so that three different environmental regions are included.

Related Work

The most current work in this area is a study funded by the Federal Highway Administration, "Improving the Temperature Susceptibility Characteristics of Hot Mixed Asphalt Concrete Through the Use of Elastomers." This work is being done jointly by the Minnesota Department of Transportation and the University of Minnesota. This is a five-year project that will evaluate both the fundamental chemical and material interactions between a wide range of polymers and asphalt cements, modified asphalt mixture properties, and the construction of a limited number of field test sections in Minnesota.

Another research effort by the Western Research Institute in Wyoming is evaluating crumb rubber in asphalt concrete. Crumb rubber research for modifying binders would be applicable to the proposed work, although it should not be the main emphasis.

Urgency

With the impending implementation of the SHRP binder and mix-design test methods and

specifications, many regions in the country will be required to use a modified binder to achieve the requirements. The use of modified asphalt cements has historically increased the cost of asphalt concrete mixtures. In these times of increased maintenance and construction demands and decreased funding, it is imperative that the benefit of modifying asphalts be proved cost effective.

Cost

Approximately \$1.5 million (\$1 million for laboratory and initial construction, \$0.5 million for 5 year evaluation and testing.). The duration would be approximately 7 years (2 years for laboratory study and construction of field test sections and 5 years for pavement evaluation and testing of field test sections).

PROBLEM 33: COMPARISON OF VARIOUS MODIFIERS TO ASPHALT CEMENTS

A great deal of confusion centers on the performance of polymer additives in asphalt. The purpose of this research would help clarify some of the costs equivalencies and performance of modifier based on SHRP results.

Objective

The purpose of this research is to determine the equivalent costs in relation to performance of various polymers when added to asphalt cements at various concentrations. The specific performance of these modifiers would be based on how they would modify the asphalt cements using the SHRP PG test procedures. Additionally, this would also help anticipate any problems that may be occurring in the industry with specific polymers in relation to each other.

Related Work

A great deal of research is underway by a number of organizations on various modifiers. However, none of this information appears to have been correlated with a given AC type with varying concentrations and costs of each additive. Literature surveys note little to no information available on research activities to identify exactly what the cost and performance equivalencies are.

Urgency

Based on the fact that a number of modifiers are claimed to improve asphalt cements, either on the high

or low temperature end, many states are now looking to meet the high and low temperature grades for their geographic region. The identification and equivalency of modifiers in asphalt cements would be an excellent reference for helping DOT personnel in directing their evaluation in identifying the polymer(s) for a given task. The polymers would include everything from recycled rubber to "virgin" polymers such as di- and co-block polymers.

Cost

The estimated cost is \$200,000 over 12 to 24 months.

PROBLEM 34: CRM IN SLURRY SEALS AND MEMBRANES

Many freeways are rubberized and overlaid with new pavements. Potential for membrane interlayers produced from rubber could greatly assist the contractor and State DOT's in improving the performance of these road projects. This would also include looking at spray applications for bridge decking as an excellent adhesive, due to the membranes cohesive and adhesive strengths, when applied between a PCC/ACC or ACC/ACC overlay. Rubber can be used as a modifier in asphalt cement for slurry seals or in tact coats in secondary and tertiary roads where rock overlay is used, and the rubber will improve adhesive bond to help hold the aggregate from being dislodged into windshields. Severe cracks can be sealed, aiding in the surface coarse life performance. The rubberized seal or membranes properties will be directly affected by the particular gradations and process used to blend.

Objectives

To research the two wet technologies presently in place in the U.S., the coarser rubber process developed by McDonald and the finer rubber developed by Rouse Rubber Industries. Cost effectiveness in relation to the cohesive and adhesive strength properties and the applications of these recycled rubber modifiers in membrane interlayers, slurry seals, and other coated applications.

Related Work

Research reporting has been very limited on work being done in Florida, Texas, and Arizona. However, asphalt cements containing from 16 percent to 20 percent fine or coarse rubber, can have a significant impact on improving the life cycle of existing road pavements through repairs and new construction. Very little work has been done to document the

performance of these membranes. This project will increase awareness and validation of how these membranes improve road life.

Urgency

The need to find ways to improve repairs and maintenance on existing roads and bridges. The concentrated asphalt rubber cements can be applied using conventional spreader trucks and greatly assist State DOT's and local agencies in improving the life of the roads, sealing cracks, and improving aesthetic values through use of conventional contractor spreading equipment. These membrane interlayers also act as moisture barriers to prevent water from seeping into the surface below the pavement surfaces or holding the aggregate in place by improving the adhesive strength bonding between ACC to ACC or ACC to PCC.

Cost

The estimated cost is \$200,000 over 12 to 24 months.

PROBLEM 35: CRM FIBER AS GEOTEXTILE IN HMA, MEMBRANES OR SMA; FIBER AS GEOTEXTILES IN ASPHALT CEMENTS

It is well known that geotextiles can provide excellent reinforcing aids in asphalt cements. Tire fibers offer an excellent low cost alternative or supplement to virgin fibers. No good use has been found for these excellent high quality fibers other than to be landfilled or in some cases incinerated.

Objective

To evaluate the cost-effectiveness of the performance of a blended mixture of tire fibers as a supplement to "virgin" geotextile fibers for asphaltic applications.

Related Work

No research has been conducted on the use of the recycled geotextiles. These recycled materials should be evaluated against a mixture of "virgin" geotextiles for using similar applications.

Urgency

The use of recycled tire rubber as a modifier in asphalt cements is becoming known and accepted. The use of crumb rubber as a material in a number of other application is also growing. However, the fiber waste

has not found a good end-use market. This could be an excellent application for these high quality rejected fibers.

Cost

The estimated cost is \$250,000 over 12 to 36 months.

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

PROBLEM 36: EFFECT OF AGGREGATE PROPERTIES ON MIX PERFORMANCE AND DESIGN

The Strategic Highway Research Program did relatively little work on aggregates, yet the mix design procedure has definite limits for certain aggregate properties. Meeting some of these requirements is extremely difficult in many parts of the country. As an example, fine aggregate angularity is posing problems for many mix designers. The restricted zone is also the subject of controversy. Also, large aggregate mixtures (greater than 50 mm) are not accommodated in the Superpave™ system.

Objective

The effects of variations in the aggregate properties in Superpave™ mixtures needs to be investigated in terms of how those variations affect pavement performance. The limits set for the consensus aggregate properties need to be verified and/or refined. The need for the restricted zone must be established. The Superpave™ mix design procedures need to be expanded to include large stone mixtures with maximum aggregate sizes of 50mm and higher.

This investigation should include both laboratory testing and full-scale accelerated loading tests.

Related Work

None known. Individual states may be investigating angularity and economic issues on a local level.

Urgency

High. Many states are moving towards rapid implementation of the Superpave™ volumetric mix design procedures.

Cost

Approximately \$350,000 over 30 months.

PROBLEM 37: CONFIRM THE SUPERPAVE™ PERFORMANCE MODELS WITH MODIFIED ASPHALTS

The Superpave™ performance models were developed largely for conventional asphalt materials and only

limited testing was performed with modified materials. Field validation with modified materials was lacking. The binder specifications, however, are supposed to be blind to the use of modifiers. In many cases, the specifications require the use of modified asphalts to provide the performance grades needed, meaning that many states will be using more modified asphalts than ever before.

Objective

Research is needed to confirm that the Superpave performance models are appropriate for modified materials and revise the models, if needed, to make them appropriate. The testing should include laboratory testing, accelerated loading tests, and pavement studies. A suite of modifiers representative of those on the market today should be used in mixtures conforming to Superpave™ mix designs.

Related Work

This research effort should be coordinated with work under two other projects:

1. NCHRP 9-10 on Superpave™ Protocols for Modified Asphalt Binders will be refining or developing binder test methods for modified asphalt cements.
2. The FHWA Models Contract will be refining the Superpave™ modeling software.

Neither of these studies will fully validate the models for modified materials.

Urgency

High. Many states, if not most, are looking towards full implementation of the Superpave™ binder specifications in 1997; these specifications may significantly increase the usage of modified materials in some parts of the country to meet the required performance grades. States are looking toward implementation of intermediate and complete mix analysis procedures sometime after 2000. (Indiana is placing three intermediate mix-design jobs in 1996.) Mix analysis requires the use of the Superpave™ models, which have not yet been validated for modified materials. This short time frame for implementation makes the validation of the models with modified materials critically important.

Cost

Approximately \$400,000 over 30 months.

PROBLEM 38: MAINTAINING THE PERMEABILITY OF OPEN-GRADED BITUMINOUS COURSES

A number of states have been interested for several years in the use of open-graded friction courses because of the many safety benefits of using such a mix. The open-graded friction courses have been especially desirable because of the drainage characteristics in removing water from the surface of the roadway and reducing the potential of vehicles to hydroplane. These mixes also reduce backspray, improve nighttime visibility, and provide excellent friction resistance. Because of the safety factors involved, the use of these mixes continues to be attractive and states have searched for ways to extend the life of these pavements. Previous problems involving stripping and raveling are being addressed by using liquid anti-strip additives, hydrated lime, modifying asphalts with polymers, and incorporating mineral fibers.

Although state agencies are looking for ways to extend the life of these pavements, another problem remains in that these pavements are subject to becoming clogged with sand and silt and other fine roadway debris. Some states have used fog seal applications as a method to try to extend the life of these pavements and reduce raveling problems, but this procedure also tends to fill the void spaces and reduce the amount of permeable voids within the structure of the surface course. For these reasons, it is important that states find a way to not only extend the life of these pavements but also improve permeability characteristics over a longer period of years.

There is also some potential for noise reduction using open-graded friction courses, however, the reduction in noise level decreases as the void structure becomes clogged. In order to maintain the effectiveness of open-graded mixtures as a form of noise reduction, it is essential that the void structure be kept clean.

Objective

Some work has already been done in this area. In Europe, for example, a special piece of equipment uses highly pressurized water which is sprayed into the pores of the friction course to dislodge and remove debris. It is followed by vacuum suction equipment mounted on the same vehicle which removes the debris from the pavement surface. The water is then

filtered and recycled to be used again in the cleaning operation.

Research needs to be conducted to see what options are available as to ways that the drainage properties of open-graded mixes can be enhanced and maintained over a longer period of years. Special machines such as those being used in Europe should be evaluated for their effectiveness, and other potential methods should also be researched. The cost-effectiveness of each method should also be studied in regard to improved pavement performance, particularly relating to permeability and extended serviceability.

Related Work

There is a proposed NCHRP Problem Statement No. 96-C-39 which deals with the effective aging and drainage characteristics on performance of open-graded emulsified asphalt pavements. That problem statement could possibly be revised to include not just emulsified asphalt pavements but pavements utilizing open-graded friction course in general. It is not known at this time, but there may be research in European countries also concerning the effectiveness of cleaning equipment for porous mixes.

Urgency

It is essential that permeability be maintained throughout the life of the open-graded friction course in order for it to be effective. This research is needed because of the importance of safety factors involved in using this mix such as reducing hydroplaning, improving the nighttime visibility, and reducing backspray. Upon completion of the research, plans could be implemented to periodically clean and maintain the open-graded friction course void structure so that its permeability could be maintained over the life of the surface course.

Cost

It is estimated that the cost of this research would be \$200,000, and would be accomplished within 18 months.

PROBLEM 39: ACCELERATED LABORATORY TESTING OF ASPHALT PAVING MIXTURES TO PREDICT PAVEMENT FRICTION

No suitable standard test method is available for accelerated polishing and testing the frictional properties of compacted asphalt paving mixtures intended for wearing course. Most agencies use the

bare coarse aggregate only for measuring and evaluating the polish and frictional properties. The most commonly used method for polishing coarse aggregate to simulate the action of vehicle tires is the British Polish wheel, although the Penn State reciprocating polisher, the North Carolina wheel, and the Wehner/Schulze (German) polish machine have also been used. The British Pendulum tester is used almost exclusively for measuring the frictional properties of the polished coarse aggregate. There is a lack of acceptable correlation between the coarse aggregate polish and frictional resistance and the asphalt pavement frictional resistance measured by the locked wheel skid trailer. This is due to some confounding factors such as aggregate gradation, fine aggregate properties, asphalt content and compaction level of the asphalt paving mixture. Moreover, the British Pendulum tester measures the coarse aggregate frictional resistance about 7 miles per hour as opposed to the locked wheel skid trailer which usually measures the pavement friction at 40 mph.

It is desirable to polish and test the asphalt paving mixture rather than the coarse aggregate only. If such a technique is developed, it can be adopted as part of the asphalt mix design process.

Objectives

1. Develop an accelerated polishing technique for polishing compacted specimens of asphalt paving mixtures in the laboratory by simulating the action of vehicle tires.

2. Develop a testing method for measuring the frictional properties of the polished, compacted specimens of asphalt paving mixtures simulating the high speed (at least 40 mph) of the vehicular traffic.

Related Work

To our knowledge, no research is in progress which is directed to achieve the preceding objectives.

Urgency

State highway agencies are using different testing and evaluation methods (such as British Pendulum, percent insolubles, loss of ignition, and petrographic examination) for approving aggregate sources to obtain good frictional properties in the asphalt pavement.

However, the same aggregate can give different pavement frictional values when used in different asphalt mix types such as dense-graded, open-graded and stone matrix asphalt (SMA). Testing the end product which is the compacted asphalt mix is logical to simulate the field conditions. Such a technique is

likely to be adopted by most highway agencies. The accelerated polishing technique and the asphalt surface friction measurement technique developed from this research can be proposed as an AASHTO standard practice and a standard test method to expedite the implementation by the state highway agencies.

Cost

The estimated cost is \$250,000 over 24 months.

PROBLEM 40: LIFE CYCLE COST ANALYSIS OF SURFACE TREATMENTS

Surface treatments are valuable tools for pavement maintenance for non-structural surface distresses. They can provide economical methods for restoring surface friction, waterproofing, and rejuvenating oxidized asphalt pavements. There are numerous types of surface treatments including, but not limited to the following: single and double chip, sandwich, cape, slurry and fog seals; microsurfacing; emulsion resurfacer and sealcoats, using conventional and modified binders.

Purposes and benefits of surface treatments may often overlap. Differing service lives often confound cost comparisons, particularly if only first costs are considered. Users need additional selection and comparison criteria for allocating limited maintenance funds cost effectively. Life cycle cost analyses of these various types of surface treatments would be a valuable tool.

Objectives

1. Gather data from available literature and surveys of owner agencies to determine typical ranges of service lives and maintenance requirements for the respective types of surface treatments.

2. Use information from step 1 to develop typical ranges of costs per year for these various types of surface treatments, including both initial and continuing (maintenance) costs. Determine if any salvage value may be applicable (for example, if a chip seal would remain in place as a crack relief layer for a future overlay).

Related Work

Some current SHRP, LTTP and NCHRP projects are studying long and short term effectiveness of a variety of surface treatment types, as is the SMERP project in Texas. There was an NCHRP study of chip seals for high traffic volumes. However, there has not been any

specific activity in these studies regarding life cycle cost analysis.

Cost

Approximately \$100,000 over 1 year.

Urgency

There is an urgent need for better information to improve cost effectiveness of maintenance and surface repair/restoration activities.

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

PROBLEM 41: CHARACTERIZATION OF NOVEL ASPHALT AGGREGATE MIXTURES BASED ON PERFORMANCE FOR PAVEMENT STRUCTURAL DESIGN

Research has demonstrated that the use of the SHRP A-003A test equipment and procedures provides a means to evaluate the performance characteristics of asphalt-aggregate mixes in fundamental engineering units. The equipment and procedures developed show promise in predicting the performance of asphalt-concrete materials in pavement structures. Examples include prediction of permanent shear deformation resistance using the repetitive simple shear test-constant height (RSST-CH), and prediction of fatigue resistance using the third-point flexural beam test. Flexural stiffness and shear modulus can be evaluated at different temperatures and frequencies using the same equipment. These tests have been used for conventional dense graded asphalt concrete, large stone mixes, stone mastic asphalts with rubber-asphalt and polyolefin modified binders, and crumb rubber asphalt concrete (Harvey, Lee, et al, TRB 1994; Harvey, Sousa, et al, TRB 1995). This preliminary work indicates that tests of this type can be used to evaluate new mix types designed to provide specific performance properties at various depths in the asphalt concrete layer, such as rutting resistance near the surface, fatigue resistance near the bottom, and varying stiffness to minimize tensile strains. This work also indicates that presently existing mix types and new mix types can be used in pavement structures designed to take advantage of the measured mix properties. In current practice advantage is often not taken of demonstrated properties of particular mix types to different distress mechanisms.

Objective

The objective would be to design mix types to provide the properties necessary at various depths of the asphalt concrete structural layer, for the following requirements:

- Permanent deformation (rutting) resistance,
- Fatigue cracking resistance,
- Skid resistance,
- Moisture damage resistance, and
- Aging resistance

These mix types can include conventional types with mix designs adjusted to obtain the required properties.

The designs would be based on properties such as those measured in fundamental engineering units using the RSST-CH and fatigue beam tests.

The mixes designed to have the properties listed above should then be included in example pavement designs which take advantage of those properties. Analysis of the pavements could use existing mechanistic analysis methods, however, development of comprehensive constitutive modeling (such as that in Research Problem Statement No. 88 of TRC No. 417) would most likely provide much better results in terms of predicting pavement performance from laboratory testing. Field validation should be included to demonstrate the enhanced performance of the new pavement designs, which would include the mix types developed in the project. Field validation could include pavement sections subjected to actual traffic and/or accelerated loading device evaluation. It would be essential that life cycle cost be evaluated as part of the pavement performance analysis.

Key Words

Asphalt-aggregate mix design, pavement performance, permanent deformation, fatigue, pavement modeling.

Related Work

Some preliminary testing has been done by Harvey, Lee, et al., TRB 95. The basis of a possible mechanistic model has been developed and is included in the SHRP A-003A final reports by Sousa, et al., and in Sousa, Weissman, et al., TRB 93. Some practical work has been done in Australia by J. Yeaman of Dynatest PMS following these principals, and a design of this type for fatigue is described in Sousa, Harvey, et al., TRB, 1994.

Cost

The project should be divided into two phases, with the first phase including all work except field validation, and the second phase consisting of field validation. The estimated cost of the first phase would be approximately \$500,000 over a two year duration. This work would include mix types development, improvement of modeling, and evaluation of pavement designs. The second phase would involve performance monitoring of test sections built in conjunction with a state DOT and/or paving contractor and would have a

duration of approximately three years. The test sections would be trafficked by normal traffic patterns, and if possible would optimally be trafficked by an accelerated pavement testing (APT) device also. The cost of the second phase would depend on the degree of cost-sharing with participating agencies or companies, the number of field sections, the types of loading applied, and degree of instrumentation.

User Community

State highway agencies, FHWA, AASHTO, FAA, and USACE-WES.

Implementation

The products of this project would be pavement and mix design guidelines, and enhanced pavement modeling software, which would be of immediate use to highway agencies and paving contractors, provided adequate validation has been included in the project.

Effectiveness

If the research findings are successfully implemented, they would result in significantly reduced pavement life cycle costs.

A2D05 COMMITTEE ON GENERAL ASPHALT PROBLEMS

PROBLEM 42: HIGH TRAFFIC ASPHALT CONCRETE INTERSECTIONS

Intersections present unique requirements for both materials and construction. Stresses imposed by traffic at intersections result from acceleration, deceleration, and standing loads which often are not addressed in conventional designs for structure or materials. Indeed, even SHRP recognizes this unique situation by recommending higher quality binders be used in such applications, but the rationale for this recommendation has not been developed. Even the sophisticated Superpave Level III performance prediction models are designed for 90km/hr traffic, not standing, or accelerating vehicles. This means prediction of asphalt concrete performance at intersections remains uncertain.

Objective

- Develop a protocol for rehabilitation and reconstruction of intersections with asphalt concrete.
- Develop a design/construction procedure which matches performance requirements to materials.

Related Work

Demonstration projects in Colorado, Maryland and other locations in 1994 and 1995 are using some European and SHRP technology to address this problem.

Urgency

Very urgent. Life-cycle costs for PCCP are often higher than asphalt, but since rutting of these materials is only a remote possibility, they are sometimes used as a last resort.

Cost

The estimated cost is \$240,000 over 2 years.

PROBLEM 43: A QUALITATIVE ANALYSIS OF SEGREGATION IN ASPHALT CONCRETE PAVEMENTS

A number of state DOTs have experienced difficulty estimating the effective service life of asphalt pavements. The phenomenon known as segregation compounds this problem. New pavement surfaces

exhibit segregation when the coarse and fine components of the asphalt concrete mix become permanently separated due to material handling. Composition of the asphalt concrete mix may also increase the tendency to produce a segregated product. The results are high air voids, low asphalt content, and low density that occurs in the pavement layer. These problems simulate an open-graded pavement surface condition which tends to allow water and air into the void system of the pavement. Water promotes freeze-thaw action. Exposure to air prematurely ages the asphalt in the pavement. These processes weaken the pavement locale and can cause advanced pavement deterioration, such as raveling, severe cracking, and the formation of pot holes.

The problem can be further expanded by the extent of the segregation, as a function of depth or lift, especially when referring to a full-depth pavement, and/or as a function of length. Overlays, as well as full-depth asphalt pavements, have similar distress deterioration modes of failure caused by segregation. Current measurement practices include lane-feet and quantitative estimates of distress severity. However, little information exists as to distress severity due to segregation and how it correlates to the rate of pavement deterioration. Unfortunately, segregation has not been quantified by severity. The costs associated with the reduction of pavement service life or repairs in addition to expected maintenance during the pavement service life needs to be addressed. Segregation hinders the identification and implementation of the optimum rehabilitation strategy at the right time, which results in the strategy being less effective.

Objective

The objective of the study is to provide methods of detecting segregation and determining the extent, as well as severity, of the condition. The study is to focus on the effect the pavement experiences by the presence of segregated area(s). This relates to overall pavement costs including maintenance and rehabilitation. This relationship is established after careful analysis of pavements that contain segregation and pavements that do not contain distresses caused by segregation. Identification procedures for segregation will be updated with the correlations of causes and effects on pavement life. One method which can be used to properly identify pavement condition is to compare extracted material from cores from segregated areas and adjacent non-segregated areas. This provides evidence on extent, severity, and, in turn, required baseline information. Past experience indicates that

segregation does not always indicate cracking and/or failure is eminent.

Research strategy will be defined as follows: (1) New procedures developed to quantify extent and severity of pavement segregation; (2) inventories established containing rehabilitated sections, distresses associated with each, and performance history of asphalt pavements as they exist; (3) sections evaluated for segregation, pavement performance, and relative success/failure rate of rehabilitation strategies with an emphasis on pertinent cost analysis.

Urgency

Benefits to be derived from this study are mostly economical in nature. Information used to justify enforcement of specific changes or adherence to specifications in asphalt concrete paving is to be derived from conclusions of the study. Benefits include:

1. Determination of proper measurement techniques for segregation (extent and severity).
2. Data accumulation and analysis on pavement sections, which would result in a data bank for baseline information.
3. Data on the reduction of service life of the pavement due to segregation and at what severity level the deterioration warrants major repairs.
4. Cost/benefit models on segregated pavements showing gains or losses associated with various rehabilitation efforts on the basis of pavement age, time of effort, and actual costs.
5. Information to develop performance-related specifications to improve the general quality of the pavement.

Cost

Work-force efforts are to be divided between field and laboratory work, with an estimated budget of approximately \$250,000 over 2 to 3 years.

PROBLEM 44: SUPERPAVE™ LEVEL 1 MECHANICAL PROPERTY TEST

Superpave™ Level 1 mix design is based on volumetric properties, aggregate characteristics and properties of the densification curve during gyratory compaction. Volumetric properties and aggregate characteristics have long been recognized as being related to performance. Considerable research has occurred to correlate these properties to performance with varying degrees of success. Properties of the densification

curve are believed to be related to performance based upon research done by LCPC but agencies have little experience with the Superpave™ gyratory, and the connection to performance is not quantified.

Some agencies are demanding increased confidence in the permanent deformation resistance of Superpave™ mixtures. In the face of uncertainty agencies are considering adopting an additional test to "confirm" the mixture. Potential tests include the Georgia Loaded Wheel Tester and the Hamburg Rut Tester. National adoption of a rut test will suffer the deficiencies of all empirical tests, how to match the criteria to traffic and the environment.

Objectives

The objective of the proposed research would be two-fold.

1. Determine the relationship between the gyratory densification curves as measured in the Superpave™ gyratory compactor and permanent deformation for mixtures designed with Level 1 volumetrics and aggregate properties.
2. Evaluate potential rutting torture tests to determine appropriate criteria for different traffic levels and high temperature environments.

Related Work

Comparative studies are occurring to compare the results of various rut testers but no work is underway to develop specific criteria for any of the machines. In NCHRP 9-9 activities are proposed to evaluate various mixtures in the Superpave™ gyratory including any identified anomalous mixtures which might not meet the Superpave™ gyratory criteria but are identified as good performing mixtures.

Urgency

Superpave™ Level 1 mix design is entering the early stages of implementation, FHWA has been suggesting the year 2000. The cost to implement an added torture test may exceed the cost of implementing Level 1 mix design itself. There is a strong need to know before implementation whether the additional testing is required. If a need exists a methodology is required to develop criteria specific to the application.

Cost

The estimated cost is \$400,000 over 24 months.

A2E03 COMMITTEE ON MECHANICAL PROPERTIES OF CONCRETE

PROBLEM 45: EFFECTS OF EARLY-AGE TEMPERATURES ON CRACKING ASPECTS OF HIGH PERFORMANCE CONCRETE

Some high performance concrete (HPC) structures experience high early-age temperatures and thermal gradients because they have higher cementitious material contents. The effects of these experiences are not well understood and lead to substantial problems during the service life.

Objective

To determine the effects of early-age temperatures and thermal gradients on cracking and other aspects of the performance of HPC which may require changes in design procedures and in codes and standards.

Approach: The cracking potential is likely to depend on rate of heat generation, thermal conductivity, shrinkage, creep, and early age mechanical properties. The effects of these parameters on cracking and the long-term properties of HPC should be investigated in field and laboratory tests conducted to obtain a fundamental understanding of thermal cracking in HPC. This understanding could then be used to establish allowable differential temperature profiles for HPC and calibrate and improve existing analytical

models in codes and standards. Models should be developed for predicting the potential for early-age thermal cracking of HPC as a function of the exposure temperature. Finally, guidelines for minimizing possible detrimental effects of high early-age temperatures and temperature differentials should be developed.

Related Work

In Europe, substantial activities are currently under way.

Urgency

There is an urgent need for addressing this issue, since higher performance concretes with generally higher cement factors are being recommended for use in transportation structures. The results of these findings may require changes in construction and design procedures and in codes and standards.

Cost

The estimated cost is \$500,000 over three years.

A2E05 COMMITTEE ON ADMIXTURES AND CEMENTITIOUS MATERIALS FOR CONCRETE

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

PROBLEM 46: DURABILITY OF RAPID SETTING REPAIR CONCRETES

The time allocated to a repair of concrete pavements and bridges is increasingly being shortened due to accelerated construction schedules. A variety of rapid setting concretes are available to fill this need, but problems have surfaced regarding their resistance to freezing and thawing, especially in the presence of deicing agents. As many of these products are proprietary in nature, the only information available concerning their properties is that supplied by the vendor. Independent studies on the durability of these materials need to be undertaken so their limits of use can be established.

Objectives

1. To evaluate the durability of rapid-setting repair concretes when exposed to conditions of freezing and thawing in the presence of water and deicing agents.
2. To examine the limits of applicability of these materials with regards to temperature of concrete an ambient conditions of placement.

Key Words

Concrete, admixtures, rapid set, strength and durability.

Related Work

Related studies can be found in reports on SHRP projects H-105 and C-206, although in these studies the focus of the work was not primarily on durability and information generated concerning this topic was limited.

Urgency

The increasing emphasis on rapid placement of concrete makes it imperative that independent studies be carried out on the durability of these materials under various conditions.

Cost

Estimated cost is \$300,000 over 3 years to review existing information, selected materials and mixtures for evaluation, and test for freeze and thaw durability and resistance to deicing agents of concretes prepared with rapid setting materials under various conditions.

User Community

AASHTO, NCHRP, FHWA

Implementation

Findings of the research may be used to provide highway engineers with data on durability of rapid setting concretes which can be used to repair concrete slabs and other elements in time critical applications.

Effectiveness

Will increase confidence in long-term durability of rapid repairs and screen out those materials which might impact adversely on performance of repaired sections.

PROBLEM 47: RELATION OF CONCRETE COMPOSITION TO CURING REQUIREMENTS

It is well known that much of the concrete placed in the United States (and presumably elsewhere) gets little or no assistance during its curing. Curing is defined (ACI 116R, page 20) as "the maintenance of a satisfactory moisture content and temperature in concrete during its early stages so that desired properties may develop."

From that definition, it is clear that if conditions exist at the location where some concrete is placed such that no action is required to achieve and maintain "a satisfactory moisture content and temperature," then the concrete will need no assistance during its curing. This raises several research questions to which answers do not seem to be available:

1. What constitutes "a satisfactory moisture content and temperature" for any given mixture?

2. How great a range of moisture contents and temperatures are permissible for various compositions of concrete?

3. What is the appropriate tolerance on moisture content and temperature for any given mix?

4. Are there circumstances in which it is economical to modify the composition of the concrete to reduce the amount of effort needed for curing?

5. Is there an admixture that could be used to cause concrete to cure adequately without assistance?

Objectives

- Determine when no action is needed to assure proper concrete curing.

- Determine whether concrete can be modified as to composition so no action will be needed to assure proper curing.

Key Words

Concrete, curing (of concrete), moisture content (of concrete), temperature (of concrete), admixtures (for concrete)

Related Work

Mather in 1987 (ACI SP-104, pages 245-259) noted that the ACI standard (ACI 308-81) recognized that "no action ... is required when ambient conditions ... are favorable" but it failed to describe such conditions. Many specifications give a time during which freshly placed concrete is required to be protected from drying. Often it is clear that this period is shorter when rapid strength gaining cements are used and longer when the cementitious materials used react more slowly. One topic that might be the subject of research is when it is prudent (or economical) to use accelerated procedures to reduce the duration when action might be needed to achieve proper curing.

Powers in 1947 ("A discussion of cement hydration in relation to the curing of concrete," Proc. HRB, Vol. 27, pages 178-188) discussed water in concrete as related to curing and noted that curing need not be aimed to achieving complete combination of either the cement or water.

In the precast industry, accelerated curing using steam may cause all the needed action of controlled curing in a very short time. Using regulated-set cement, one can develop quite high strengths very quickly—for example, 3000 psi in 30 minutes. If the required service strength of the concrete is 4000 psi such concrete would need protection against moisture loss for perhaps only 20 minutes after placement.

Urgency

This study would result in significant reduction of cost of construction and repair.

Cost

Approximately \$100,000.

User Community

Guide specifications for concrete and ACI 308 could be revised to eliminate unneeded activity.

Effectiveness

Much concrete that now receives no assistance in curing and is not thereby hurt will be legitimized. Other concrete that now is the recipient of unnecessary effort will no longer be treated, with consequent cost savings.

PROBLEM 48: HIGH-REACTIVITY METAKAOLIN FOR HIGH PERFORMANCE CONCRETE

High-reactivity metakaolin (HRM) is a pozzolan known to improve the properties of portland cement concrete. HRM contribution is similar (or better) to silica fume in the area of hardened concrete properties. One major advantage of HRM is that it does not reduce workability as silica fume does. Hence, it is proposed to study the fresh concrete properties of HRM concrete in order to use HRM for high performance concrete.

Objective

To obtain the influence of HRM on properties of freshly mixed concrete. The variables to be investigated are: (i) range of cement content, (ii) range of cement replacement with HRM, (iii) water-binder ratio, and (iv) use of admixtures with emphasis to high-range-water-reducing admixtures. Properties of hardened concrete should also be obtained to evaluate any changes in the hardened concrete properties.

Key Words

Concrete, cementitious material, pozzolan, durability, strength, workability.

Related Work

Based on the current state-of-the-art, the following observations can be made:

- HRM in powder form exhibits engineering properties that are comparable to, and in some cases, better than silica fume slurry.

- The optimum level of HRM is between 5 to 10 percent for portland cement formulation.

- Inclusion of HRM is not detrimental to air void system.

- Since the HRM reacts with free lime that is formed during the hydration, it reduces the adverse alkali effects.

- HRM improves the modulus of elasticity.

- It is possible to obtain a one-day strength of 5000 psi using HRM.

Urgency

HRM can be effectively used for the renovation and hence could become a very useful material for the infrastructure rehabilitation. The results of the research can be directly used for formulating the mixture proportions.

Cost

The estimated project duration is 15 months with a cost estimate of \$150,000.

User Community

State DOTs, FHWA, AASHTO, ACI, ASTM, PCA.

Implementation

The findings of this research may be used to provide highway engineers with data and information on providing high strength, high performance and impermeable concretes. These concretes can be used in the construction of durable transportation structures.

Effectiveness

Longer-lasting concrete structures can be built with greater savings.

PROBLEM 49: EFFECT OF VISCOSITY-ENHANCING ADMIXTURES ON ENGINEERING PROPERTIES AND DURABILITY OF CONCRETE

Viscosity-enhancing admixtures (VEAs) also known as anti-washout and anti-bleeding admixtures, are water-soluble polymers that modify rheological properties of cement paste concrete. They can be incorporated in mixtures intended for underwater placements, production of extremely workable and segregation free concrete, shotcreting with high sagging resistance, bleed-free cement grouts for filling post tension ducts, etc. Studies on these relatively new admixtures concentrate on their effects on workability and cohesiveness, but there is limited research on their effects on engineering properties and durability of concrete. VEAs are often incorporated with the HRWRs which have been reported to cause premature hardening or excessive set retardation.

Objectives

1. To evaluate potential incompatibilities of VEAs (polysaccharides) available on the U.S. market with commonly used HRWR in various cement grout classes.

2. To investigate the effect of VEA on the kinetics of cement hydration and porosity.

3. To evaluate the influence of VEA on important engineering properties, including strength development (compressive, splitting tensile, flexural and bonding to reinforcing bars), creep, and drying shrinkage, as well as on potential durability (chloride and oxygen diffusion, carbonation, frost and scaling resistance's, alkali silica reactivity, etc.).

Key Words

High-range water reducer, compatibility, polysaccharides, grout, kinetics, hydration, strength development, cohesiveness, washout, porosity.

Related Work

Research conducted for the U.S. Army Corps of Engineers provides data on the influence of VEAs on fresh concrete properties. Substantial information developed by Japanese construction companies is also available on the selection of VEAs and optimization of concrete mixtures for underwater construction and production of self-leveling concrete. The majority of the Japanese literature is done however using proprietary admixtures.

Urgency

The use of VEAs to enhance cohesiveness in cement grouts and concrete is relatively new in the U.S. Because of the lack of experience with such admixtures, user agencies require guidelines for selecting VEAs and other compatible additives. Information concerning the potential benefits and limitations of such admixtures are also needed to supplement data provided by admixture manufacturers.

Cost

Estimated cost over two years to review existing literature, identify compatible VEA-HRWR systems and evaluate their effects on mechanical properties and durability of various concrete classes is \$200,000.

User Community

AASHTO, FHWA, ASTM, PCA, ACI

Implementation

The results of the research can be developed into specifications. Guidelines can be compiled to provide recommendations on the proper selection of VEAs, their modes of addition, and potential advantages and limitations.

Effectiveness

The results of this study could highlight the benefits and limitations of VEAs so that best advantage can be attained from their rheological enhancing properties.

PROBLEM 50: SELF-CURING CONCRETE

Many failures in concrete construction can be traced to lack of proper curing of concrete. Curing affects both rate of strength gain and ultimate strength, durability of concrete, and most other properties. Specific procedures must be followed to achieve proper curing, especially under adverse placement conditions. Concrete which is less sensitive to curing procedures, but still able to meet specified strength and durability requirements, would be desirable.

Objectives

1. To evaluate the possibility of developing a "self curing" concrete.

2. To apply the self-curing technology to concretes under actual field conditions.

Key Words

Concrete, curing, strength, durability

Related Work

No related work is immediately obvious. A technology review in the area would be beneficial.

Urgency

Not immediately urgent, but has good long-term potential for avoidance of curing-related problems.

Cost

Estimated cost is \$300,000 over 3 years for pilot study.

User Community

AASHTO, NCHRP, FHWA

Implementation

The findings of the research may be used to provide highway engineers with options to specification of curing regimes which may be difficult to implement under adverse field conditions.

Effectiveness

Proper curing is the most important function which is often neglected and/or not properly done. Self-curing concrete would eliminate the problem and improve the strength and durability of the concrete. This would also save a considerable amount of money in the construction of transportation structures.

PROBLEM 51: APPLICATION OF INCINERATOR AND WASTE-TO-ENERGY ASHES

Large quantities of fly ashes from waste-to-energy plants are accumulated representing hazardous waste compilations.

Objective

Establish the chemical properties and uniformity of ashes from waste-to-energy plants. Based on test data, determine ranges in ash properties and the corresponding influences on strength and durability when used as a cementitious and stabilizing material in concrete pavements and in stabilized subbases.

Keywords

Fly ash, incinerator ash, waste-to-energy ashes, concrete strength properties, durability.

Related Work

Related work on fly ashes in concrete has been conducted by Federal Highway Administration, U.S. Environmental Protection Agency, and U.S. Bureau of Mines.

Urgency

Elimination of these materials through measures other than storage is of high priority because of the rise of heavy metals entering the ground water and the elimination of unsightly storage piles.

Cost

Based on 18 engineer and 24 technician months including office and laboratory supplies and support, the estimated cost is \$163,000.

User Community

NCAA, AASHTO, ASTM, FHWA, ACI, NRMCA.

Implementation

The investigation should provide data for a user specification suggesting implementation containing QC/QA, and standard operating procedures for the production and the use of fly ash as a cementitious material.

Effectiveness

The early resolution in the optimum usage of incinerator waste-to-energy ashes will help to resolve the present expansive land-fill problems and resolve a negative problem into a positive advantage.

PROBLEM 52: SILICA FUME RESEARCH NEEDS IN TRANSPORTATION

The use of silica fume concrete for bridge-deck overlays has become a widely accepted practice by many state highway agencies. Primarily due to its favorable effects on permeability and compressive strength and therefore durability. However, experience suggests that the use of silica fume in concrete may contribute to high shrinkage levels that can lead to deck cracking.

Objectives

1. To develop optimum mixture designs (including fiber modified), and combinations with other admixtures, such as fly ash and slag.
2. To carry out comprehensive testing for mechanical properties (compression, indirect tension, flexure, modulus of elasticity, heat signatures, creep, and fatigue).
3. To test for permeability (chloride permeability—rapid and long term).
4. To evaluate the bonding of silica fume overlays.
5. To determine the porosity.
6. To measure shrinkage (unrestrained and restrained drying shrinkage, plastic shrinkage).
7. To determine the effects of curing.
8. To conduct rapid freeze-thaw test.
9. To carry out cost analysis and optimization studies.

Keywords

Concrete, durability, mixture proportions, permeability, silica fume, strength and workability.

Related Work

1. In view of the fact that silica fume is a well-established, highly effective pozzolonic, supplementary cementitious material with a very wide coverage in several national and international conferences, workshops and journals, it would be sufficient to list the topics covered, which included the effect on i) physical properties of concrete: water remand and consistency, bleeding and segregation, air-entrainment, setting time, heat of hydration, and ii) mechanical properties of concrete: compressive, tensile and flexural strengths, curing, creep, plastic and drying shrinkage cracking, permeability, resistance to aggressive chemicals, alkali-aggregate reaction, durability, corrosion protection, abrasion resistance, frost resistance, and resistance to high temperature exposure.

2. The National Cooperative Highway Research Program has recently awarded a contract for a

comprehensive evaluation of the performance of silica fume concrete.

Urgency

The research is very timely and cost-effective because of the continued concerns regarding corrosion in reinforced and prestressed concrete and the identified characteristics of mineral admixtures to mitigate this problem, particularly silica fume. The implementation of the research findings in the transportation industry is evidenced by the current interest in using silica fume for a large segmental bridge in California. While silica fume concrete has already been used for bridge decks, there is still considerable potential for using it in the substructures. Also, the durability of highway and airport pavements will be considerably enhanced by silica fume.

Cost

The estimated cost is \$500,000 and the project would have a 3-year duration.

User Community

AASHTO, FHWA, ACI, TRB, PCA

Implementation

The results of this research would provide highway engineers with adequate information on the correct proportioning of silica fume in concrete. The silica fume concretes which are high strength, high performance and durable, would be used in the construction of transportation structures.

Effectiveness

The findings of the research will give confidence to the engineers in using the long term durable, high strength and high performance concrete in construction with significant savings.

PROBLEM 53: EVALUATING LATEX-MODIFICATION OF CONCRETE TO MITIGATE ALKALI-SILICA REACTIVITY

Most quality aggregates and portland cement can be combined into a concrete mixture to make a durable and long-lasting product. There are some locations, however, where silica aggregates and cement react as the concrete cures and produce expansive forces that cause premature failure of the concrete. Reducing

cement content and/or replacing aggregates, current solutions to this problem, are not always practical or economical. Alternate solutions to this problem are needed.

Objective

It is known that reducing moisture content will reduce the effectiveness of ASR in concrete. Since latex-modified concrete contains low water content initially, has reduced permeability to water in the hardened state, and increased tensile strength as well, it might prove a cost effective solution to this problem.

Research should examine the effects of two levels of latex, 10 percent and 15 percent latex solids/cement, in mixes with two cement factors. Other means of controlling ASR, such as through the incorporation of supplementary cementitious materials, will also be compared to that of latex. The latex should be styrene butadiene, normally used for bridge deck overlays.

Keywords

Latex-modified concrete, latex, durability, alkali-silica reactivity, reactive aggregates.

Related Work

None

Urgency

The destructive effects of ASR on the nation's concrete infrastructure are well documented. Cost-effective solutions to this problem will benefit the public by fewer and lower cost repairs, and less obstruction to traffic.

Cost

Estimated cost \$150,000 over a 2-year period.

User Community

ASTM, AASHTO, FHWA, and NIST.

Implementation

The findings of the research may be used to provide highway engineers needed methods for effectively using marginally reactive aggregates.

Effectiveness

Will facilitate the use of marginally reactive aggregates and save considerable amount of money and natural resources.

**PROBLEM 54: PREVENTION OF
CEMENT/ADMIXTURE INCOMPATIBILITY
PROBLEMS**

Certain combinations of portland cement and admixtures exhibit adverse mix properties when combined including: premature stiffening, anomalous setting behavior, rapid slump loss, "sticky" finishing, inability to maintain entrained air, and poor workability. Virtually every admixture used in PCC is subject to these incompatibility problems given the right combination of cement chemistry and other admixtures used in the mix. When these problems arise, the resulting PCC can have severe deficiencies in strength development and durability.

Objective

1. To investigate the chemical and physical properties of cement/admixture combinations which can result in compatibility problems.

2. To develop strategies to minimize or eliminate compatibility problems while still allowing the use of the same cement/admixture(s) combination(s).

Keywords

Admixtures, workability

Related Work

None

Urgency

There have been major changes in the methods used to manufacture portland cement during the last decade. High C₃S cements ground to upper limit of the specifications are common and their tendency to develop problems with admixtures has increased substantially. This problem is extremely important if we are to learn how to adjust procedures to fit modern materials and equipment.

Cost

\$200,000

User Community

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

Implementation

The results could be used to develop guidelines and specifications for the use of admixtures when workability and compatibility problems arise.

Effectiveness

Knowledge of how to minimize these problems would result in better quality concrete at a considerable savings of time and money.

A2F03 COMMITTEE ON MANAGEMENT OF QUALITY ASSURANCE

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

PROBLEM 55: MATERIAL ACCEPTANCE USING QUALITY-CONTROL TESTING VERIFIED BY AGENCY QUALITY ASSURANCE AND IAST

As transportation budgets tighten, agency inspection resources are reduced. This has resulted in more states using contractor QC tests for acceptance provided they are verified by the agency. Qualifying the verification process as agencies move ahead with performance based specifications is essential for success.

Objective

1. Identify key properties to be tested as part of a qualified QC/QA program. Also identify standardized test procedures for these key properties.

2. Identify and address key areas/concerns in a QA verification procedure. Such as:

- a. Time lag between contractor and agency testing.
- b. Inter-lab comparison procedures and calibrations when testing reheated samples.
- c. Validation of allowable differences between agency and contractor results.
- d. Number of agency verification tests required for both companion samples and audit samples taken at random.

3. Identify testing (operator and equipment) and inherent material variability associated with optimum conditions so specification limits for a given target mixture property can be established for incentive payments. Justification of incentives through ties with pavement performance should also be explored.

Related Work

While the SHRP Program (Level One SuperPave) has identified key properties relating to performance of asphalt mixtures, it lacks specific recommendations for a QC/QA program. An acceptance program using only state tests is straight forward but one utilizing contractor tests verified by the agency is not. Since many states have moved in this direction and set up their own QC/QA processes, this proposed research should draw from existing programs, address areas that need further development and develop a standardized approach to QC/QA under this concept. Data base information from existing programs should be used in the investigation.

Urgency

Critical decisions are already being made concerning starting levels and fiscal support for QC/QA programs. Considerable resources have been invested in developing existing programs. These investments must be considered in any recommendations made regarding development of a qualified QC/QA program.

Cost

The estimated cost is \$250,000 over 18 months.

PROBLEM 56: QUALITY CHARACTERISTICS OF PAVEMENTS FOR USE IN PERFORMANCE-RELATED SPECIFICATIONS

Performance-Related Specifications (PRS) require knowledge of and the ability to measure key quality characteristics of pavements that control performance and are under the control of the contractor. These quality characteristics include material properties and various other aspects of construction (i.e. dowel bar location). A true PRS cannot be developed until these quality characteristics can be identified and measured during construction.

Objective

Identify both material related properties and construction related aspects that can be used in QA specifications and are strongly related to pavement performance. Develop practical, rapid ways to measure these properties and aspects, preferable in situ, (or practical tests that correlate well with these key properties and aspects) for use in PRS. Flexible and rigid pavements and overlays must be included.

Related Work

There exists several past and on-going PRS developmental research projects. Researchers must become aware of these efforts and coordinate with the on-going projects.

Urgency

PRS development and implementation cannot proceed without knowledge of the key material properties and

construction aspects, and the ability to actually measure them in practice on a construction project. Achieving this capability is extremely urgent to PRS development. Current research does not adequately fund this objective.

Cost

The estimated cost is \$350,000 over 24 months.

PROBLEM 57: OPTIMAL ACCEPTANCE PROCEDURES FOR STATISTICAL CONSTRUCTION SPECIFICATIONS

Statistical acceptance procedures are currently used by approximately 75 percent of the states and their use appears to be growing. Whether the acceptance procedure leads to a simple pass/fail decision or an adjustment in contract price, the proper design of such plans is critical to their performance. Poorly conceived plans may range from being totally ineffective to impractically severe. The fact that both extremes have been found in published national standards indicates that these problems are not isolated cases but are fairly widespread. There is a need to clearly define the objectives of statistical specifications, determine those statistical procedures that best meet these objectives, prepare a number of illustrative examples, demonstrate their performance with properly constructed OC curves, and then widely publicize the findings.

Objectives

- Identify specific pitfalls and problem areas—i.e., examples that *don't* work—probably in a generic way.

- Identify successful approaches—there will often be more than one—and then determine which method is best in terms of appropriate measures and by using proper analytical procedures. Advantages and disadvantages should be discussed. For example, an attributes acceptance procedure may be less efficient than a variables procedure but may be necessitated because the population being sampled is distinctly non-normal, etc.

- This work should address the determination of performance related criteria, suitable statistical measures of quality, the method of defining acceptable and rejectable quality levels, factors influencing the optimal choice of lot sizes and sample sizes, risk analysis using OC curves, and should be applied to both pass/fail and pay-adjustment acceptance procedures.

Related Work

There are numerous publications available on highway quality assurance, not all of them valid. They will have to be reviewed with a discerning eye. An annotated bibliography might be useful.

Urgency

This research is extremely relevant considering the current NQI emphasis, the value of the highway infrastructure to which these procedures are applied, and the potential cost of making incorrect acceptance decisions.

Cost

The estimated cost is \$100,000 to 200,000 for a duration of 18 months to 2 years.

PROBLEM 58: FORECASTING LIFE-CYCLE COST OF QUALITY LEVELS

Several transportation agencies and constructors have implemented, or are implementing, Total Quality Management Systems. Many of these organizations have separate Quality Control/Quality Assurance (QC/QA) programs in place. As the federal, state, and local funds for transportation infrastructure continue to shrink, determining the cost-effectiveness of quality levels should be the first critical step in maximizing the return on the investment of scarce capital in transportation infrastructure.

Objective

The primary objective of this research will be to forecast the life-cycle cost of quality levels, which should take into account the cost of prevention, appraisal, correction, and failure.

Related Work

Many research projects on TQM or QC/QA are in progress; but we are not aware of any project in this area.

Urgency

Many transportation agencies are rushing to implement continuous quality improvement programs to increase their cost-effectiveness. Measuring the life-

cycle cost of quality is urgently needed to document the overall cost-effectiveness of these activities, and to prevent any potential errors in this rush.

Cost

The estimated cost is \$375,000 for 18 to 24 months.

PROBLEM 59: INCENTIVE/DISINCENTIVE SPECIFICATIONS RELATED TO PERFORMANCE SPECIFICATIONS

Many agencies have implemented specifications with incentives and/or disincentive for specific measured quality characteristics (some specs only include disincentives). What is the resulting consequence of these variety of specifications on future performance of the pavements if say, only one quality characteristic is included, if several quality characteristics are included, if only one quality characteristic is included? Also, what is the effect of the magnitude of the incentive/disincentive on performance? Is there a downside to incentives/disincentives on pavement construction projects? Note: It may be desirable to include both performance and costs in this study.

Objectives

- Determine the range of effects that incentive/disincentive specs (of a wide range of types) have on pavement performance.

- Determine how the magnitude of incentives/disincentives effects performance. Performance is defined by smoothness, friction, and physical distress (cracking, rutting, faulting, . . .).

Both flexible and rigid pavements are to be included.

Related Work

None addressing this specific statement. Related research underway by FHWA on Performance Related Specifications.

Urgency

Many agencies would like information on this topic so that they could improve on their QC/QA specs.

Cost

Approximately \$300,000 over 18 months.

PROBLEM 60: ECONOMIC ASSESSMENT OF LOT AND SUBLOT SIZES IN RELATION TO QC/QA SPECIFICATIONS

In the development of QC/QA specifications, state highway agencies (SHA's) arbitrarily identify a LOT as the amount of product that is to be judged acceptable or unacceptable on the basis of a sample composed of a stated number of test results. The LOT is also arbitrarily stratified into a number of SUBLOTS equal to the sample size to be selected from the LOT.

The number of samples usually remains constant for a LOT; however, there are times when the number of SUBLOTS or the size of the LOT change. Such conditions affect the statistical and economical risks to the contractor and SHA.

Objective

Identify a logical approach to the determination of the most appropriate LOT size and number of SUBLOTS for materials used in flexible and rigid pavement construction.

Related Work

FHWA recently awarded a contract focused on measurement and specification of quality. Part of this research activity involves an evaluation of the LOT size as it relates to quality; however, economical considerations are not specifically identified.

Urgency

Many SHA's include price incentive/disincentive approaches in their QC/QA specifications. The price adjustments are quite often confounded by the arbitrary changing of the LOT or SUBLOT size. For example, if the LOT size is made larger, the cost of rejecting the material or adjusting the pavement can have severe negative consequences on the contractor. If the LOT is reduced, the cost of testing may be more than the benefits provided. Current research does not specifically fund the objective identified.

Cost

The estimated cost is \$475,000 over 30 months.

PROBLEM 61: REDEFINING THE ROLE OF INDEPENDENT ASSURANCE SAMPLING AND TESTING IN A QUALITY CONTROL/QUALITY ASSURANCE SPECIFICATION

Independent assurance is the discrete monitoring of a project's sampling and testing by personnel not directly involved with the contract.

Many quality control/quality assurance specifications include sampling and testing by the contractor, inspection of the contractor's sampling and testing by the agency, and agency sampling and testing. The role of independent assurance sampling and testing has not been clearly defined.

Which samples and test should be monitored; contractor, agency or both? What rate of monitoring is necessary? Since two sets of tests are already being tested, is independent assurance overly redundant? With limited resources, what should independent assurance's emphasis be?

Objective

Define specific goals of a proper independent assurance program for a quality control/quality

assurance specification. Ideally this would include monitoring, sampling and testing rates which define who is the target of the inspection.

Related Work

None that the submitter is aware of at this time.

Urgency

Current specifications may not be providing the most value to the agency with the amount of resources being expended.

Cost

Approximately \$100,000 over 1 year.

A2F04 COMMITTEE ON CONSTRUCTION OF BRIDGES AND STRUCTURES

PROBLEM 62: CORROSION OF HIGH STRENGTH STEEL TENDONS IN PRESTRESSED CONCRETE BRIDGES

Corrosion of high strength steel tendons in prestressed concrete bridges can be a major problem unless precautions are taken to protect the tendons from corrosive environments. For some types of bridges corrosion protection is very costly, and the effectiveness of some methods which are currently being used has not been evaluated over long time periods.

Related Work

Recently, high strength non metallic fibers have been developed which can be incorporated with epoxy resins to create high strength corrosion proof reinforcing or prestressing elements. The composites may be manufactured as rods, fabric mats, braided rope or semi-rigid tendons. In addition to being corrosion proof, these materials are nonmagnetic. A wide variety of these materials have been successfully used as concrete reinforcing and prestressing tendons in Japan at a cost that is competitive with high strength steel.

Urgency

Research is needed to establish design parameters so that nonmetallic tendons may be used with domestic codes and specifications. Some of these parameters are prestress loss, transfer length, relaxation, effects of high and low temperatures and behavior at ultimate strength. In addition, anchorage systems used with these tendons need to be evaluated and improved.

PROBLEM 63: ECONOMICS OF MODERN TIMBER BRIDGES IN THE UNITED STATES

There is an abundance of misinformation regarding the economics of timber bridges in the United States, resulting in poor perceptions of timber bridges by decision makers. The economics should be based on initial cost, performance under traffic, maintenance, and life span. Claims for the best economy are made by various designs for timber bridges such as "T" beams, stressed decks, box beams, parallel chord truss with metal plated connections, "A" frame, and so on.

The problem is that no one can ascertain these claims. However, there are perceptions that many of these designs cannot compete with those with other materials, i.e., prestressed concrete, steel and

reinforced concrete, even for short spans in rural regions.

Facts regarding low initial cost, low maintenance, long life, satisfactory performance, ease of design and construction (for local economy) and so on, are difficult to obtain. Almost all designs claim theirs are the best! The question is then why cannot these compete with other types of bridges when contracts for construction are let. Most of the modern timber bridges built in recent years have been "demonstration" bridges that exclude bridges of other materials.

Objective

Research is needed to ascertain the economies of modern timber bridges, designed in accordance with AASHTO bridge specifications, to assist the decision makers in selecting a bridge material. The economics should include: design costs, initial construction costs, projected maintenance costs, and life-cycle costs compared to those of the bridges of other materials.

It is noted that determination for the life-cycle cost of any type of bridge will be one of the most difficult phases in this research.

Related Work

The Forest Product Laboratory (FPL), USDA Forest Service, and many universities including West Virginia University, Bucknell University, University of Maine, and Iowa State University, and others, under the auspices of the National Timber Bridge Initiative Program and FPL, are conducting research on timber bridges.

Urgency

It is urgent because there may be economical timber bridge designs that can help solve our nation's bridge replacement programs. Yet, no one seems to know which of these bridge designs are economical. Every researcher and agency claim their bridges are most economical. These claims must be evaluated by an independent party to arrive at the most economical timber bridge designs.

Cost

The estimated cost is \$60,000 over two years.

PROBLEM 64: DETERMINING CABLE BAND BOLT TENSIONS ON IN-SERVICE MAIN CABLE SYSTEMS (SUSPENSION BRIDGES)

A bridge owner's periodic maintenance plan for a suspension bridge crossing should include either retensioning the main cable band bolts, or ascertaining that they have sufficient bolt tensions. Creep or continued compaction of the main cable under service loads sometimes may lead to reduced tension in these bolts. Also, any wrapping wire maintenance such as rewinding adjacent to cable bands can lead to additional compaction of the main cable, further reduction in cable diameter, and consequently, loss of cable band bolt tension. This is particularly true when wrapping wire is applied under a tension that exceeds that of the original wrapping.

There are several techniques to accomplish the task of determining cable band bolt tensions available to bridge operators today. They range from simply removing the bolt and reinstalling it to a prescribed tension, to either applying a torque wrench or hydraulic bolt tensioning system to the bolt to measure the tension. In the case of removing bolts and resetting them to a specific tension on a one-by-one basis, this runs the risk of overstressing any existing bolt that may have been installed in an overtight state. The latter methods can be inaccurate if care is not taken in obtaining a reading the moment that the measurement in the bolt-to-nut interface is observed. Also, these methods are time consuming and labor intensive since repeated measurements at a single point are necessary to assure accuracy.

Objective

To develop an in-situ method of determining bolt tensions in cable bands, or improve on existing methodologies to obtain accuracies on the order of ± 3 percent to 5 percent without multiple measurement activities. This will result in significant cost savings over current methods.

Related Work

There are several suspension bridge owners that are either in the process of awarding construction contracts which include cable band bolt retensioning in their scope of work, or are in the planning stages. An assessment of methods utilized thus far and their success rate can be made at this time.

Urgency

Many of our nation's suspension bridges are 50+ years old and are prime candidates for rehabilitation/ retrofit work. It is expected that 10 to 20 suspension bridges

could undergo this type of cable work in the next few years with an estimated cost of \$5-10 million. Research into this area should occur in the next one to two years.

Cost

Cost will be difficult to estimate initially since it will depend on how much research and development costs will be shared with existing bolt tension equipment manufacturers and what must be independently supported. An estimate of \$150,000 is provided for the purposes of this research problem statement.

A synthesis of bolt tension methods that have been utilized on suspension bridges throughout the country should take three to six months. Research into new methods and materials may take one year with both advancing concurrently. A summary report would be issued in the early part of the second year.

PROBLEM 65: DEVELOPMENT OF A MULTI-SENSOR BRIDGE MONITORING SYSTEM

The Federal Highway Administration has estimated that of the approximately 578,000 bridges in this country, 136,000 are considered structurally deficient and another 103,000 are functionally obsolete. A tough task that faces the bridge engineer when inspecting a deficient structure is damage assessment, i.e., quantifying the effect of damage on the structural integrity, the overall performance and the load carrying capacity of the bridge. Cost-effective bridge rehabilitation makes it necessary to accurately and very early on identify the presence of damage and quantify its effect on the structural integrity of the bridge. There is a need to develop effective, reliable bridge monitoring systems that can be used to:

- Evaluate the effects of damages on the capacity and performance of the structure,
- Detect abnormal conditions during routine surveys,
- Assess the effectiveness of repairs and maintenance programs, and
- Check the performance compared with the design assumptions.

Objective

The development of a multi-sensor bridge monitoring system, with portable instrumentation, and capabilities for transmitting data off site. The research should address fundamental issues such as:

1. Development of the instrumentation,

2. The different types of sensors needed (e.g. strain, vibration, remote viewing, embedded sensors),
3. Signal acquisition, processing, analysis and display, and
4. Development of guidelines for data evaluation, and assessing the performance of the structure.

Related Work

Sensors are available, but actual integration in a system has not been accomplished.

Urgency

Bridges around the nation are showing deterioration and damage, with a large percentage of them being rated as deficient. The massive investment made in the nation's highway infrastructure over the past several decades is at risk from deterioration compounded by inadequate inspection and maintenance procedures. One of the most critical needs is the development of appropriate nondestructive evaluation technology to facilitate the assessment and rational prioritization of maintenance and repair. If a resident sensor system can improve bridge inspection and evaluation, the ramification could have enormous value as aging and deterioration of many highway bridges is recognized as one of the major problems facing structural engineers today.

Cost

The estimated cost is \$300,000 over 3 years.

PROBLEM 66: LIFE CYCLE COST-BASED ENGINEER'S ESTIMATES FOR BRIDGES

Consideration of life cycle cost is required by the 1991 ISTEA legislation. No broadly applicable methodology currently exists.

Objective

To develop a specific methodology to provide an objective and accurate estimate of life-cycle cost for bridge projects. The methodology should accommodate reconstruction and rehabilitation as well as new construction.

It is recognized that the application of the new life cycle cost methodology will have a substantive effect on the concept and design of bridge projects.

Following completion of this project, an ongoing review board should be established to modify the

methodology as real-world experience with its use is gained, and to make changes as required with the advent of new materials and technology, and the accumulation of new and more complete data.

Related Work

On December 15 and 16, 1993, FHWA sponsored a two-day program entitled "Life Cycle Cost Symposium" in Washington, D.C. This workshop was the landmark beginning of FHWA's efforts to comply with the life cycle cost provisions of ISTEA.

Urgency

The need for a balanced, well-supported, approach to life-cycle cost analysis is urgent. With no methodology in place, federal and state agencies, and special interest groups are approaching the problem from different angles: their positions on life-cycle cost analysis are hardening, and finding a solution acceptable to all groups involved becomes more difficult with the passing of time.

At the FHWA workshop in December 1993, the hope was raised that FHWA funding of bridges could be broadened (by Congress) to include maintenance—perhaps with a commensurate reduction in federal share of project funding. The research project contemplated here will propose two alternate methodologies—one assuming the status quo, and the other assuming an expansion in the ability of FHWA to fund maintenance. An analysis of the consequences of the two approaches will be provided, and should serve as an important basis for the Congressional debate likely to follow.

Cost

Total funding of at least \$100,000 is required, divided 40 percent in year one, and 60 percent in year two.

An initial report will be available for comment in one year. A detailed final report, including appendices with relevant data and parameters will follow at the end of the second year.

PROBLEM 67: NEW METHOD FOR CONNECTING FIELD SPLICES FOR BRIDGES

The fabrication and erection industry needs a simple method for field splicing rolled beams and welded plate girders. The method should not require shop assembly and should have a large degree of tolerance in its application. Two potential applications are envisioned:

Case 1: Field splicing at piers;

Case 2: Splicing within a span where shear and moment are present

Objective

A relatively simple mechanism could be developed that clamps to girder flanges and is anchored by means of wedges, eccentric cams or some other method. The clamps should then be tied together with very high strength strand, rods, plates or other. This should result in new field splicing fixtures and appropriate design criteria.

Related Work

None.

Urgency

Shop assembly and drilling of conventional field splice material is expensive. Field assembly and bolting is also expensive. Costs could be reduced considerably if during erection, girders could be picked and set directly on piers as opposed to having to hang one or both ends of a girder from field splices within the span. Subsequent to erection, the crew could then install the splicing fixture. Shop and field benefit could be substantial.

Cost

The estimated cost is \$50,000 over 1 year.

A2F05 COMMITTEE ON CONSTRUCTION MANAGEMENT

PROBLEM 68: MANAGEMENT OF PARTNERING EFFECTIVENESS

Partnering has been used widely in the transportation sector for the last three years. The partnering processes have evolved in various states in both length and content. It is appropriate, now that a history exists, to evaluate the effectiveness of partnering in meeting its intended objective.

Objective

Measure quantitatively and qualitatively the effectiveness of partnering across the U.S. in the transportation sector.

Related Work

None.

Urgency

Within 1 to 2 years.

Cost

The anticipated cost is \$150,000 over 1½ years.

PROBLEM 69: OPTIMUM DEPLOYMENT OF INSPECTION RESOURCES

Budget constraints and other mandates have limited the number of people that can be assigned to inspection duties. Supervisors must make difficult choices regarding how to deploy inspection resources in cases where it is not possible to cover all inspection needs with the available resources.

Objective

Develop a method for transportation construction agencies to prioritize their inspection needs so they can assign inspection resources in the best way. Also, the study should identify critical inspection tasks that must be provided; this will help managers maintain minimum resources in budget negotiations.

Related Work

None. Some past studies have attempted to identify appropriate staffing levels for construction projects. These have not been successfully applied in the past. Should be coordinated with NCHRP Project 10-39, Construction Testing and Inspection Levels. This project should extend Project 10-39.

Urgency

This study should be implemented as soon as possible. Transportation agencies are facing personnel constraints, but must maintain construction quality. Delays would result in suboptimum inspection on current construction projects.

Cost

The cost is anticipated to be \$200,000 over 24 months.

PROBLEM 70: THE IMPACT OF INSPECTION ON HIGHWAY CONSTRUCTION PROJECTS

Tremendous amounts of resources have traditionally been assigned to the inspection of highway construction projects. In recent years, there have been drastic reductions in the resources in transportation agencies to do inspection. Several other practices are being considered or implemented to compensate for this lack of resources. Little definitive data exists to evaluate the effect of these developments.

Objective

To evaluate the current practices in highway construction project inspection as to their impact on the success of projects. Basically, the concern is whether the inspection efforts for highway projects are effective.

Related Work

Many changes are being considered or implemented in the delivery processes for highway construction processes with more responsibilities being transferred from transportation agencies to other participants in the construction industry.

Urgency

All transportation agencies are under pressure to reduce personnel with many of these reductions being made in traditional inspection personnel functions. The concern is whether these reductions are too far and that the success of projects will decline.

Cost

The anticipated cost is \$200,000 for 2 years.

PROBLEM 71: BASELINE AND BENCHMARKING FOR CONSTRUCTION MANAGEMENT FUNCTIONS

As the concepts of TQM, downsizing, and outsourcing become more widely prevalent in the highway sector, a process will be needed to identify measures of process performance and standard to make change decisions.

Objective

1. To identify critical measures which provide an indication of relative performance.
2. To identify the relative performance for key elements of typical construction management processes.

Related Work

Initial concept study on one state's construction division to identify some baseline elements.

Urgency

Needed to address common needs to improve efficiency and effectiveness of construction management processes. This effort will support decisions on reorganization, outsourcing, down sizing, and TQM.

Cost

The estimated cost is \$250,000.

PROBLEM 72: THE ROLE OF CONSTRUCTION MANAGEMENT FOR DESIGN-BUILD PROJECTS

The use of design-build in the construction industry is gaining increased interest due to the need for more

efficient use of project funds. However, many members of our industry have been reluctant to consider design-build because there is a lack of trust between the owner and the contractor in completing a quality project.

Design-build places sole responsibility for design, schedule, quality, and cost on one entity—the design-builder. Scope, budget, and schedule are established and agreed upon up front before major owner expenditures or investment. This single responsibility concept is the most popular reason for considering the design-build method of project delivery. Design-build provides for early guarantee of cost, a single contract to manage, a possible faster delivery of the end product, and team continuity. Design-build can run the risk of a reduced owner role in the A/E selection, loss of control of the project, and potential compromising of project quality.

Design-build projects will increase, and the industry must be prepared to accept that fact. The role of a construction manager may facilitate acceptance of design-build by becoming the owner's on-site representative, and can assure the owner of a quality product.

Objective

Research is proposed in two parts. Part I would be a paper search of the history of design-build projects both nationally and internationally, and classifying design-build projects by size, complexity, and by those that used a construction manager and those that did not. An analysis of the outcome and effectiveness of the design-build approach would be conducted, particularly as a comparison between the use of a construction manager versus the absence of construction management on the design-build project. Part II would focus on future design-build projects. Utilization of a construction manager on certain projects and a comparative analysis with other projects that did not use a construction manager would be conducted. The criteria of analysis for effectiveness of a construction manager on design-build would be based on Part I conclusions.

Related Work

The results of this study will help establish a higher confidence level in using design-build for transportation projects. The role of a construction manager as the owner's eyes and ears to assure an acceptable end product will be tested. It will also provide opportunities for reviewing and analyzing performance-based specifications of the owner in a design-build delivery system.

Cost

Cost to be determined. Schedule: Part I – 1 year; Part II – 4 years.

PROBLEM 73: ASSESSMENT OF SENSOR TECHNOLOGIES TO QC/QA OF CONSTRUCTION OPERATIONS

DOTs devote considerable energies to documenting important attributes of the construction process. Contractors expend similar energies to quality control. Automated real-time data acquisition using sensor technologies has the potential for improving the QC process while corrective action can be taken and provided a permanent electronic record of important QA attributes.

Objectives

The objectives are as follows:

- To identify potential construction applications of sensor technologies to QC/QA.

- To recommend appropriate sensors.

- To conceptually design the system where appropriate.

Related Work

A system for the automated feedback of compaction operations has been developed and another for monitoring pile driving operations is under development. Both systems have originated from Penn State.

Urgency

This research is important to identify targeted development operations. Development of systems will greatly support reconstruction of highway infrastructure facilities.

Cost

\$200,000.

A2F06 COMMITTEE ON CONSTRUCTION EQUIPMENT

PROBLEM 74: THE IMPACT OF "SPECIFICATIONS" ON THE SELECTION OF CONSTRUCTION EQUIPMENT AND METHODS

Construction specifications can be written so an end result is specified, or so a method is specified. For equipment intensive operations, method specifications can be problematic. When an equipment type is specified, the opportunity for contractors and equipment manufacturers to innovate is limited. If the specification is outdated, transportation agencies do not benefit by having the latest equipment and methods on their jobs. However, there may be some circumstances where it is desirable to use a method specification because the owner would benefit by retaining control over the equipment and methods used. It is not clear when end result specifications should be used and when method specifications should be used. The cost of misusing these specifications has never been quantified.

Objective

To perform a systematic review of specifications that influence the selection of construction equipment and to identify situations where end result specifications are appropriate and where recipe specifications are

appropriate. Researchers should identify good examples of the use of each type of specification and quantify the cost of using the wrong type of specification.

Related Work

Current activities have focused on materials specifications. End result specifications have also been developed for certain aspects of paving and grading. Current activities are incomplete.

Urgency

The study should be launched as soon as possible. Misused specifications have the potential to stifle innovations in construction equipment and construction methods. This increases the costs of capital programs for transportation agencies.

Cost

The estimated cost is \$250,000 over 24 months.

A2F07 COMMITTEE ON FABRICATION AND INSPECTION OF METAL STRUCTURES

PROBLEM 75: THE PRELIMINARY INVESTIGATION AND RECOMMENDATION OF NEW STEEL/FIBER REINFORCED PLASTIC HYBRIDS

Steel is a well known and reasonably well understood material for the construction of highway, rail and transit bridges. Steel is both strong and stiff enough for economical use in transportation structures. Fiber reinforced plastics (FRP) represent a relative new comer to the bridge industry that offers strengths equal to or greater than steel. The current draw back of these FRP/composite materials in bridge construction is their relatively low modulus and related live load deflection problems. Currently these two materials are fighting each other for their respective market shares.

Objective

The objective of this research is to evaluate the feasibility of combining available FRP's with steel, in a new or old structural shape or form that results in a *new hybrid*. The shape and form of this new hybrid is currently unknown. The possibilities are endless. The outcome of this initial work would be a recommendation for a better defined research program.

Related Work

1. None known for the new *hybrid/ composite*.

2. Significant independent research activities in steel, reinforced and pre/post-tensioned concrete and FRP's.

Urgency

This research is purely economics driven. There are funds being invested on all sides trying to improve the economics (market share) of various products individually. Recognizing the strengths, weaknesses and real costs of the individual products, is an economical hybrid that combines the best of each material to provide an economical, strong, durable bridge, a more cost effective solution than solutions based upon a unique material.

Cost

An initial estimate of \$45,000 is offered for one year of research. Many individuals are experts in various fields. Initially this research needs to be conducted by an individual with an understanding of all the materials in addition to their use in bridge structures. At this time, an investigation and report developed by a single individual outlining the possibilities is more appropriate than forcing a solution(s) with a large committee.

A2F09 COMMITTEE ON APPLICATIONS OF EMERGING TECHNOLOGY

PROBLEM 76: APPLICATION OF BIOTECHNOLOGY TO ROADWAY LANDSCAPING

Landscape maintenance requires excessive resources in terms of water, fertilizer, pesticide, and manual labor when compared to other maintenance categories.

Objective

Update the design and construction of roadway landscapes by using genetic engineering to develop "designer plants" which would have the following characteristics:

- A nitrogen-fixing bacteria to lessen or eliminate dependence on chemical fertilizer.
- A xerophytic nature to reduce the need for water.
- A natural resistance to pests.
- A growth habit which would greatly lessen the need for pruning or mowing.

The research would be expensive and would be done in stages with application and benefits at each stage. Implementation of each stage would save millions of dollars in materials and payroll, as well as provide environmental benefits.

Key Words

Genetic engineering, gene manipulation, biogenetics.

Related Work

Most of the work done to date is in the field of agriculture. One of the most publicized products is the tomato that does not spoil.

Urgency

The suggested research has the potential to free up a large portion of landscape maintenance funds for other purposes. In view of the demands on resources, this process should occur as soon as possible.

Cost

The estimated cost of the initial stage of feasibility investigation including laboratory and limited field studies is \$500,000.

User Community

AASHTO, FHWA and other transportation agencies.

PROBLEM 77: INTEGRATING REAL TIME CONSTRUCTION SITE DATA WITH MULTIMEDIA DATABASE MANAGERS

In recent years, a variety of nondestructive sensing technologies have been introduced to the construction site. Most of these sensing modes produce either rasterized image (weld x-rays), a time series of rasterized images (pavement images), or a time series of analog values (pavement profile). Many of these sensing technologies are used in isolation of each other and do not employ any structured archiving methodologies. This makes it extremely difficult to integrate (and fuse) diverse data. This lack of archiving organization precludes the on-line storage and use of data during the post construction facility operation and maintenance.

Objective

In the past, it has been shown that conventional relational database management systems (dbms) can be used to archive data such as bridge sections and member connectivity. However, subjective sensor data such as rasterized images could not be integrated. This research will investigate the feasibility of incorporating this information into an "as built" model using a multimedia database management system. This research will also investigate storage requirements, media (magneto optical disk, CD-ROMs, WORMS), economic feasibility, and computing demands. A prototype system modeling an example transportation facility will be constructed.

Urgency

As states demand more and more acceptance testing and as-built documentation, this technology will become instrumental.

Cost

\$90,000.

A2J01 COMMITTEE ON CEMENTITIOUS STABILIZATION

PROBLEM 78: SULFATE INDUCED HEAVE PROBLEMS—IDENTIFICATION AND CONTROL

When the stabilizers most used in clay soils, lime, portland cement and fly ash, are applied to materials with sufficient soluble sulfates in them, a three dimensional heave can occur causing pavement systems to deflect, heave and buckle. Although measurement of soluble sulfates is not new or unusual, the methodology to be used has not been standardized and the result is variations in amounts of sulfates reported. In addition, the frequency of sampling for sulfates testing is often far too small, causing materials containing significant soluble sulfates to be overlooked, or to be the only ones sampled. To deal with the problem of the amount of sulfates present, which is believed to be highly variant, better sampling programs must be investigated and testing be standardized.

Using certain stabilization construction techniques, which include double applications, of lime in particular, and/or the use of additives, sulfate induced heave in clays with low and, in some cases, moderate levels of soluble sulfates has been controlled. Yet, the field measures used to date are largely undocumented in reports. In addition, those clays with high levels of soluble sulfates have not been successfully stabilized or controlled. There is a need to further develop possible construction procedures, agent applications and other stabilizing methodologies to control sulfate induced heave and to test these in full scale field trials.

Objectives

To establish a standard method of measurement of soluble sulfates and a frequency of sampling subgrades to accurately identify the nature of the sulfate heave problem which may occur. To identify stabilizing methodologies, construction techniques and possible agents which can be used to control sulfate induced heave. To verify the applicability of the methods, techniques and agents utilizing full scale field test sections.

Key Words

Sulfates, clays, stabilization, heave, subgrades, lime, portland cement, fly ash.

Related Work

A good deal of work has been done on identifying a standard 1-part soil to 10-parts water extraction method for measurement of soluble sulfates, which is believed to indicate well the potential for a heave problem. Low sulfate amounts are believed to be below 0.5 percent or 5,000 ppm. Moderate amounts range to 1.0 percent or 10,000 ppm and high sulfates contents are believed to be over 1.0 percent. The frequency of testing as indicated by research to date may be at least one test every 50 lineal feet of roadway.

Stabilizing methods, techniques and agents have been researched mainly in the laboratory using a three dimensional swell test to simulate field situations. Some correlations of sulfate test and laboratory swell test results to field behavior have been done. A limited number of alternative methods, techniques and agents have been laboratory tested and applied in limited field trials. The success in the laboratory and field has been mixed.

Urgency

This research is of highest priority because of the relatively large damage which has been done to roadway pavement systems and which will occur. The documented damage, alone, which has caused removal and/or complete rebuilding of pavement systems amounts to several millions of dollars. The amount of damage expected without control of this phenomenon far outweighs the estimated expenditures for research.

Cost

The estimate to conduct the research exclusive of building test sections is approximately \$500,000. The estimated time to complete this research is two to three years.

User Community

AASHTO, FHWA

Implementation

Standardized sampling and testing to identify potential sulfate induced heave and methodologies, techniques and agents to control the problem where it exists.

Effectiveness

If this research is completed it can mean practical control of sulfate induced heave in treated clays.

PROBLEM 79: RESILIENT MODULUS TESTING PROTOCOL FOR CEMENTITIOUS STABILIZED BASE AND SUBBASE MATERIALS FOR PAVEMENT CONSTRUCTION

Resilient modulus (M_1) is currently the fundamental parameter used in the mechanistic analysis and design of pavements by the American Association of State Highway and Transportation Officials (AASHTO) as well as the National Association of Australian State Road Authorities (Austroads). Several types of dynamic testing devices have been developed and calibrated to measure the resilient modulus using either indirect tensile or direct compressive stresses. The repeated triaxial compression device is the most popular of all the equipment used because it combines reliability and repeatability with ease of operation. A range of test procedures and guidelines have recently been developed, both in the US and in Australia, that can be used to measure the resilient moduli of asphaltic concrete and unbound materials. However, no generally accepted method has yet been established for cementitious stabilized materials.

Objective

The basic objective of this research is to develop a laboratory testing procedure that will accurately and reliably evaluate the resilient modulus of cementitious-stabilized materials. Such a methodology must also combine simplicity with high repeatability of the results. This will involve the investigation of the effect of the loading parameters: loading configuration, waveform type, frequency and periodicity, the effect of confining pressure, the establishment of the number of conditioning cycles sufficient for repeatable results, deformation/displacement measurement technologies, and appropriate stress levels. In addition, specimen size, the effect of specimen preparation procedures, curing conditions, specimen conditioning, and curing period, will have to be investigated.

Key Words

Cementitious, waveform, confining pressure, conditioning, stress levels, sample preparation, curing.

Related Work

Test protocols for resilient modulus are being developed for asphaltic concrete and unbound

materials by the American Society for Testing Materials and the Strategic Highway Research Program in the U.S. and by the Standards Association of Australia. Evaluation of resilient modulus of various cemented materials has been and remains a primary concern of most highway material research groups.

Urgency

The results of this research will allow the accurate and reliable determination of the resilient modulus of cementitious stabilized materials. It will:

- Improve predictive capabilities;
- Improve understanding of short and long term behavior; and
- Allow better correlation with field performance.

This will expedite the large scale utilization of cementitious stabilized materials in pavement construction. Given the increasing shortages of the conventional materials used in roadway construction today, the capability to use cementitious stabilized residual materials is of economic benefit. It is necessary to have testing protocols to demonstrate such materials have adequate strength, and durability.

Cost

Approximately \$500,000 over a 3-year period.

User Community

AASHTO, FHWA, ASTM, state DOT's, highway construction and maintenance industry, research institutes and universities.

Implementation

Standardized testing of resilient modulus of cementitious stabilized materials. Use of research results in AASHTO pavement design and rehabilitation.

Effectiveness

If the highway construction industry permits the replacement of conventional base and subbase materials with cement stabilized residual materials, then the economic benefits can be enormous. These benefits will result from:

- Utilization rather than disposal of residuals;
- Conservation of high quality conventional material; and

■Possible reduction of in-place cost of base or subbase.

PROBLEM 80: TESTING PROTOCOLS AND MIX DESIGN PROCEDURES FOR FLOWABLE FILL

Flowable fill is rapidly emerging as a new and highly useful geomaterial. Nonavailability of a standard testing protocol and mix design approach have been major concerns for the users of this material. In order for experience to be shared most effectively, testing evaluation should adhere to elements of a standard protocol. In addition, proportioning the mix components can be achieved through a rational and logical mix design procedure, as opposed to a trial and error procedure.

Objective

Engineers and contractors need the technical support of well defined material testing protocols and simple logical methods of selecting material components and their proportions. This can be achieved through refinement and validation of testing procedures, on a variety of materials, at one of the existing centers for flowable fill research. The testing validation should include representative samples of many candidate materials, and their mixtures, for flowable fills. Mix design procedure presently exists for limited material populations. These should be expanded to more general application and be verified by testing.

Related Work

1. Research in Progress: Laboratory study has been relatively limited in both universities and Departments of Transportation. Purdue University has been a center for research.

2. Nature of Research: The potential for using non-marketable constituents such as Class F fly ash, spent foundry sands, coal combustion bottom ash, and the like, has been recognized and is being studied. Ready mix concrete suppliers are becoming more interested in marketing the product.

Urgency

Flowable fill is a very versatile material, and its use in highway applications can be expected to increase dramatically in the immediate future, because of several advantages associated with the use of this material, in comparison with compacted soil. Engineers and contractors have an important need for the information to be generated.

Cost

The testing, evaluation of results, and writing of standards and procedures can be accomplished in 2 years at a cost of \$100,000.

A2J02 COMMITTEE ON CHEMICAL AND MECHANICAL STABILIZATION

PROBLEM 81: STABILIZATION OF VOLATILE ORGANIC COMPOUNDS WHICH ARE RESIDUALS OF CERTAIN USED SOLVENTS

Millions of asphaltic concrete extraction tests have been conducted using solvents such as carbon tetrachloride and/or 1, 1, 1-trichloroethane. For years, the residuals of such tests were "thrown out the door" or disposed of in some similar fashion. The by-products from such disposal have leaked into the ground water systems and are today evident, in varying degrees. They came to be found in the forms (among others) of 1, 1-dichloroethane; 1, 2-dichloroethane; 1, 1 dichloroethene and 1, 1, 2-trichloroethane. The EPA has placed many of these residuals on the hazardous waste list and declared many of them as carcinogenic. Currently, no economical method exists for stabilizing (or otherwise tying-up) these volatile organic compounds (VOC's). The threat to health can only be guessed as these residuals work their way into the drinking water systems via migration to wells.

Objective

The objective is to find some way to stabilize or bind-up the loose VOC's and obtain a resultant non-hazardous product.

Key Words

Carbon tetrachloride, trichloroethylene, trichloroethane, solvents, dry cleaning fluids, grease solvents, stabilization, volatile organic compounds.

Related Work

Florida State University was reported to have been working on this problem in the recent past with the concept not unlike the process of enzyme stabilization.

Urgency

The State of Florida has already invested more than ten million dollars trying to clean up one small borrow-pit where spent solvent has intruded the surficial ground water table. Other sites are sure to exist. The cost of clean up by known methods could be exceedingly high. If no action is taken, the effects on environment and health of the general public could be

even more costly and disastrous. Therefore, priority of research on this issue is extremely high.

Cost

Estimated cost is \$150,000 over three years.

User Community

Anyone who has run a large number of asphalt extraction tests (most state DOT's) should have a significant interest in this research. This would also impact universities teaching civil engineering, counties and cities and commercial testing laboratories. Auto service stations and dry cleaning establishments also generate large quantities of such used solvents. Finally, the EPA and all state counterparts to EPA should have a great interest in this project.

Implementation

Place stabilization procedure in the care of EPA and FHWA. Those agencies will distribute the procedures to the states who, in turn, can make it available to the counties, cities and testing labs.

Effectiveness

If economical stabilization procedures are developed, the effectiveness will match that of the introduction of Coca-Cola.

PROBLEM 82: UTILIZATION OF BY-PRODUCT GYPSUM FOR HIGHWAY CONSTRUCTION

The sustainable utilization of materials for highway construction purposes requires effective use of both naturally-occurring and industrial residual materials. Whereas naturally-occurring materials such as crushed stone, sand and gravel have been the target of extensive research efforts (largely sponsored with state and federal funds), research directed at the use of industrial residual materials for construction purposes has been comparatively limited. One of the largest potential sources of industrial residuals is by-product gypsum produced by a variety of industries (e.g. phosphoric acid, hydrofluoric acid and titanium production). In addition, vast amounts of by-product

gypsum are being produced by coal-burning power plants from the wet scrubbing of stack gases. There has been some success with ad hoc uses of such materials, but traditional methods of evaluation are both unsuitable and unreliable for such by-products because they depend largely on empirical correlations developed for "traditional" materials such as crushed stone. However, crushed stone materials are becoming increasingly costly. Thus, if a proper match can be found between material needs for highway construction and maintenance and the availability of low cost industrial residuals, both the highway construction community and the industrial section will benefit economically and environmentally.

Objective

The basic objective of the research is to develop the necessary methodology for the technically acceptable, economically viable, and environmentally acceptable uses of by-product gypsum for routine highway construction and maintenance. This will involve investigations of the improvement of engineering properties of residual materials, evaluation of potential environmental problems and assessment of economic values.

Key Words

Industrial residuals, reuse, recycling, sustainable development.

Related Work

Relatively substantial uncoordinated research efforts related to the utilization of by-product gypsum for a variety of construction applications in the U.S. have been conducted by:

- Phosphate Research Institute, University of Miami;
- Florida Institute for Phosphate Research (FIPR);
- Florida Department of Transportation;
- Texas A& M University;
- Texas Department of Transportation
- Institute for Recyclable Materials (IRM), Louisiana State University.

Presently, the principal research efforts are at FIPR, Texas A&M, and IRM. These efforts are primarily directed at the utilization of by-product gypsum for highway base construction. For this purpose, the by-product gypsum is generally stabilized with some combination of cement, fly ash and sand.

Urgency

Supplies of naturally-occurring construction materials are being depleted and are being subjected to increasingly stringent environmental regulation. Both factors have and will continue to result in increases in cost. Alternative materials, whether low quality natural materials or industrial residuals, need to be investigated to serve as replacements for the higher quality, higher cost materials currently in use. In addition, the disposal of industrial residuals is a major problem and viable, large volume uses of such materials would be of substantial benefit to industry, the highway community, and society in general. Delaying significant research efforts directed at utilization of alternative materials until a crisis exists will be unproductive and not cost effective. Research that will increase the rate of introduction of alternative materials for highway construction will result in a better utilization of scarce resources.

Cost

\$5 million over a 5 to 10 year period. However, as with traditional materials, a continuing research program must be maintained.

User Community

AASHTO, FHWA, ASTM, state DOT's, Highway Construction and Maintenance Industry Research Institute/Centers, universities.

Implementation

Research findings should be implemented through the use of demonstration projects with a research agency working in cooperation with a state DOT. Tentative design methods, material specifications, and construction specifications can be developed by research agencies in cooperation with state DOTs and modified on the basis of experience.

Effectiveness

If the public perceives that utilization of by-product gypsum for highway construction poses an acceptable environmental risk, the societal impact will be seen as very positive; i.e., converting (recycling) what is now considered a waste material into a usable product. Rather than stacks of waste materials, secondary products can be generated that may help to reduce the cost of highway construction and maintenance as well

as reduce the environmental degradation associated with the mining and production of natural materials.

PROBLEM 83: LOW-VOLUME ROAD PERFORMANCE ENHANCEMENT STRATEGIES USING STABILIZATION ADDITIVES

Deterioration of secondary or "farm to market" roads across the country is a critical problem for local government. In most cases, increased traffic volumes and axle loads have overloaded existing base and subgrade materials that support the wearing surface. These low-volume roads are prone to more severe rutting, cracking, and disintegration than has historically been the case. Premature break-up of a low-volume road wearing surface is often caused by base and subgrade failures. Since routine resurfacing does little to solve the base or subgrade deficiencies, reconstruction costs to successfully repair these roads continue to increase. Many local governments can no longer satisfactorily maintain their low-volume road system because of the increased frequency and extent of high-cost rehabilitation actions.

Objective

The objectives of the research are two-fold: (a) quantify the physical, chemical and mechanical benefits derived from Full Depth Reclamation of base and subbase materials using various chemical stabilization agents to increase density and load bearing capacity of secondary roads, and (b) develop a rational evaluation procedure to quantify the engineering properties of the stabilized materials for inclusion in both AASHTO and mechanistic low-volume road design procedures.

Key Words

Chemical stabilization agent, full-depth reclamation, base material, subbase material, structural coefficient.

Related Work

Full-depth reclamation has been successfully used by a large number of local and state transportation agencies. The process using a site-specific chemical stabilization agent is rapidly gaining acceptance across the country. Maine, Massachusetts, New Hampshire, New York and Vermont have specified the use of calcium chloride in Full Depth Reclamation projects.

Other chemical stabilizers such as lime, fly ash, lime/fly ash mixtures, soil cement, sodium chloride and asphalt emulsions have also been successfully used in full-depth reclamation.

A major difficulty in using the current AASHTO Pavement Design Guide is the absence of reliable structural coefficients, which are required for the empirical thickness design models, for chemically-treated base and subbase materials.

Urgency

There is an absence of fundamental engineering properties of chemically stabilized base and subgrade materials that can be used for rational low-volume road design. The demand from state and local agencies for appropriate testing and evaluation methods as well as for current data is growing because of the need for longer life cycles and better performance of their highway system.

Cost

Estimated cost of laboratory baseline study is \$350,000 and the field evaluation is \$400,000 (total \$750,000) over a five-year period.

User Community

State and local agencies.

Implementation

Results of this research can be used by state and local agencies and modified on the basis of experience.

Effectiveness

The effectiveness of chemical additives for base stabilization has been documented in several recent TRB publications. Two papers specifically relating to successful chloride stabilization case studies are, "Liquid Calcium Chloride for Dust Control and Base Stabilization of Unpaved Road Systems" by H. Kirchner and J. Gall, Transportation Research Record 1291 (1991) and "Full-Depth Reclamation of Asphalt Roads with Liquid Calcium Chloride" by J. Pickett, Transportation Research Record 1291 (1991).

A2J03 COMMITTEE ON MINERAL AGGREGATES

PROBLEM 84: EVALUATION OF THE EFFECTS OF AGGREGATE FINES ON THE PERFORMANCE OF HOT MIX ASPHALT CONCRETE

The importance of rheology in performance of asphalt binders has been clearly defined in the SHRP research program. Indeed, the most prominent part of the SHRP asphalt research program to date is the performance grade binder specifications which are being used widely. These binder specifications grade binder performance based on Dynamic Shear Rheometer (DSR) properties at high and intermediate pavement temperatures, bending compliance properties and direct tensile properties at low pavement temperatures and viscosity properties at very high temperatures (simulating mixing and placement temperatures). The new SHRP performance grade specifications certainly improve our ability to select and specify binders based on fundamental material and engineering properties. However, the effect of the aggregate-binder interaction is not considered. The interaction between the binder and the mineral dust or minus 0.074 mm aggregate fraction (minus 200 sieve size material) is of particular importance.

Goodrich in two classic AAPT papers in 1988 and 1991 illustrated the importance of considering the interaction between asphalt and fine aggregate on rheological performance of the mastic. Goodrich showed that the aggregate effect must be considered over the full range of temperatures. He showed that the aggregate influence lowers the glass transition temperature by 10°C or more and that the aggregate effect is even more pronounced over the higher range of temperatures (i.e., between 0 and 60°C).

With extended use of the new SHRP binder specifications, it is imperative that we now evaluate the effect of binder-mineral dust interaction and binder-fine aggregate interaction in general on the performance of asphalt mixtures. For the first time, tools are now available and affordable to perform such research on a wide scale basis.

Objectives

- Evaluate the effects on various mineral fillers or dust-asphalt binder interactions on rheological properties (especially those identified by SHRP for performance grade specification). Mineral fines from a specific geographical region should be paired with typically used binders from the same region.

- Extend the evaluation of the effects of asphalt-mineral filler interaction to mixture testing and performance prediction based on selected asphalt-

aggregate combinations as identified in the screening (rheological) test phase. The mixture evaluation should be based on SHRP level 3 mixture testing and should use the Superpave™ performance models to predict performance.

- Extend the study to evaluate the effects of fine aggregate (smaller than 2 mm, approximately that passing the No. 10 sieve size) as warranted by rheology testing in the screening rheology tests.

Related Work

The development of the SHRP binder test protocol, the SHRP performance grade specifications, the SHRP mixture test (for permanent deformation, fatigue, and low temperature fracture) provide the tools to effectively and efficiently evaluate the effect of a factorial combination of asphalt binders and aggregate mineralogies and size distributions on mastic rheology and mixture performance. Furthermore, recent developments have made it possible to effectively and efficiently determine the size distribution and particle shape distribution of very fine aggregate fractions such as mineral filler. This can be effectively done using the Particle Size Analyzer which is affordable and available.

Urgency

The availability of analytical equipment, test protocols and performance modeling procedures have made it possible, for the first time to effectively and efficiently investigate the effects of asphalt-fine aggregate interaction on asphalt mixture performance. The study is critical because the development of the SHRP test protocol did not consider the effects of aggregate to the extent necessary for appropriate mixture design and analysis. This needs to be done aggressively. The study of the effects of asphalt-fine aggregate interaction using an extensive matrix of binders and fine aggregates is imperative.

Cost

The cost of such a study is reasonable based on the availability of test equipment and the confidence in the testing protocols due to the SHRP experience. A reasonable test program could be accomplished in 12 months for \$100,000.

PROBLEM 85: INCREASED USE OF FINES IN PORTLAND CEMENT CONCRETE

The recommended gradation for fine aggregates limits the amount of fine particles which can be used in portland cement concrete. The reasons for the limitations are that more water and more cement are required, the mix design may be uneconomical, and, particularly for natural sands the fines are often clay which increases water demand and may cause expansion. As a result, by-product fines have become waste materials. As aggregate sources dwindle near urban areas, development of new sources is increasingly difficult and transportation of aggregates becomes more expensive. Increasing the amount of fines in concrete should be carefully investigated with the objectives of using aggregates more efficiently and decreasing aggregate costs, while producing concrete of equal or better performance.

Objectives

The objectives are:

1. To determine the types and amounts of fines currently available which are suitable for use in concrete.
2. To review previous research on the use of fines in concrete.
3. To develop mix designs for the most common types of fines available.
4. To determine the fresh concrete properties and the mechanical and durability properties of concrete as a function of the amount and type of fines.
5. To recommend changes in specifications to permit greater amounts of fines to be used which will result in concrete of equal or better performance as concrete without fines.

6. To determine the cost of fines concrete in place relative to concrete without additional fines.

Related Work

In 1985 Malhotra and Carette reported on the use of limestone dust (96 percent passed a No. 200) as a partial replacement for fine aggregate. Water-cement (W/C) ratios of 0.40 to 0.70 and sand replacements of 5 to 20 percent were used. For a w/c ratio of 0.40 there was a 10 percent loss in compressive strength for a replacement of 10 percent. No significant reduction in properties occurred for w/c = 0.53 and a replacement of 5 percent. Other research has shown similar findings. With advancements in admixtures, it is likely that concrete can be proportioned using fines which will exhibit very good properties.

Current research at the Center for Aggregate Research, Austin, Texas, is focused on potential uses of by-product fines. However, the work does not overlap the proposed objectives. There is no other known research in progress at this time.

Urgency

With proper selection of materials and careful mix design, there is a good potential for producing quality concrete at equal or less cost. The use of more fines would conserve diminishing aggregate resources and, at the same time, would eliminate a by-product material which has little current use which increases production costs ultimately passed on to the user.

Cost

The cost of this study is estimated at \$500,000 over a 3-year period.

A2K01 COMMITTEE ON SOILS AND ROCK INSTRUMENTATION

PROBLEM 86: METHODS TO ASSESS COSTS-BENEFITS OF INSTRUMENTATION IN DESIGN AND CONSTRUCTION

Current design methods for roadways and related facilities contain no way to incorporate the benefits of instrumentation into the design process. Although results from instrumentation can considerably reduce the uncertainty in a design and help avoid failures, most codes of practice do not provide a way to incorporate this benefit into the design. Consequently, instrumentation is usually perceived as an unnecessary add-on to the project cost. Unable to quantify the true benefits of instrumentation to the project, many instrumentation programs become severely curtailed, poorly implemented, or entirely eliminated.

Methods exist to quantify the benefits of reduced uncertainty gained from instrumentation programs. However there is not a direct linkage between these methods and the commonly used design procedures that are based on a factor of safety approach.

Objective

This research will develop a method, or methods, to obtain reduction factors to be applied to design factors of safety that allow for the benefits of using instrumentation. The method, to be based on uncertainty analysis, will allow design engineers to quantify the reduced costs that can result from lower factors of safety permitted when a project utilizes instrumentation. The resulting method must be sufficiently simple in scope that it can easily be applied by design engineers with existing data.

Key Words

Instrumentation, cost-benefit analysis, safety, design, foundations.

Related Work

Much research has been done in civil engineering over the past 20 years to develop ways of using statistics and probability analysis in civil engineering design. Many techniques exist to apply these methods to various aspects of design. Some codes now incorporate the use of load and resistance factors that are based on probabilistic analyses to better quantify the effects of uncertainty in the design process. No methods exist that directly include the benefits of instrumentation into design and cost evaluations.

There is considerable ongoing effort to include instrumentation into projects to reduce costs related to uncertain elements. Instrumentation technology and methods are being continually refined in various research and implementation projects. This effort seeks a rational mechanism to expand the benefits of instrumentation to all projects.

Urgency

This topic is rated of highest priority by A2K01. The results are urgently needed to provide parameters required by new design methods that are based on limit state design. The results are also needed to have a quantitative mechanism for correctly using instrumentation to lower the overall costs of projects.

Cost

\$200,000 over 3 years.

User Community

AASHTO, FHWA, FAA, NCHRP, USACE, DOE, EPA, state transportation agencies, engineering profession

Implementation

Results of this work should be presented at various professional meetings for review and comment.

Proposed revisions to current design methods, codes and Federal design guidelines should be prepared to incorporate results into existing design procedures. A series of workshops, seminars or both should be developed to describe the use of the research results.

Effectiveness

Implementation of this research will result in safer and more cost effective structures. Wider use of instrumentation on projects would reduce the number of failures that result from design inadequacies, construction deficiencies, or factors unknown during design. Through wider use of instrumentation, greater knowledge will be gained to lower uncertainties in design and allow further reductions in factor of safety used in design procedures to cover our uncertainties. The improved knowledge gained from instrumentation of projects will help produce improved design methods that result in better performing facilities with longer life

and reduced costs. While difficult to quantify at this stage, evidence exists to suggest benefit-cost ratios for good instrumentation programs of 10:1 to 100:1 or more.

PROBLEM 87: REMOTE LANDSLIDE MONITORING SYSTEM

Most State transportation agencies have hundreds of sites where earth or rock movement is imminent or occurring that pose a high level of risk to the traveling public. There is seldom sufficient resources to eliminate the risk and, therefore, the owners must manage their system to reduce the risk as much as possible. This is often done by closing the facility at critical periods, maintaining 24 hour patrols and other techniques. Both the cost and the risk associated with these approaches can be greatly reduced if a remote automated landslide monitoring system can be implemented.

Objective

Develop a reliable, portable, low-cost remote monitoring and warning system to be installed at potentially unsafe sites. The system would consist of a series of selected sensors for the concerns at the specific landslide site. These sensors would be connected to a monitoring unit which would then process the data and with preset guides transmit warning signals to the appropriate sites (the Maintenance Office) where action can be taken. The monitoring unit would have a communications link to a response unit through satellite or other communications links for remote sites. The sensing instruments would be designed to measure the key elements of the specific site which might include ground water elevation, vertical or horizontal movements, freeze-thaw cycles, or others. The heart of the system would be a portable control unit that could be programmed to respond to sensor readings and transmit this information to people that can react.

This type of unit could be moved from site to site as necessary to allow the managers to keep the facility open to use until landslide or other activity is imminent and, therefore, only closing the facility for short times when absolutely necessary. This would result in improved public relations, improved performance of the transportation facility and reduce costs both short-term and long-term for the owner.

Key Words

Instrumentation, remote, data processor, landslides, satellite communications, management.

Related Work

The concepts of remote warning systems for danger to transportation facilities have existed for years, but have always been expensive and have seldom proved reliable in severe environments where most slides take place. Some recent work in Europe and in California have demonstrated that the instruments and sensors are much more reliable. Some recent work by Loren R. Anderson has demonstrated the effectiveness of satellite communications from remote sites. It appears that all of the technology exists to develop a low-cost easily deployable system that could be attached to a diverse group of sensors meeting the site specific conditions to allow the managers of systems to safely keep the facilities open and to plan corrective measures.

Urgency

The increase in deaths from rock falls and bridge collapses has demonstrated that the rate of deterioration at our transportation facilities is exceeding our ability to rebuild and replace them. A low-cost, site specific monitoring system would allow the owners to maintain the facilities to their highest capacity until disruption is imminent. Therefore, this type of a system is needed in many areas across the country to help the owners manage their limited resources and still provide the safety to the traveling public. There are also direct cost savings resulting from reduced manual observations.

Cost

Approximately \$150,000 to develop a system with a number of prototype units and run field performance tests to verify the effectiveness of the system.

User Community

All owners of transportation facilities would have a potential use including all members of AASHTO, all State highway agencies, all public transportation agencies, and all local governmental agencies.

Implementation

Full implementation of this technology might require the development of appropriate training courses and workshops as well as the necessary manuals and guides for the specific instrumentation packages developed.

Effectiveness

A measure of the effectiveness of this type of a monitoring system would be its acceptance by the user groups and its deployment to critical sites. A second level measure would be how each facility owner uses the information to manage his specific transportation facility. If totally effective, it would reduce costs, improve public service and possibly save lives.

PROBLEM 88: DETERMINING THE PITTING CORROSION OF STEEL ELEMENTS IN SOIL

Steel elements, placed in soil as part of engineering structures, exhibit either uniform corrosion and/or pitting corrosion. Current laboratory and field measurement methods determine corrosion rates of steel in soil as average rates. Since there is no differentiation between pitting corrosion and uniform corrosion, the service life of structures can be seriously over-estimated.

For proposed engineering sites containing steel elements buried in soil, coarse grained soils are usually favored over fine grained soils to achieve higher strength and lower corrosion rates. Corrosion rates of steel in soil, for the most part, came from the work by Romanoff. These rates are based on weight loss and represent average rates for the steel elements studied. Romanoff reported pitting as being one to four times greater than average corrosion.

Laboratory testing can measure the pitting susceptibility of steel manufactured using different processes. Steel subjected to different mechanical manufacturing processes (i.e. cold worked, annealed, hot worked, etc.) when tested in aqueous solutions will have varying pitting tendencies.

With present technology and designs based on average corrosion rates, there isn't a reliable method to evaluate the life of steel structures in soil and be certain that pitting corrosion will not occur and cause premature distress to these structures.

Objective

Develop an instrument and method to measure the pitting potential of steel elements buried in soil. Develop the technology to measure the in-place metal loss due to pitting corrosion which can also be used to monitor the life expectancy of steel structural elements in soil.

Key Words

Corrosion, local corrosion cells, pitting corrosion, corrosion rates, disturbed soils, undisturbed soils, steel corrosion, corrosive soils, instrumentation.

Related Work

▪ *Underground Corrosion*, National Bureau of Standards, April 1957, Melvin Romanoff, PB-168 350

▪ *Durability/Corrosion of Reinforced Soil Structures*, Earth Engineering & Sciences, Inc., March 25, 1986, by Victor Elias, FHWA/RD-89-186, Contract DTFH 61-85-C-00167

▪ *The Effect of Thermo-Mechanical Treatment on the Pitting Corrosion of Reinforcing Carbon Steel Bars*, 1992, M. Eslamloo-Grami, J.R. Groza and R. Bandy, Department of Mechanical, Aeronautical and Materials Engineering, University of California, Davis, and Department of Mechanical Engineering, California State University, Sacramento. This work completed under separate contracts with the State of California, Department of Transportation, Division of New Technology, Materials and Research, Sacramento.

▪ *Corrosion of Mechanically Stabilized Embankment Reinforcements*, Kevin S. Flora and Douglas M. Parks, California Department of Transportation, Division of New Technology, Materials and Research, FHWA/CA/TL-F91TLO6, final report draft March, 1993.

▪ *Criteria Related Studies for the Cathodic Protection of Reinforced Concrete Bridge Elements*, John Bartholomew, Jack Bennett, William Hartt, David Lankard, Albert Saques, Robert Savinell and Thomas Turk, ELTECH Research Corporation, performed under the Strategic Highway Research Program, SHRP-C/UFR-92-XXX, DRAFT Report, 1992.

Urgency

This problem is faced by most owners of structures having steel elements in either disturbed or undisturbed soil. It should have the highest priority.

Cost

The development of this technology/methodology and any related testing equipment to accomplish this task could exceed \$250,000.

User Community

This problem is shared by all owners of transportation facilities and owners of steel foundations, steel reinforcements in Mechanically Stabilized Embankments, the state DOT's (AASHTO), FHWA, all public work agencies, FAA, DOE, EPA, academia and the engineering community in general. This is a very complex and widespread problem.

Implementation

Initial implementation will probably occur with individual states and municipalities who are trying to determine the life expectancy of their existing structures. If an instrument and/or measurement technique is developed, the engineering community will be able to use the findings to design new structures having lower life cycle costs.

Effectiveness

By providing the ability to detect and measure pitting corrosion, engineers could optimize the use of cost effective materials having low corrosion rates to extend the life cycle of structures containing steel elements buried in soil.

A2K03 COMMITTEE ON FOUNDATIONS OF BRIDGES AND OTHER STRUCTURES

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

PROBLEM 89: CAPACITY OF FOUNDATIONS AND MSE RETAINING WALL SYSTEMS DURING EARTHQUAKES

The transportation engineering community is now becoming aware of the need to ensure the stability of bridges and their foundations in all parts of the country against earthquake loading. Experiences from the Mexico City Earthquake of 1985 and the Loma Prieta Earthquake of 1989, among others, have suggested that loss of pile capacity may occur during seismic events in both clay and sand. Such loss of capacity may be the result of buildup of pore water pressures to the point where they influence pile capacity but do not produce liquefaction, to the redistribution of effective stresses in the soil mass and/or to the degradation of soil fabric. Most existing information related to loss of capacity due to vibratory loading is based on experiments that considered loading of the pile through the structure or the pile head, not through the soil, as occurs during earthquakes. Since the degradation characteristics of soils near piles are likely to be very different where loading is applied through the soil, special attention needs to be given to this form of loading before design guidelines can be developed.

Methods of computation for external stability of MSEW structures subject to seismic loading have not been studied to the same degree as have the effects on internal stability and stresses in reinforcement. The effect of surcharges or the type of reinforcement (extensible or inextensible) on developed dynamic earth pressures and inertial forces is largely unknown and inferred from limited analytical studies on structures with no surcharge constructed with relatively stiff reinforcement.

Additional research efforts are therefore warranted, and would be best undertaken at research universities having shaking table and centrifuge capabilities in possible cooperation with NSF, where it is believed matching program funds may be available.

Objective

The objectives of the research are to (1) adapt or develop analytical procedures to forecast capacity changes in foundations during seismic events, (2) to establish methods of computation for external stability of MSEW structures (3) to conduct experiments or to access existing data for use in verifying the analytical procedure(s) and (4) to use the analytical procedures to develop recommendations for engineers who are

producing new designs or evaluating the safety of foundations for existing structures.

Related Work

None known.

Urgency

High.

PROBLEM 90: ARTIFICIAL INTELLIGENCE IN THE DESIGN AND CONSTRUCTION OF FOUNDATIONS FOR TRANSPORTATION STRUCTURES

Perhaps the single most pressing problem affecting the design and construction of foundations for transportation structures is the failure of state DOT's to employ knowledge that has been acquired through formal research and through experiences acquired both within the agency and by others. As a result, foundation costs remain excessive, and occasionally designs are inadequate. The problem is especially prevalent in the construction of new foundations and in the evaluation of existing foundations, in which resident engineers and inspectors are not knowledgeable of proper construction methods and cost-effective remediation of problems that arise during construction or rehabilitation. An effective way of making this knowledge available to practitioners in a way that they will use, is by means of the decision support system, a user-friendly microcomputer program containing a knowledge base and a set of rules developed by experts and verified independently by other experts. This method of mass technology transfer is very effective, especially for younger personnel, who have had considerable experience learning through computers, and should be able to break the barrier of "if it is not done in my state (or district), I don't want to hear about it."

Objective

The objective of this research would be to (1) review existing expert systems and neural network programs that address design, construction and rehabilitation, both in the U.S. and elsewhere, and to adapt those that are feasible for use in DOT technology transfer. (2) to adapt or develop a shell program that would

maximize user friendliness while permitting the proper logic to be employed (probably fuzzy logic). (3) to develop the composite software system and to have it verified by recognized experts in design and construction. (A related objective would be to have an arm of the FHWA, perhaps the National Highway Institute, develop a course that could be given in house in each state to familiarize state personnel with the software.)

Related Work

No formal activities in this subject area are known to exist currently, although some research on expert systems in deep foundations is known to be underway at Clemson University, Auburn University and the University of Houston

Urgency

High.

PROBLEM 91: IMPROVED USE OF NONDESTRUCTIVE EVALUATION METHODS TO EVALUATE LOADING BEHAVIOR OF DEEP FOUNDATIONS

At present, the only effective means of evaluating the loading behavior of deep foundations is through high-strain dynamic testing or through static loading tests. These tests are expensive and are time consuming to set up for purposes of evaluating the capacities of piles or drilled shafts that are suspected of having inadequate capacity. Recently developed non-destructive evaluation methods, whose principal purpose is to detect defects, may also be capable of being used to infer stiffness and, either directly or indirectly, capacity. If appropriate enhancements of these techniques and/or modifications to methods for their interpretation can be developed, capacities of piles or drilled shafts suspected of having defects can be assessed, and the importance of the defect on bottom line performance evaluated quickly and economically.

Objective

The objectives of the research will be (1) to determine which NDE methods can be adapted to capacity evaluation, (2) to adapt one or more such methods, and (3) to compare the results of static loading tests with results obtained using the adapted method, using piles and drilled shafts that have previously been tested at National Geotechnical Experimentation Sites and elsewhere.

Related Work

None known.

Urgency

High.

PROBLEM 92: DESIGN METHODS FOR PILE GROUPS TO RESIST DYNAMIC LATERAL LOADS

Heavily loaded bridge foundations often consist of groups of driven piles or drilled shafts. Approximate methods have been developed in the past by several academic researchers to analyze groups of piles subjected to lateral shears and overturning moments due to static loads or to slow cyclic loading. However, design methods are not generally available to analyze pile groups subjected to dynamic loads, such as impact loads from ships, ice loads and seismic events. In particular, there is a need to develop methods that are as simple as possible for forecasting deflections and rotations at the interface between the piles and superstructure and distributions of shears, moments and axial thrusts among the piles in the group.

Objective

The objectives of the research are to investigate existing methods for analysis of laterally loaded pile groups and to adapt such methods to the analysis of dynamic loading (both loading through the pile cap and loading through the soil). Using these analytical methods parametrically, and other information, design methodologies are to be developed and reported.

Related Work

None known.

Urgency

High.

PROBLEM 93: EXPEDIENT STATIC LOADING TESTS FOR PILES AND DRILLED SHAFTS

While static methods of pile design have advanced considerably during the past years, and while dramatic advances have been made in the high-strain dynamic testing of piles and drilled shafts, there remains a need to conduct static loading tests. However, the costs for

such testing are presently in the range of \$50-100 per ton of maximum load, which is often too high to justify static loading tests in the case of smaller construction projects and for conducting fundamental research on pile-soil interaction, especially for prototype-sized drilled shafts, whose capacities can exceed 1000 tons. There is a need to develop or adapt expedient testing methods that are capable of applying high static loads to piles and drilled shafts, that give reliable results and that are inexpensive.

Objective

The objectives of this research are (1) to identify and evaluate existing low-cost static testing expedients, (2) to evaluate the reliability of the results obtained from such expedients and develop modifications, if necessary, and (3) to propose new expedient testing methods if existing expedient testing methods, as modified, are not considered feasible and reliable.

Related Work

None known by government agencies, but private industry in the USA and elsewhere is known to be developing expedient static testing methods.

Urgency

High.

PROBLEM 94: LOADING TEST DATABASE FOR DEEP FOUNDATIONS

Before methods of analyses and design are accepted for specifying deep foundations, the ability of the method to produce a safe and economical design should be established. A common procedure for assessing these methods is to compare predicted behavior with measured behavior. The types of foundations could include driven piles, drilled shafts, auger-grout piles, mini-piles, and drilled-and-grouted piles.

Uncertainties associated with predictive methods are also illuminated by comparing predicted and measured behavior for a large number of tests. Ideally, a convenient and readily accessible collection of carefully documented axial loading tests on deep foundations would provide the researcher, design engineer, or licensing agency a convenient tool for evaluating new and existing methods.

The results from this collection of axial loading tests represents a unique opportunity to evaluate current methods for predicting axial behavior, to improve the design methods, and to provide for an accessible data base so that design methods can be

evaluated rapidly. Use of a database is especially important in the evaluation of resistance factors for the development of new LRFD factors for foundations.

Objective

The objectives of the research effort are to collect, interpret, and transcribe a large amount of loading test data into an electronic, relational database and use the database to evaluate methods for predicting behavior of deep foundations. The database will be used to evaluate the ability of current methods to predict axial behavior of deep foundations. An additional objective of this research is to make the database available publicly so that other researchers, design engineers and licensing agencies can use the database for their purposes. An easily accessible database can potentially enhance and encourage the development of technology and new methods of deep foundation analysis, design and construction by making available the detailed results of past loading tests.

Related Work

Several deep foundation data bases of varying detail have been developed or are currently being developed. These include databases by the FHWA at Turner-Fairbank, University of Illinois, University of Florida, University of Texas, Cornell University, Texas A&M University, University of Houston, and perhaps others. These databases were developed for differing purposes and are not consistent in detail or format.

Urgency

High.

PROBLEM 95: EVALUATION OF AUGERED PILES FOR LOAD BEARING IN HIGHWAY STRUCTURES

Augered piles (piles that are constructed by drilling a borehole with a continuous flight auger and grouting or concreting the hole as the auger is withdrawn) have been used for decades as bearing piles in the private sector but are almost never used in that manner in highway construction and other segments of the public sector. Lack of usage in the public sector stems from a perceived lack of quality control and a lack of appropriate methods for computing static capacity. There are many instances in which augered piles could be economically superior to either driven piles or conventional drilled shafts, so that further study of augered piles is warranted.

Objectives

The objectives of the research are (1) to evaluate methods of augered pile construction around the world and to determine which quality controls and quality assurance techniques will be needed to make augered piles acceptable in the bridge engineering community, and (2) to evaluate or develop design models for predicting the capacity of augered piles in the major soil types.

Related Work

None known.

Urgency

Medium.

PROBLEM 96: CORROSION OF DRIVEN STEEL PILES

Many older bridges are supported on driven steel piles. Whether foundation rehabilitation is needed may depend largely on whether such piles are substantially corroded. Some research studies have concluded that corrosion in driven steel piles is not a problem as long as a substantial portion of the pile is below the water table. Yet, there have been a number of instances in which corrosion has been observed when apparently "safe" piles have been exposed. There are no applicable guidelines for investigating a site to determine whether corrosion is likely to have occurred or will occur with new construction. As a result, protection is often recommended by corrosion engineers who are unfamiliar with the corrosive behavior of steel piles, which can result in solutions that are overly conservative and expensive.

Objective

The primary objective is to develop reliable criteria which will allow the design engineer to determine the likelihood of corrosion in existing piles or in piles to be driven and to quantify the probability that the amount of corrosion will be detrimental to the foundation new or at some time in the future. This objective should include recommendations for *in situ* and/or laboratory tests that will be appropriate for assessing probable corrosion of steel piles on a specific site.

Related Work

None known.

Urgency

Medium.

PROBLEM 97: FEASIBILITY OF AND DESIGN METHODS FOR LOAD-BEARING SHEET PILE ABUTMENTS

According to FHWA statistics, 41% of the nation's 578,000 bridges are either structurally deficient, thereby requiring replacement, or functionally obsolete, requiring either widening or structural replacement. Many of these bridges have short span, and rehabilitation can benefit from the application of technology that produces cost-effective abutments. Steel sheet piling can carry both lateral and vertical loads, thus affecting considerable economy over separate wall and bearing-pile systems. Further economy can be realized by the fact that shoring and cofferdams can be eliminated during construction, thus accelerating the process. Cost savings nationally could potentially exceed \$1,000,000,000.

Objective

The objectives of this research would be to (1) acquire information on the design and performance of load-bearing steel sheet pile abutments in both the USA and elsewhere, (2) conduct either analytical or experimental studies (or a combination) to investigate the effects of sheet pile-soil interaction, use of tiebacks, application of combined loading and similar effects, so as to provide a rational basis for design methods, and (3) to develop a straightforward design method that can be confidently applied by design engineers.

Related Work

None, although some load-bearing steel sheet pile abutments are known to be in service in New York state.

Urgency

Medium.

A2K04 COMMITTEE ON SUBSURFACE SOIL STRUCTURE INTERACTION

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

PROBLEM 98: THERMOPLASTIC PIPE DESIGN PROCEDURE

The current "Soil Thermoplastic Pipe Interaction System" design procedure (Section 18 and LRFD Section 12) was written in the early 1980's based on the corrugated metal pipe design procedure. This leads to a design that is fundamentally incorrect in several ways. As currently used by many states, the current procedure limits these pipes to relatively shallow heights of cover based on wall thrust limits, yet the mode of failure predicted has never been seen in practice, either in the field or in research. Other questions of performance limits are ignored in the current procedure, such as deflection limits and profile stability. The current procedure relies on ring compression limits even though this mode of failure has never occurred in practice or in research. At the same time, the current procedure ignores other, necessary performance limits, such as deflection and wall profile stability. The viscoelastic nature of these materials is largely ignored or misinterpreted within the design procedure. This all tends to limit the cost effective application of these products in transportation applications. In many cases this tends to limit the cost effective application of these products. In others, designs may be unconservative or susceptible to unexpected failure modes.

With over 40 states currently using some thermoplastic pipe in some applications, correct design guidance is very important.

Objective

The objective of this work will be to provide a clear, concise design procedure for this growing class of products that will also permit the cost effective application of these products in transportation industry applications with utmost safety. The design procedure should include buckling, deflection, pipe stiffness, and wall stability as key issues.

This new design procedure should then replace the current AASHTO standard for the reasons previously discussed. The development of this standard will involve a thorough review of existing research, a review of other related standards, a review of current state practice, and some original research and test development.

To support the design procedure, this research will develop a test method to evaluate and demonstrate the long term stability of profile walled plastic pipe,

and an analytical method for checking profile designs. The analytical method will be validated by tests. (One manufacturer has a test under development that shows some promise.)

Key Words

Thermoplastic, Polyethylene, Polyvinyl Chloride, Corrugated Pipe, profile wall pipe, buckling, wall thrust, deflection, profile stability, time dependency, pipe stiffness, flexibility factor.

Related Work

Soil box testing has been and is being done at Utah State University on many of these products. Results of these tests should be collected and compared as to relative performance and performance limits. This work has been funded by industry, state DOTs, and federal agencies. Loading tests using a quite different cell have been conducted at Ohio University. One large study funded by the FHWA and the Ohio DOT is nearing completion. Other tests have been conducted at OU on smaller diameter pipe funded by the USEPA. A number of industry funded tests have also been conducted at OU. Dr. Shad Sargand of OU will be monitoring the installation and performance of a 42 in. diameter plastic pipe on an Ohio DOT project being installed in spring of 1996 with 50 ft. of cover.

The University of Massachusetts (Amherst) has been involved in a wide range of thermoplastic pipe studies, including the 100-foot-deep burial of a 24 in. diameter pipe outside Pittsburgh funded by industry, PennDOT, and the FHWA; the pipe backfill study nearing completion funded by NSF and FHWA pooled funds; and various industry funded studies in PE pipe performance including a laboratory ring compression limit test.

Finite element design work conducted by Dr. Michael Katona in the 1980s and more recently by Dr. A.P. Moser and by Dr. Ian Moore may provide additional design guidance in this area.

Over 30 state DOTs have conducted performance studies on these pipe types over the past 10 years. These studies cover field performance of these pipe types, either considered alone or compared to traditional pipe products.

Additional design and pipe stiffness testing has been conducted by Dr. Lester Gabriel at California

State University, Sacramento; durability testing involving abrasion resistance has also been done.

Data from most if not all of these sources should be collected and compared as to relative performance and performance limits.

Urgency

The use of thermoplastic pipe in transportation related construction projects has grown 40% annually since 1991, with increases in quantity and sizes. Use of these materials on state DOT projects has seen similar growth with over 40 states using HDPE pipe and over 30 states using PVC pipe for a variety of applications. Plastic crossdrain pipes are now fairly common. Adding to the problems of designers is the competitive environment, which has seen an unprecedented negative commercial focus on these materials by competing industries. This research will provide product performance limits and a technically sound design basis which will help eliminate the negative commercial focus.

Cost

The estimated cost of this work is \$500,000 over 2 years. This covers analysis of the currently available research reports as well as those nearing completion at this time. Included will be the perfection of a profile stability test currently being studied by the industry. Any product qualification test costs would ultimately be funded by the participating industries.

User Community

AASHTO, FHWA, FAA, AREA, NAVFAC, U.S. Army Corps of Engineers, BuRec, BIA, USEPA, U.S. Forest Service, all state DOTs, counties, cities, and other public and private engineering and design organizations.

Implementation

The results of this project will provide a technically sound design procedure for these products while providing proper wall design guidance beyond current standards. It will provide a means of assuring long term, cost effective performance of these materials.

Effectiveness

The project results will provide a sound technical design basis for these products while limiting designs

that may have technical faults. The work should result in substantial increases in user confidence in appropriately designed and manufactured products. The effectiveness will become apparent in specification changes and altered use limits.

PROBLEM 99: CRITERIA FOR FLOWABLE FILL IN BACKFILL

Flowable fill, also known as Controlled Low Strength Material, is a fill placed without compaction typically by mixer truck. It generally is composed of portland cement, fine aggregate, fly ash, and water. It achieves the desired strength through cementing and through the composition of the aggregate. There are many uses of this type of fill including backfill, pavement base, structural fill, and high or low permeability fill.

Proper backfill in trenches and around small structures usually involves placement of backfill into thin layers with labor intensive compaction. Improper backfill envelope design or lack of control of compaction by agencies, which may not have the necessary expertise, often creates undesired settlements across roads and sometimes unacceptable stresses on the buried structure. Replacement of this backfill by flowable fill removes the necessity for compaction with its problems and also becomes more efficient in placement by reducing required trench widths. Flowable fill must be weak enough so that it can be later removed, if necessary.

Since this is an innovative material, it is necessary to determine the criteria for flowable fill properties that are needed for proper backfill envelope design and proper material placement to assure adequate performance. Since flowable fill uses locally available recyclable materials, such as fly ash or bottom ash, and local aggregates combined with cement and water, the properties that are obtained can have wide ranges. It is necessary to determine how interrelationships of the properties of the constituents affect flowable fill properties. It is necessary to determine how the required properties will be monitored in the field. Criteria for backfill envelope design are also required.

Objective

Develop criteria for needed properties of flowable fill by field testing. Conduct laboratory and field testing of flowable fill to quantify the interrelationships between constituents and fill properties. Develop laboratory and field testing methods to monitor quality and backfill performance. Develop backfill envelope design criteria based on these findings.

Key Words

Culverts, backfill, fly ash, grout, soil loads, laboratory/field testing, soil structure interaction.

Related Work

The American Concrete Institute has formed a committee to address some of the properties for flowable fill. Brewer and Hurd have investigated the use of this material for the Ohio Department of Transportation.

Urgency

The A2K04 Committee determined this project to be of high priority with significant benefit to transportation in our country. Thousands of miles of utility and drainage systems are being installed and replaced across our roads each year. Flowable fill offers an efficient backfill method with potential benefits in quality improvement.

Cost

This program is envisioned as a multi year effort with each year \$100,000 to \$150,000. The total program will last three years with a cost of \$300,000 to \$450,000. It is likely that co-funding could be obtained from other interested parties such as utilities, organizations, and other government agencies.

User Community

FHWA, AASHTO, local Departments of Public Works, utilities (gas, water, sewer, electric and telephone), contractors, and consulting engineers.

Implementation

All the user community can use the results to replace or enhance current backfill procedures. Ready mixed concrete manufacturers can use the results to develop a diversity of sources.

Effectiveness

Flowable fill has the potential to improve the quality of backfills, especially for small excavations and to decrease the amount of premium backfill.

PROBLEM 100: REPRESENTATION OF LIVE LOAD ON TWO DIMENSIONAL BURIED STRUCTURE ANALYSIS MODELS

Several recent research reports dealing with flexible buried long span structures have pointed to large discrepancies between measured live load responses and those calculated by currently available two dimensional techniques. These techniques are generally based on an adaptation of the Boussinesq elastic relationships for a semi infinite elastic medium. They do not account for rigid flexible inclusions, such as a culvert, within the medium. More recently two ¼-dimensional finite element methodology has employed a semi-finite live load. While this technique more rigorously distributes live load in the plane of the analysis, it still depends upon the same approximations in the third dimension.

In addition, no two-dimensional solution exists for the prediction of buried structure responses due to moving live load across a skewed alignment. This problem has been ignored for small diameter culverts under adequate fill. However, for long span structures under shallow cover with heavy live loads, it may need to be considered.

Objective

Develop accurate live load representations for implementation in currently available, two dimensional analysis methods for both stiffened and unstiffened top acres.

Assess the need for impact factors to account for the effects of moving loads.

Develop a two dimensional design method, if possible, for dealing with live loads on skewed alignments.

Key Words

Buried structures, culverts, soil structure interaction, live loads, load distribution, corrugated metal plate, structural plate.

Related Work

Recent research on live loads on long span buried structures has been conducted in both the U.S. and Canada. Much of this work was done on relieving slabs designed to distribute wheel loads over the top arc. It will be a useful background for the proposed research.

Urgency

A rational method for determining the applied live load at any given cross section for various corrugations, top arc stiffeners, skew alignments, soil types and cover heights would add significantly to the design technology for shallow cover long span structures. Next to structure geometry and soil unit weight, live load is the most important design parameter, yet it is the least defined in current technology. Since long span buried structures are playing a major role in rehabilitation of the nation's highways, significant public dollar savings may be realized by developing accurate live load representative.

Cost

Approximately \$200,000 to \$250,000 over 2 years.

User Community

AASHTO, FHWA, FAA, AREA, U.S. Army Corps of Engineers, all state DOT's, counties, cities, and other public and private engineering and design organizations.

Implementation

The results of this research will provide a more accurate representation of the distribution of live loads to be incorporated into the design of buried structures.

Effectiveness

The project results will provide a sound technical design basis for live load design of buried structures which will result in a more economical and safer design.

PROBLEM 101: THE DESIGN OF BACKFILL ENVELOPES FOR UNDERGROUND STRUCTURES

Current AASHTO structural design specifications for culverts and other hydraulic structures do not adequately address the design of the select backfill envelopes required to provide adequate structural performance. The required AASHTO Section 12 LRFD offers no improvement in its current form.

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

acceptable 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. In addition, the number of pipe materials and backfills (e.g., CLSM CDF, Flash Fill, etc.) have proliferated without any updating of backfill requirements.

The AASHTO structural design requirements for culverts and hydraulic structures should be revised to provide adequate guidelines for the design and construction of backfill envelopes, foundations, etc.

Current methods of soil structure interaction analysis (e.g., finite element programs, "Soil Eval" program, buckling theories, etc.) are now available to aid the designer in providing backfill/foundation requirements based on sound engineering principles. However, work is still needed to fully evaluate the following:

- Influence of installation procedure and bedding conditions on backfill properties affecting structure performance; and
- Influence of the backfill envelope on long term changes in buried structure loads and deflections.

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 for 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.

Key Words

Conduit, culverts, backfill envelopes.

Related Work

Some research that has been done to address these issues is as follows:

- CANDE update by S. Musser,
- Buckling work by E. Selig and I. Moore,
- "Soil Eval" work by Bowser Morner,

- NSF Project on Pipe Backfill by T. McGrath and E. Selig, and
- NCHRP Project 12-45

However, 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

Given consideration of the current revisions to the AASHTO design specifications for culvert structures, there is an urgent need for development of guidelines for the design of backfill envelopes for underground structures.

The expected cost of future bridge replacements 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.

Cost

Estimated to be \$400,000 to \$500,000 over 3 years.

User Community

AASHTO, FHWA, FAA, AREA, NAVFAC, U.S. Army Corps of Engineers, USEPA, U.S. Forest Service, all state DOT's, counties, cities, and other public and private engineering and design organizations.

Implementation

All the user community can use the results to replace or enhance current backfill procedures.

Effectiveness

The project results will provide a sound technical basis for the design of backfill envelopes. The work should result in substantial increases in user confidence in appropriately designed backfills.

PROBLEM 102: MEASUREMENT OF EARTH PRESSURES ACTING ON EXISTING LATERAL RETAINING STRUCTURES

A number of major U.S. government agencies are embarking on programs to rehabilitate old structures. As a first step, it is necessary to know the level of lateral stresses acting on the structures, and what stresses may be added as a result of the rehabilitation process. Since the structures in many cases have been in place for long periods of time, the existing earth pressures will reflect the effects of initial placement, structural deflection, creep, subgrade movement, surcharging, and vibrations among others. Stress concentrations may also have developed in areas where there are structural shape transitions, and arching may play a role if the backfill is located in a constrained environment. Little is known about the nature of long term loadings on structures. Added to this is the problem of the stresses that might be induced by the unusual construction processes that are often used in rehabilitation efforts. All of this suggests that we need to be able to measure and predict the long term earth pressures acting on existing structures as well as those induced by various construction activities.

Objective

Develop reliable methods to measure the existing lateral stresses on older structures, and those that might be induced by nearby construction processes. This probably will utilize some of the existing technology for in situ testing of soils in a modified form.

As a result of the measurements develop analytical methods which can be used to predict the loadings without recourse to measurements, or with only a minimal use of them. The research will require equipment innovations with testing in controlled laboratory environments, followed by a series of field tests involving actual projects. Analytical work will also be needed after the phenomena are explored through the field work.

Key Words

Earth pressure, retaining structures, lateral stresses, tunnels.

Related Work

Transportation Research in Progress: no specific research projects are known to be underway. However, several major projects which are under

consideration are facing the issue. For example, the Westside Highway Project in New York will involve building structures adjacent to the Holland and Amtrak tunnels. The Muni turnaround in San Francisco will have excavation and construction above the BART tunnels.

Other research: The Corps of Engineers is considering the problem for a research thrust because of the expected rehabilitation of numerous navigation structures.

Urgency

This problem is important since our major agencies project that in the near future, the majority of their budgets will be directed towards the cause of rehabilitation, not new construction. Much of the geotechnology we have developed addresses new structures, not existing ones. Measurement of lateral stresses on existing structures is an area which will allow us to capitalize on the coming emphasis of our funding agencies.

Cost

The estimated cost is \$200,000 to \$250,000 over 2 years.

User Community

AASHTO, FHWA, FAA, AREA, U.S. Army Corps of Engineers, all state DOT's, counties, cities, and other public and private engineering and design organizations.

Implementation

The results of the research will provide a sound design procedure for considering the effect of new construction on existing retaining structures, tunnels, etc.

Effectiveness

This work will result in minimization of disturbance to existing structures due to adjacent new construction. The project results will provide a sound technical design basis for live load design of buried structures which will result in a more economical and safer design.

PROBLEM 103: 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 consolidation, time dependent deviatoric creep and soil migration. 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 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 modeled, 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.

Objective

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 modeling 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.

Key Words

Conduits, foundations, backfill, long-term performance, soil/conduit behavior.

Related Work

Research regarding long term plastic properties for thermoplastic pipe materials is currently being performed. Transportation Research Record 1431 reports on culvert distress and failure case histories. 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 longevity. There is also a similarly urgent need to incorporate long term performance considerations in the design of future conduit installations.

Cost

Approximately \$300,000 to \$350,000 over 3 years.

User Community

AASHTO, FHWA, FAA, AREA, NAVFAC, U.S. Army Corps of Engineers, USEPA, U.S. Forest Service, all state DOT's, counties, cities, and other public and private engineering and design organizations.

Implementation

The user community can use the results to incorporate long term soil/conduit behavior into the design of conduits and conduit backfill envelopes.

Effectiveness

The project results will provide a sound technical basis for consideration of long term soil/conduit behavior in conduit design. The work should result in substantial increases in user confidence in appropriately designed conduit/backfill systems.

PROBLEM 104: CASE HISTORY EVALUATION OF TRENCHLESS CONSTRUCTION PROCEDURES

Trenchless construction is the process of installing or replacing underground utility systems without open-cut excavation. This includes the use of pipe jacking, microtunneling, horizontal directional drilling, and guided boring systems. There is an urgent need for good case history information to improve planning and design on future projects.

Trenchless construction is of key importance for transportation systems because it allows for installation of conduits and utilities without disruption of surface facilities, which often involve major transportation arteries. For this reason, there has been explosive growth in trenchless construction, with substantial cost savings resulting from the undisturbed operation of highways, railroads, and water transportation systems.

Case histories of trenchless construction are urgently needed to provide valuable feedback to the design and planning community about the capabilities of the methods, their successful aspects, and potential pitfalls. Among the most important areas for case history development are jacked box tunnels and utility installation under interstate highways, and directional drilling in dense urban environments.

A major application of jacked tunnels is planned at the Boston Central Artery/Tunnel Project which involves 30-ft-high reinforced concrete box structures jacked under the busy railway facilities at Boston South Station. Documented experience with jacked tunnel construction in Europe and Asia would provide valuable background for the proper conceptualization and planning of this type of project. Recent trenchless construction for New York City airports are important sources of information regarding appropriate methods of construction, remote guidance, subsurface condition effects, and the constraints imposed by surface facilities. Considerable technology transfer is possible between the gas and oil industries and the transportation industry with respect to directional drilling. Recent developments with directional drilling for gas and oil operations have important lessons for trenchless applications at highways and urban environments.

Objective

Collect and organize comprehensive case histories of trenchless construction, covering a variety of methods with promise for the transportation industries. Using this information, improve design guidelines for using trenchless installations (by pipe jacking, microtunneling, horizontal directional drilling, and guided boring, etc.) beneath roadways.

Key Words

Trenchless construction, soil loads, pipe jacking, microtunneling horizontal directional drilling, guided boring.

Related Work

The Army Corps of Engineers and the Trenchless Technology Center at Louisiana Tech University are conducting a field evaluation program of microtunneling equipment and guided boring systems. The Gas Research Institute has sponsored research for several years to analyze pipeline loadings at railroad crossings. This work showed that the current design methodology was conservative and new pipeline crossing equations were developed.

Urgency

Each year, thousands of miles of utility systems are being installed and replaced beneath our highways and roads. Excavations are disruptive at best and very costly for transportation agencies. Case history feedback for planning and design improvement is urgent and of high priority.

Cost

The case history evaluation will last five years with a cost of \$400,000. Cofunding is likely from several other interested organizations, such as public and private utilities, manufacturers, and other government agencies.

User Community

FHWA, AASHTO, NHTSA, local Department of Public Works, utilities (gas, water, sewer, electric, telephone), contractors, and consulting engineers.

Implementation

All types of design engineers (consultants, utility engineers, transportation designers) and contractors could use the results on upcoming construction projects using Trenchless Technology. Manufacturers could use the results to improve their products.

Effectiveness

Trenchless technology has the potential to significantly reduce the cost of disruption and protect our country's roadway system from further deterioration.

A2K05 COMMITTEE ON MODELING TECHNIQUES IN GEOMECHANICS

PROBLEM 105: CHARACTERIZATION OF SOIL PARAMETERS USING COMPUTATIONAL NEURAL NETWORKS (CNNs)

To develop a CNN-based system for identifying the characteristic of geotechnical soil parameters such as optimum moisture content, maximum dry density, unconfined compression strength, angle of internal friction, coefficient of permeability, compression index and consolidation coefficient, without routinely conducting the needed extensive laboratory tests. Using easily-obtained engineering soil properties and indices is a hard task for well-trained geotechnical engineers and difficult task for new engineers with little geotechnical experience. Moreover, many state highway agencies are/or will be experiencing attrition in their geotechnical ranks and their replacements generally lack such extensive experience or knowledge of local geologic conditions. As those employees leave their agencies so is their invaluable experience. Unfortunately, current practices do not have the capability to save or recycle this expertise. Consequently, this experience is lost forever.

Objective

The main objective of this research project is to develop efficient and accurate neural network-based predictive tools that can easily be used to identify the expensive and time-consuming geotechnical engineering parameters from easily obtained soil properties and indices.

Related Work

Similar research activities, but on a very small scale, have been conducted at Kansas State University, Clemson University, Clarkson University and other geotechnical companies. These initial research studies have shown a great promise for utilizing CNNs in efficiently characterizing various soil parameters.

Urgency

Usage of the powerful CNN-based predictive tools will significantly enhance DOT's geotechnical engineering decision-making process in three-ways. Firstly, it will enable geotechnical engineers, in many cases, to accurately predict geotechnical engineering soil parameters from easily obtained soil properties and indices, without the need to perform the lengthy and costly laboratory experiments particularly in situations where time and money are scarce. Secondly,

geotechnical engineers can use these tools to validate their experimental results and therefore assess any deviation from the CNN predictions. Thirdly, new experimental soil data will be used to update the CNNs by retraining the networks simultaneously on both original and the new data sets; consequently, expanding the domain of applicability and accuracy of the CNNs.

Cost

First year: \$150,000; second year: \$150,000; third year: \$160,000. Total of \$460,000 over a 3 year period.

PROBLEM 106: FROST EFFECTS IN NATIVE BACKFILLS OF EARTH REINFORCEMENT STRUCTURES

Although many design codes prevent or discourage the practice, local poor or marginal backfills are being increasingly used in the construction of wall and slope earth reinforcement structures as an active cost saving measure. Even the use of frost susceptible native soils as backfill in cold climates is becoming more common as owners and agencies look for ways to save on construction costs. Although frost heave or heave loads imposed by these soils, or for remediating retaining structures constructed with these soils, is not available. Such guidance is needed to catch up with the increasing use of poor or marginal soils in construction projects, and to reflect the tolerance to frost heave-induced deformation that the structure warrants.

Objectives

1. To estimate ground freezing and frost heave loads imposed on earth reinforcement systems by poor or marginal backfills at realistic in-situ moisture contents subjected to freezing and thawing.
2. To find the extent to which current reinforcement systems can be used in poor or marginal soils subjected to freezing and thawing.
3. To develop guidance on the use of poor or marginal backfills in earth reinforcement retaining systems in cold regions.

Related Work

1. Research in progress: The submitter is aware of no research in progress in this specific area.

2. Related research activities: The U.S. Army Cold Regions Research and Engineering Laboratory is (1) monitoring a conventional retaining wall subjected to frost heave loads on structures. Laval University has developed numerical techniques to model frost heave loads on structures. Polyfelt, Inc. has sponsored a study on the use of poorly draining backfills with reinforced soil structures.

Urgency

The problem is becoming increasingly severe, particularly in low budget and remote construction projects with higher deformation tolerances, as economic pressures increase for transportation agencies.

Cost

The cost is estimated at \$400,000 over 4 years.

PROBLEM 107: THAW WEAKENING AND PERMANENT DEFORMATIONS IN BASE AND SUBGRADE SOILS

During spring thaw in a cold climate, when the base/subbase and/or subgrade of a flexible pavement structure becomes saturated, permanent strains can occur in the base course and subgrade materials under the repeated loads imposed by heavy vehicles. These strains can lead to excessive permanent deformation and rutting at the surface that, on a seasonal basis, dominate the yearly pavement deformation and rutting at the surface that, on a seasonal basis, dominate the yearly pavement deformation. Effectively including spring thaw in pavement performance transfer functions depends upon (1) a clear understanding of the pavement response to base and subgrade thaw weakening, and (2) simple yet appropriate models of the thaw-weakening process for use in pavement design and analysis, laboratory testing, and field evaluation. As

the response of primary concern is permanent deformation of the thaw-weakened base or subgrade soil and the resulting surface course deformation, the problem is due to the plasticity rather than the elasticity of the base and subgrade materials. This then poses a further problem for pavement evaluation, since current mechanistic models are limited to elastic analysis.

Objective

1. To develop soil mechanics-based techniques for predicting the performance of base/subbase and subgrade materials in flexible pavements, including their contributions to permanent rutting deformation, during critical thaw weakening periods.

2. To develop criteria that will ensure that the base/subbase and subgrade materials will be stable in the thaw recovery period.

Related Work

1. Research in progress: The submitter is aware of no research in progress in this specific area.

2. Related research activities: There have been considerable studies to look at permanent deformations of base and subgrade soils. Recently plasticity-based modeling has been applied to this problem. These studies do not focus on thaw weakening, however.

Urgency

As wheel loads increase with increasing truck loads, ability to design, rehabilitate, and appropriately limit loads for this critical thaw period becomes increasingly important.

Cost

The estimated cost is \$400,000 over 4 years.

A2K06 COMMITTEE ON SUBSURFACE DRAINAGE

PROBLEM 108: GEOCOMPOSITE EDGE DRAIN INSTALLATION CONCERNS

Installation of prefabricated longitudinal edge drains next to new or old pavements has become more common as the detrimental effects of subsurface water upon the maintenance free life of pavement systems has become more widely recognized. Installation practice generally requires excavation of a trench adjacent to the pavement. No general specifications or construction procedures are available to ensure adequate trench backfill compaction or proper geocomposite edge drain placement. Field experience indicates that often construction compaction is minimal or ineffective, or edge drains were damaged by compaction or trench settlement forces. Lack of compaction of backfills leads to:

1. Settlement of the trench backfill;
2. Deformation of the edge drain product;
3. Lack of edge support for the pavement structure.

The settlement of the trench creates a maintenance problem. The loss of edge support may result in a substantial loss of pavement fatigue life due to resulting higher strain under loading.

Objectives

The objectives of this research are:

1. Evaluate current construction practices in this area;
2. Evaluate loss of pavement edge support due to drain trenching operations with both good and poor compaction procedures;
3. Determine construction practices needed to minimize construction damage or deformation of the geocomposite edge drain products;
4. Propose and evaluate appropriate construction procedures and backfill materials to achieve high levels of trench backfill compaction and good soil/geotextile contact without destroying or damaging the edge drain.

Key Words

Backfill, installation/construction procedures, compaction, trench, edge drain, geocomposite, underdrain.

Related Work

Past work has been performed on large utility trenches. Work is being performed by the Kentucky Transportation Center to determine the effects of compaction forces on the edge drain structure. Edge drain performance reports by the Georgia DOT, Indiana DOT, Iowa DOT, Ohio DOT, West Virginia DOT, PennDOT, Illinois DOT, Ontario Ministry of Transport, and NCHRP Report 367, discuss geocomposite edge drain performance and installation. Current ongoing work also includes NCHRP Project 1-34, "Performance of Subsurface Pavement Drainage," and NCHRP Synthesis Project 20-15, Topic 25-07, "Update of Synthesis 96 - Pavement Subsurface Drainage Systems."

Urgency

Prefabricated pavement edge drains are being used to a greater extent now than in the past. Due to installation problems, some agencies have eliminated these cost effective products from their specifications (Indiana, Illinois), while others have restricted their use (New York, Ontario). 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. Properly installed and specified, these products have proven to be a very cost effective means of increasing pavement service life.

Cost

The estimated cost of this research is \$250,000 over 3 years.

User Community

State DOT agencies, FHWA, FAA, and universities currently involved in geosynthetic research.

Implementation

The findings of this research should be distributed to all state DOT agencies, FHWA, FAA, and geocomposite edge drain manufacturers and installers for development of improved specifications and installation procedures.

Effectiveness

The implementation of the findings of this research will provide for better, more effective, and longer term performance of the geocomposite edge drains, resulting in longer pavement service life.

PROBLEM 109: METHODS TO MITIGATE PRECIPITATE POTENTIAL OF SUBBASE AGGREGATES

In the next several years, restoration, rehabilitation and reconstruction of our highways will be our major program effort. To accomplish this use of recycled PC concrete, rubblized or cracked and sealed PC concrete pavements and steel slags has proven to be an economical approach to provide granular materials for subbase and porous media backfill. However, it has been observed that porous media and underdrain pipes become encrusted with CaCO_3 (Tufa) precipitate which is formed by chemical reactions on the free lime inherent in these materials. This leached material has plugged the installed subsurface drains or blinded geotextile filters or wraps such that the free moisture becomes trapped in the pavement section causing early surface distress.

Objective

To develop methods to reduce the precipitate potential of recycled PC concrete, rubblized or cracked and sealed PC concrete pavements, and steel slags used as subbases.

Key Words

Rubblized, cracked, sealed, pavement, Tufa precipitate, drainage, slag.

Related Work

At present, some States are investigating the reasons that underdrain systems have failed and have recognized the above problem to exist. The University of Toledo is conducting research for the Ohio DOT to develop methods to identify the precipitate potential of subbase aggregates and offer potential methods to reduce that potential.

Urgency

There is a considerable benefit to be gained by keeping needed subsurface drains functioning throughout the

life of a pavement. With the use of recycled (waste) materials being economical, any detrimental effects on other entities of the pavement system should be corrected to obtain the most cost-effective installations.

Cost

The estimated cost of this research project is \$300,000.

User Community

The findings of this research should be distributed to all state DOT agencies, AASHTO, and FHWA.

Effectiveness

The implementation of the findings from this research will result in better design of subsurface drainage systems which will allow for continued use of recycled materials, and provide for longer pavement serviceability.

PROBLEM 110: APPLICATION OF AASHTO PAVEMENT DESIGN DRAINAGE COEFFICIENTS TO THE DESIGN OF FULL DEPTH ASPHALT CEMENT PAVEMENTS

The new AASHTO Pavement Design method uses a drainage coefficient in the design of concrete and aggregate base bituminous pavements to account for the effects of good, fair or poor subsurface drainage on pavement performance. Unfortunately, the coefficient is not applied to the bituminous layer, thus full depth bituminous pavements may be designed without taking drainage into account. In fact, the new design may encourage the use of non-drained full depth pavements in areas of proper drainage because this one pavement is not penalized by a poor drainage coefficient.

Objective

To determine the appropriate drainage coefficients to use with full depth bituminous pavements.

Key Words

Subsurface drainage, aggregate, performance, bituminous.

Urgency

The new AASHTO Pavement Design Guide will be in place in all 50 states within three years. It is absolutely necessary that drainage coefficients are in place for all pavement types before full implementation.

Cost

The estimated cost of this research is \$125,000.

User Community

The results of this research should be incorporated into the AASHTO Pavement Design Guide for use by state DOT agencies, FHWA, and AASHTO.

Effectiveness

The results of this research will provide for improved pavement design methods leading to longer service life and reduced maintenance costs.

PROBLEM 111: 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 objectives of the study are:

1. To define the various types of free-draining layers used in pavement systems.
2. To determine the effects of gradations and material characteristics on the layer performance.
3. To determine the permeability criteria for each type of free-draining layer to ensure pavement performance.

4. To develop standardized laboratory procedure(s) to measure compliance with permeability criteria.

Key Words

Permeability, self-cleaning, specification, test procedure.

Related Work

Some of the current activities include:

- Studies by the California Department of Transportation;
- Studies of open-graded base course gradation requirements by Pennsylvania, Illinois, New Jersey, West Virginia, North Carolina, and Wisconsin;
- Studies of open-graded base course performance by the Central Laboratories of the Ponts et Chaussées, France; and
- Numerous FHWA studies.

Urgency

While the influence of water in pavement systems has been well documented, the required permeability to ensure the desired level of pavement performance is not well documented and varies with region and specifying agency. Complicating the problem is that there is currently no standardized laboratory tests for measuring the permeability of the different types of materials used in pavement drainage layers.

Cost

The estimated cost of this research is \$225,000.

User Community

The results of this research should be distributed to all state DOT agencies, FHWA, and AASHTO. The laboratory test procedure to measure the permeability should also be submitted to ASTM for incorporation into their Book of Standards.

Effectiveness

The results of this research will lead to improved design methods and criteria, improved performance of the free draining layers, and lead to reduced maintenance costs.

PROBLEM 112: DEVELOPMENT OF A RAPID TEST METHOD TO DETERMINE IN-SITU HORIZONTAL PERMEABILITY OF UNBOUND MATERIALS

With the promulgation of free draining bases (FDB) in pavement design standards around the country, there arises the need to specify and determine the in-place horizontal permeability of these FDB materials, the desirable performance measure. Currently, 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, those materials finished on grade are generally non-homogeneous both through the depth of the layer and transversely across the pavement width. In particular, a number of Division Offices of FHWA have been encouraging State DOT's to specify a desirable minimum material permeability. 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 in. or greater.

Key Words

Coefficient of Uniformity, gradations, rapid permeameter, test procedure, specification.

Related Work

Insitu permeability measuring devices and procedures have been developed for dense graded bases.

Urgency

The need for this test method is immediate since State DOT's are already specifying and using FDB's.

Cost

The estimated cost of this research is \$115,000.

User Community

The results to be distributed to all state DOT agencies, FHWA, AASHTO, and consultant testing laboratories.

Effectiveness

This research will result in a standard test procedure which will allow uniform, consistent testing of free draining base material. The test results will be incorporated into the pavement design process leading to more effective and improved service pavements.

PROBLEM 113: PREDICTION OF DIFFERENTIAL ICING OR FROSTING DUE TO THERMAL PROPERTIES OF PAVEMENT STRUCTURAL MATERIAL

There is a nationwide push to adopt more permeable base materials to promote subsurface pavement drainage. Publications from Scandinavia indicate that such materials may result in differential icing conditions.

Objective

The study objective is to determine whether the solution to one problem, subsurface drainage, is producing another problem, differential icing. More specifically, the study must produce an analytical method (with real data input and verified by field studies) to predict whether differential icing will occur.

Key Words

Subsurface drainage, permeable base, analytical.

Urgency

The new AASHTO Guide strongly promotes subsurface drainage through the use of highly permeable bases. The highway engineering profession must assure itself that these measures are not creating a massive difficult to remedy, safety problem.

Cost

The estimated cost of this research is \$325,000.

User Community

The results of this research should be distributed to all users of the AASHTO Pavement Design Guide, all state DOT agencies, FHWA, and universities with geotechnical and pavement design studies.

Effectiveness

The results will either verify the validity of the current philosophy of subsurface drainage, or results in changes to the design procedures seeking to maximize drainage, while addressing the safety issues of differential icing.

PROBLEM 114: STABILITY OF OPEN-GRADED BASE COURSES

Although the benefits of well drained pavements have been clearly shown, there has been hesitancy on the part of practitioners to use open graded base courses because of concerns regarding stability, especially during construction. The stability of the open graded base course is a major consideration in the design and construction of this course.

Among the factors affecting the stability of open graded bases are aggregate gradation, particle angularity, and whether or not the base is stabilized with bitumen or portland cement. In general, the more stable a base course material is, the less free draining it is.

The optimal open graded base design provides both adequate stability and drainability at the least cost. Many different open graded base designs have been used. Information is needed regarding the stability (especially during construction), drainability, and costs of these bases.

Objective

Compare the stability under construction operations of various open graded base designs. Compare the drainability of various open graded base designs. Determine comparative costs of various open graded base designs. Develop selection criteria based on stability, drainability, and cost to determine the most economical designs of open graded base courses.

Key Words

Aggregate, gradation, particle angularity, bitumen, portland cement, drainability.

Related Work

Oregon has conducted research on the stability of stabilized and unstabilized open graded base courses. The cost of various open graded bases should be available from various state DOT's.

Urgency

The increased emphasis on the use of free draining open graded base courses makes development of economically oriented selection criteria of critical interest.

Cost

The estimated cost of this research is \$250,000.

User Community

The results of this research should be distributed to all state DOT agencies, FHWA, AASHTO, and universities with geotechnical and/or pavement design programs.

Effectiveness

The research will result in procedures which will optimize both stability and drainage of open graded base courses, while providing the most economical solution.

PROBLEM 115: DETERMINATION OF GEOTEXTILE SUBSURFACE DRAINAGE CHARACTERISTICS THROUGH MEASUREMENT OF LARGEST PORE OPENING AND PORE SIZE DISTRIBUTION OF GEOTEXTILES

Geotextiles are routinely used as filters in Prefabricated Geocomposite Edge Drains, Geotextile Wrapped Underdrains and Geotextile Socked Perforated Pipes for subsurface drainage. To ensure the adequate performance of these subsurface drainage systems, it is critical that the geotextiles should meet the permeability and retention criterion throughout the life of the structure. The ability of a

geotextile to meet these requirements is primarily a function of the pore-size distribution of the geotextile.

Despite the importance of the pore-size distribution of a geotextile, no method has been universally accepted. Available standard test methods (dry, wet, and hydrodynamic sieving) can only measure larger pore openings. The dry sieving method, which is currently the standard test method in the United States, is limited to testing thin, nonwoven geotextiles. In addition, the available test methods are time consuming and expensive. It has been found that the clogging potential of a geotextile is related to the finer pore openings of a geotextile. Therefore, a method is needed which can be used to measure both the larger and smaller pore openings accurately.

Recently, it has been shown that the bubble point method can be used to measure the complete pore-size distribution of a geotextile. In addition, this method can also be used to measure gas and liquid permeability and porosity of geotextiles. Preliminary results indicate that this technique is suitable for both woven and nonwoven geotextiles. The bubble point method is simple and rapid and provides reproducible results. The bubble point method has the potential to be accepted as a world-wide standard test method.

Objective

The overall objective of this proposed research is to evaluate the feasibility of replicating existing methods (pore opening and permeability) by a rapid and accurate method. The specific objectives of this research are as follows:

- Measure the larger pore openings of a variety of nonwoven and woven geotextiles using the bubble point method, compare the results with both dry and wet sieving results, and provide correlation factors between bubble point and sieving results;

- Measure the smaller pore openings and porosity of the geotextiles using the bubble point method and compare the results with image analysis results;

- Measure the liquid and gas permeability of the geotextiles using the bubble point method and compare the results with liquid permeability test results performed in accordance with ASTM D4491; and

- Develop a users manual describing the procedures to evaluate the larger pore openings, pore-size distribution, permeability and porosity of geotextiles with the bubble point method. The manual should also include typical results.

Key Words

Subsurface drainage, geotextile filters, pore-openings, dry sieving, wet sieving, bubble point method.

Related Work

The only related work in this area has been the evaluation of the performance of geotextiles in transportation-related drainage applications, such as in highway edge drains, selected retaining wall drains and erosion control systems. This study was performed at the Geosynthetic Research Institute (GRI) at Drexel University. The investigation noted completely clogged prefabricated geocomposite edge drains at several sites due to soil piping through the geotextiles. In this study no attempt was made to measure pore openings or porosity of the geotextiles.

Urgency

Geotextiles are consistently being approved and rejected solely on the bases of large pore openings provided by manufacturers. Manufacturers' data are based on results provided by the dry sieving method. Since this method has limitations, the data becomes questionable for some types of geotextiles. Since the smaller pore openings of the geotextiles are not provided, it is impossible to evaluate the clogging potential of geotextiles without performance testing. A simpler method is needed for the evaluation of the larger and smaller pore openings of geotextiles.

Cost

The estimated cost of this research is \$70,000 per year, for 2 years for a total of \$140,000.

User Community

This research will benefit designers, state DOT agencies, FHWA, researchers, and manufacturers.

Implementation

The results of this research should be distributed to all state DOT agencies, FHWA, and geotextile manufacturers. It should be available to all researchers.

Effectiveness

The implementation of the findings of this research will provide for better, more effective, and long-term

performance of geotextile filters, thus providing more effective subsurface drainage of pavement sections.

A2K07 COMMITTEE ON GEOSYNTHETICS

PROBLEM 116: SENSORS TO MONITOR THE LOAD IN GEOSYNTHETIC REINFORCEMENT

The structural contribution of the geosynthetic in geosynthetic reinforced embankments is usually unknown. When it has been measured, it is often significantly different from that determined theoretically. This problem is becoming more significant because of the need to use low quality fill in embankments and other structures reinforced with geosynthetics. Information obtained from monitoring the in-soil behavior of the reinforcement over time is needed to determine actual factors of safety for design strength and creep.

In addition, it appears that wide-width geotextile strength tests permit strain to develop over a much greater reinforcement length than that which develops in in-situ as deformation of the soil-geosynthetic system occurs. This produces incorrect geosynthetic tensile and stress-strain relationships for design. Use of the correct stress-strain relationships of the soil and geotextile could lead to a reduction of nearly 50% in the amount of geotextile required for the same safety of the wall.

Objectives

1. The development of a means of directly measuring and recording the load in the geosynthetic in reinforced structures such as embankments. Thus, frictional resistance can be calculated, and the relationship between earth pressure and load in the geosynthetic can be established. The measurement should not rely on indirect strain measurements because such measurements are influenced by stress relaxation.

2. Once the above information is available, evaluate geosynthetic strength tests currently used in design. If necessary, devise new strength tests to properly characterize operational strengths of textiles in deforming earth masses both during initial deformation and ultimately at failure. This should be confirmed with monitored field behavior.

Related Work

Some external deformation and geosynthetic strain measurements of reinforced structures have been made.

Urgency

Being able to document the load in reinforcing geosynthetics will allow the determination of the factor of safety. This will affect the rate of construction as well as being able to continuously monitor the stability of the structure.

Cost

Development costs \$350,000, site implementation and validation \$200,000 over 2 years.

PROBLEM 117: LIFE CYCLE PREDICTION AND COST IMPROVEMENT MODEL FOR USE OF GEOSYNTHETIC SEPARATORS AND REINFORCEMENT IN ROADS

A primary failure mechanism in roadways is loss of support due to the gradual intermixing of the subgrade and base course aggregate. The successful use of geotextiles to separate base materials and subgrade soils to maintain the integrity of the base is well established. Recent studies also indicate a potential to use geogrids and high strength geotextiles to reinforce the base, improving its support capacity. Although these concepts are sound, there is a lack of quantifiable performance and life prediction models, as well as a lack of effective implementation guidelines.

Objective

Quantify the performance improvement and the life cycle extension of roads constructed or rehabilitated with geosynthetic separators and/or reinforcement. Develop guideline implementation documents, defining life cycle costs and benefits of using geosynthetic separators and reinforcement in roads for the user community in design and in planning using pavement management systems.

Related Work

Several states have installed road test sections using geosynthetics. Some studies are well documented and include control sections. Little work has been done, however, on follow-up monitoring and reporting. FHWA has published a design manual for using geotextiles in paved and unpaved roads, but life cycle cost benefits of rehabilitating roads using geotextiles

have not been determined. Some research on road base deterioration caused by subgrade soil infiltration has been done by the Washington DOT.

Urgency

In light of ample evidence for the separation and reinforcement benefits of geosynthetics in roads, there is a great potential for saving construction and maintenance dollars for highway agencies. A study of this issue will reveal the lack of implementation of this simple, cost effective solution to most road problems. The benefits of geosynthetic use in roads and highways must be quantified.

Cost

The total estimated cost is \$125,000 over 1 to 2 years:

1. Perform a road improvement assessment, by reviewing existing reports on this concept and getting agency help to review and document additional case studies of existing roads which utilize geosynthetic separators and reinforcement. (\$50,000).

2. (a) Summarize how geosynthetics work in roads to improve the road performance. This should be based on existing literature; (b) quantify the extended life cycles for roads and the cost benefits associated with extended life cycles when geosynthetics are used. (\$75,000)

PROBLEM 118: GEOTEXTILE SEPARATORS FOR OPEN-GRADED BASES

Open graded or "drainable" pavement bases are being increasingly proposed to help mitigate pavement drainage problems and increase pavement longevity. However, there is significant doubt as to how long the drainability of these bases can be maintained because of infiltration of fine soil particles from fractures in the surface and by pumping from the subgrade.

Objective

Investigate the suitability of (1) encapsulation of open graded and drainable bases with properly designed geotextile separators, and (2) a properly designed geotextile separator only. The effects of initial aggregate placement and long-term performance characteristics of the geotextile should be investigated with emphasis on the permeability and drainage characteristics of drainable bases.

Related Work

Some work has been conducted on pavement edge drains at Purdue University and at Drexel University (GRI). Some research has been conducted by the University of Washington, Seattle on geotextile separators.

Urgency

As more and more open graded and drainable bases are being used, assurance of their long-term performance characteristics is very important. Premature failure of the pavement system due to contamination of drainable bases is exceedingly costly. However, if open graded drainable bases can be maintained throughout their normal pavement life, very large cost savings in rehabilitation of pavements are likely.

Cost

Approximately \$250,000 over two years.

PROBLEM 119: IDENTIFICATION AND COST BENEFIT OF METHODS USED TO REDUCE REFLECTION CRACKING IN ASPHALT OVERLAYS

Premature cracking of asphalt concrete overlays is a serious national problem. A number of different techniques have been employed in an attempt to delay premature cracking of an overlay. Techniques that have been tried include the use of paving fabrics, geogrids, special additives to the asphalt concrete, and the use of selected types of asphalt. The field performance of overlays using these techniques have ranged from clear successes to failures in which the modified overlay appeared to perform worse than non-improved overlay sections.

Objective

The objective is to identify the most promising existing techniques for delaying reflection cracking, then perform a detailed study of these techniques to determine their cost effectiveness. The research effort should include consideration of how much money is justified to spend on delaying reflecting cracking compared to other alternatives such as maintenance and sealing of cracks after they develop. Overlay design strategies that show the most promise include infiltration barriers (such as pavement fabrics and heavy duty membranes), and special asphalt concrete

stress relieving interlayers (either modified or not) and heater scarification.

Related Work

NCHRP Synthesis of Highway Practice #171 (Fabrics in Asphalt Overlay and Pavement Maintenance) gives a current summary of the current status of delaying reflection cracking.

Urgency

As the serviceability of the highway infrastructure continues to decrease, the construction of overlays will greatly increase in the future years. This project will help to identify:

- Justifiable levels of additional expenditures for delaying reflection of cracking; and
- The best available techniques for achieving this goal.

Therefore, the urgency is high because of the large amount of overlays that are anticipated in the coming years as a result of the ISTEA legislation.

Cost

Initial update of the synthesis is needed with emphasis on the cost effective alternatives: \$50,000 over 2 to 3 years. If additional research is necessary, it should be identified and carried out in the second stage. The second stage research would range on the order of \$200,000 to do laboratory and field tests to verify recommendations found in the initial study.

PROBLEM 120: EVALUATE GEOMEMBRANES TO CONTROL EXPANSIVE SOILS ON TRANSPORTATION FACILITIES

Expansive and/or frost-susceptible soils occur in over 40 of the 50 states. Their damage to transportation facilities, highways and streets, airports, railroads, buildings, canals, pipe lines, and sidewalks exceeds the \$10 billion a year estimate made a decade ago. Approximately 100 projects have been tentatively identified as using geomembranes to control this destructive action. Their effectiveness needs to be assessed.

Objectives

Locate projects which have used geomembrane encapsulated soil layers and similar structures to control expansive or frost-susceptible soils and secure information on the testing used, the construction practices, the bid price, the geomembrane chosen and reasons, the rate of placement, problems encountered, and subsequent evaluations. It may be necessary to do additional field evaluations to obtain performance characteristics and, therefore, cost benefit ratios. Once this is done, guidelines can be set up to more effectively apply geomembranes in the control of expansive soil damage to transportation facilities.

Related Work

Texas monitors 23 geomembrane sites, other sites are being monitored in Wyoming, Arizona, Bureau of Indian Affairs, Kentucky, Mississippi, Alabama, Georgia, California, Australia, Columbia, South America and China. A paper on Texas experience was presented at the 7th International Conference on Expansive Soils in August 1992. Membrane encapsulated soil layer test sections were installed in Alaska and New Hampshire in the 1970's as a means to control frost heaving and thaw weakening of frost-susceptible soils. They have not been monitored since.

Urgency

Clay shale and similar soils with destructive expansive capabilities as well as frost-susceptible soils continue to cause damage to transportation facilities that is expensive to repair. In addition, personnel who worked on older projects are retiring and important information is lost with their departure. As the need to improve our procedures increases (as do financial concerns), gathering of their knowledge and information is needed.

Large costs savings are available if the damage from expansive and frost-susceptible soils can be reduced or eliminated by this technique.

Cost

Estimated cost is \$150,000 over 2 years.

PROBLEM 121: DETERMINATION OF FACTORS OF SAFETY FOR INSTALLATION DAMAGE

A review of the literature that established widely used factors of safety for installation damage of

geosynthetics shows that in many cases there are no statistically significant differences between the mechanical properties of new products and exhumed samples. Since installation damage to geosynthetics has been documented, it is believed that the large variability in the product index properties has masked the effect of installation damage. Therefore, new, appropriate factors of safety should be developed based on sound statistical methodology. This is important because failures of the products due to installation damage could be critical.

Objective

Use statistically correct and relevant methods to calculate installation damage factors, then develop appropriate factors of safety for specific products based on their intended function(s).

Related Work

Some work is being carried out at the Royal Military College of Canada.

Urgency

Very urgent, design factors of safety against installation damage are important.

Cost

Estimated cost is \$150,000 over two years.

PROBLEM 122: MARGINAL SOIL USED IN RETAINING WALLS

Nonwoven geotextiles and geocomposites, with in-plane permeability, can provide drainage for backfill soils in retaining walls. This offers the possibility to use lower cost silt and clay soils (even when saturated) as backfill. Normally, geosynthetic reinforced retaining walls are constructed with free draining backfill; but use of lower quality fill would significantly cut the cost of the structure.

Objectives

The objectives are as follows:

1. To conduct research into both short- and long-term behavior of retaining walls built with fine grained backfill subjected to static and dynamic loading. (This

will probably include small and large scale model tests.)

2. To develop design procedures using soil and geosynthetic properties determined in conventional laboratory tests.

Related Work

Some related research has been done at the Colorado DOT and the University of Maryland.

Urgency

High because the potential cost savings by using clay and silt soils as backfill to construct retaining walls are extremely high.

Cost

The approximate cost is \$250,000 (for preliminary studies, centrifuge testing, and monitoring of field installations) over two years.

PROBLEM 123: SOIL GEOSYNTHETIC INTERACTION

Although geosynthetics are increasingly being used in the construction of reinforced retaining walls, slopes, and embankments on soft ground, the mechanism of interaction between the soil and geosynthetic reinforcements is not well understood. Preliminary studies indicate that several parameters affect interaction properties, but it is difficult to generalize for design purposes. Both long-term (creep) properties as well as dynamic properties require study.

Objectives

Determine both the short-term, including dynamic, and long-term behavior of geosynthetics in realistic soil reinforcing systems and environments. Studies of soil-geosynthetic friction, stress-strain behavior, and creep response are required, the interface characteristics of geosynthetics in contact with soils, rocks, aggregates, waste materials, etc., should be quantified. Develop realistic models of soil-geosynthetic systems and develop procedures for obtaining appropriate stress-deformation-time parameters for design.

Related Work

Some research is underway on this topic at MIT, LSU, Purdue, Drexel, University of Washington, University

of Colorado at Denver, and GeoSyntech consultants, among others.

Urgency

Very high priority. The economical use of geosynthetics in stabilization and reinforcement application is impeded by this lack of information. Replacing conventional retaining structures with reinforced walls and slopes can cut the cost of construction in half.

New products such as very high strength composites and geogrids are continually being developed. In critical situations, expensive full-scale, heavily instrumented test sections are the only way to verify design procedures. While such tests are extremely valuable, the design process could be greatly improved and reinforced soil structures could be made even more economical and reliable if soil geosynthetic interaction was fully understood.

Cost

The estimated cost is \$300,000 over two years.

PROBLEM 124: THE EFFECT OF COLD TEMPERATURE ENVIRONMENTS ON THE PERFORMANCE OF GEOSYNTHETICS

Very little is known about the performance of geosynthetics subjected to extremely cold temperatures. However, designers and installers believe that there is: (1) increased susceptibility to installation damages at temperatures below freezing, and (2) freeze-thaw degradation of some geotextiles. There is more clear evidence for geomembrane stress-cracking at extremely cold temperatures, although this problem is not completely understood.

Objective

To identify whether there is evidence for increased susceptibility of geosynthetics to damage during installation, storage and/or use at cold temperatures. This will consist of a survey of the literature and northern installations to document any known or suspected cold-related damage to geosynthetics. A summary of the work done to date on the known problem of geomembrane damage at cold temperatures will be included because there may be important links to the performance of geotextiles and geogrids in cold

regions. There will also be laboratory tests conducted to determine whether freezing and thawing can accelerate degradation of geotextiles and/or geogrids.

Related Work

Some work has been done to develop tests to predict the susceptibility of geomembranes to impact damage at cold temperatures. Past laboratory work was conducted on the freeze-thaw durability of geotextiles; but new products have been developed since and the tests could be improved to more realistically represent conditions in the field.

Urgency

It is extremely important to know whether installation damage factors of safety are different at cold temperatures, and whether we can expect a degradation of tensile strength of reinforcing materials at cold temperatures.

Cost

Approximately \$200,000 over 2 years.

PROBLEM 125: DETERMINATION OF THE EFFECTIVENESS OF GEOGRIDS IN STRENGTHENING PAVEMENT SECTIONS

Increasing traffic loads, increasing tire pressures and distribution of traffic patterns on multi-lane highways demand better pavement design than has been available in the past. Records clearly indicate that unacceptable distortion takes place in many of the country's pavements that were constructed without reinforcement. However, field trials indicate that there is improved performance with the use of geogrids in pavement sections, and this should be investigated further.

Objective

To perform literature and information searches on existing projects. Many projects are partially reported and require up-to-date assessments. New projects need monitoring and careful assessment. Practical construction site results should be correlated with significant laboratory studies that have taken place within the last decade. A comprehensive report should be prepared for designers that includes construction guidelines.

Related Work

Summaries and field trials have indicated improved performance with geogrids in pavement sections. Montana DOT is currently funding some research in the area. The work in this field needs to be coordinated.

Urgency

The urgency is very high in that we are rebuilding a major part of our Interstate and other transportation systems and the potential is there to increase the life of many of these pavements by introducing reinforcing now.

Cost

\$70,000 for a review and synthesis of known research for 1 year. \$180,000 to conduct the necessary laboratory test models, and plan appropriate field trials to verify conclusions over 2 years.

PROBLEM 126: PERFORMANCE PREDICTION FOR GEOTEXTILES BASED ON QUALITY CONTROL INFORMATION

An important problem facing users and potential users of geosynthetics is the prediction of long-term performance of the materials and the structures built with them. Lack of access to long-term performance in use information has contributed to the establishment of policies in some organizations and agencies that prevent geosynthetic use in permanent structures. The geosynthetic using community needs a framework for finding, assessing and using information pertinent to its interests.

The geosynthetic industry's experience has led to the following conclusions: (1) geotextiles have been successfully used for extended periods, (2) historical data concerning products exists in the files of the producers and (3) correlation of information in the historical archives with geosynthetics functions in use should be done. Textile producers have produced manufacturing product and process and quality control information for polymer, fiber, yarn and fabric for many applications—including aerospace, automotive, medical and geotechnical. This information includes, among other things, melt flow indices, tensile strength of fibers, yarn and fabrics, tensile modules of the fabric, mass per unit area and other product-specific information. Much of this information is related to acceptance and rejection criteria for both incoming raw material as well as

outgoing finished product and is typically referenced by the using industry.

Objective

The overall objective is to retrieve historical data on product quality and correlate it to functions in use. This correlation would permit a two-fold result. First, products designed using "today's" guidance as well as those designed earlier could be assessed in terms of fitness for use. Second, the end product of this work will be the successful prediction of behavior over time based on a large, statistically relevant body of data.

This correlation process be independent for each product class (i.e., needle-punched, heat bonded, woven, etc.)

The project will consist of the following phases:

1. Synthesize published data, details of exhumation and quality control information.
2. Collect and organize archived information, including polymer definition, fiber type, fabric construction and specific index properties.
3. Collect and organize application-specific design parameters and document cases of geosynthetics that have been successfully functioning for 10 years or longer.
4. Use information gathered in the first three phases to develop a body of statistically relevant data to establish clear relationships between process and product control data to functions in use.

This will help evaluate the effectiveness of current design guidance as well as permit the geotechnical designer to use geosynthetics with confidence in permanent structures.

Related Work

FHWA is currently conducting a durability study. Results will be available in 1997-1998 time frame. A protocol for field exhumation of materials, data gathering and analysis has been established and may be used in the proposed work. Work proposed herein should be well-coordinated with and take advantage of results published by the FHWA study.

Urgency

This is very urgent because of the cost savings that can be provided by geosynthetics use in permanent structures.

Cost

The approximate cost is \$150,000 over 2 years.

PROBLEM 127: USE OF GEOTEXTILES AND GEOGRIDS IN BRIDGE ABUTMENTS

Geotextiles and geogrids can potentially reduce the cost of abutments by strengthening the underlying materials and bridging the differential settlements that occur over soft foundations. They also can be used behind higher abutments to reduce the lateral load on the backs of the abutments and wingwalls. There is a great need to have a design methodology for these applications.

Objective

Develop a design methodology and construction procedures for the use of geotextiles and geogrids in bridge abutments, especially in rehabilitation and replacement of structures.

Related Work

Geogrids have been used in England for the construction of abutments of at least one bridge, more

recent work has demonstrated the ability of the reinforced soil mass to reduce the differential settlements and to reduce lateral stresses on the backs of walls. In addition, the Corps of Engineers has investigated the use of membrane encapsulated soil layers in bridge abutments. Nothing, however, has brought these together in a unified approach to design methodology.

Urgency

Tens of thousands of bridges on the local and state level are supported on low quality foundation soils requiring high costs of deep foundations. If the use of geosynthetics can be applied effectively, the potential of savings can reach hundreds of millions of dollars a year.

The potential exists to save \$50,000 - \$100,000 per abutment by using geosynthetics in the structure foundation or in the structure backfill.

Cost

Approximately \$225,000 over 3 years. This would include literature search, centrifuge modeling testing, development of a design methodology and testing in field applications by at least one instrumented design.

A2L01 COMMITTEE ON EXPLORATION AND CLASSIFICATION OF EARTH MATERIALS

PROBLEM 128: IDENTIFYING AND CONSERVING PRODUCTIVE AGRICULTURAL LAND IN ENGINEERING CONSTRUCTION

When the requirements for fill soil exceed the volumes available from the excavation on the site, the difference is commonly acquired by "Borrow" from adjacent acreage. While it is desirable to minimize the haul distance from borrow source to fill, the alternative uses of the land should be considered. A particular scenario to be avoided is the removal of valuable agricultural land from production in order to produce a construction fill. Either natural soil of lesser value, or industrial byproducts such as coal combustion ashes, spent foundry sands, or scrap tire shreds might be considered as a replacement.

Objectives

- Development of a rapid and simple procedure for the establishment of the value of natural soils as fill in vicinity of new construction sites.

- Identification of lesser valued soil or industrial byproducts within the vicinity or selected haul radius of the construction site.

- Development of procedure for identifying the costs of alternative and waste materials.

- Assessment of on-ground sensing and ratings that can be used by the project engineer for determining the relative values of industrial waste materials and lesser value fill soils.

Related Work

A. Work in progress. Modern construction siting and planning involves increasing attention to use of

digitized maps and data through the use of geographic information systems (GIS). Rating of agricultural land values using soil types, proximity to the construction, and identification of alternate industrial by-products are examples of GIS applications.

B. Related research activities. Ground sensing of more detailed agricultural soil parameters is being developed by "precision farming" researchers. An organic matter sensor has been developed and sensors are being tested for identifying soil texture and soil moisture. Agronomists have recently been defining soil quality and these interpretations can change soil definitions.

Urgency

Two benefits of enormous importance can accrue from such research activity: 1) increased food production capacity by saving prime agricultural lands and 2) a productive use of industrial discards as engineering substitutes for natural soils in fill construction rather than landfill disposal. Benefits will accumulate with time.

Cost

Development of the demonstration for the technology for selected pilot locations can be accomplished for \$150,000 over a period of 2 years.

A2L02 COMMITTEE ON SOIL AND ROCK PROPERTIES

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

PROBLEM 129: PAVEMENT WATER CONDITION AND EFFECTS ON SOIL AND AGGREGATE BEHAVIOR

Effects of water in saturated soil are relatively well understood from many geotechnical studies. However, pavements are built largely with and on partially saturated soil and the behavior of these near surface layers may have very significant effects on the pavement performance. Water conditions have also been shown to have a large influence on the support offered by granular sub-base and base layers. There is a clear need to be able to make clear predictions of the water condition and its influence on soil and aggregate behavior, but there is no organized source from which likely water conditions may be assessed, nor can the effect of moisture on material behavior be adequately predicted.

Objectives

The objectives of this research statement are to determine:

1. What water conditions exist beneath pavements in unbound aggregate and subgrade layers. It should be the aim to cover a broad range of soils, climatic regions and local topographic arrangements. Seasonal variation will be an important variable to describe.
2. The influence that these conditions have on the characteristics of the aggregate and subgrade properties of relevance to pavement performance.
3. The optimum effort to be put into sub-surface drainage systems in order to improve pavement performance in an economic manner.
4. Design guidelines which will allow a realistic assessment of water conditions and their effect on pavement performance.

Related Work

1. The first of these topics would need to draw on data from SHRP LTPP sections and from other sources, such as MnRoad, which is currently being obtained. Work on the effect of moisture on relevant aspects of aggregate behavior has been carried out by French engineers at LCPC. Less work has been carried out on soils in relevant, non-saturated, conditions.

2. Related research on the quality of pavement drainage systems is nearing completion and a new NCHRP contract on aggregate assessment testing has recently been let.

Urgency

The importance of this topic is both economic and environmental. At present good quality road building materials are quarried for construction and re-construction and used in volumes large enough to ensure adequate pavement performance under all credible sub-pavement water conditions. In many cases these lead to very conservative assumptions which, in turn, make necessary the use of thick, first quality aggregate in pavement layers. A more reliable and accurate assessment of subgrade performance could allow thinning of pavement layers in appropriate circumstances, and/or the use of marginal materials in construction - specifically the re-use of old pavement layers during re-construction schemes. This could result in less quarrying, less waste generation and more economic construction.

Further benefits would be to reduce the occurrence of pavement failure due to over-optimistic assumptions of subgrade condition and to enable drains to be constructed only in the most effective locations. Thus there is considerable environmental and economic urgency for this work. The work is likely to attract the support of other TRB committees, e.g. A2K06.

Cost

The estimated cost is \$300,000. A minimum period of 3 years would be required to obtain and interpret data, perform laboratory testing and to prepare design guidelines.

PROBLEM 130: SYNTHESIZE QUALITY ASSURANCE TESTS AND INSTALLATION PRACTICES FOR USE OF RECYCLED MATERIALS

Existing test methods and construction control procedures are not adequate to guarantee suitable long-term performance of earthworks constructed using recycled waste products. Some items that are commonly used in earthwork construction are recycled

concrete aggregate, recycled asphalt pavements, coal fly ash, rubber tires, recycled glass, and numerous other local recycling products. Many of these recycled products are contaminated by associated materials from their original sources, such as asphalt in the recycled concrete, asbestos in the recycled asphalt, paper and metal in with the recycled glass, and others. New test methods and acceptance procedures are needed to properly use these materials in a cost effective manner in transportation construction. Also, some of the materials do not respond like natural earthwork to compaction energies, vibrations, or seepage.

Objective

A number of states and private agencies have developed guides and test methods to allow them to make engineering decisions about suitability and long-term performance of these recycled materials in-place. This information needs to be thoroughly investigated and evaluated for suitability nationwide and the information disseminated in a central location for practitioners.

Key Words

Residual Materials, reuse, material performance, index properties, design guidelines, health and safety.

Related Work

There is numerous small research projects addressing specific concerns in certain areas of the recycling processes. These are not coordinated and may not be of adequate breadth of investigation to resolve the total spectrum of problems. I know of no coordinated effort to help judge the long-term performance of any of the recycled materials planned for construction in transportation facilities.

Urgency

As more local agencies are being pressed into recycling as an alternative to landfilling of various municipal wastes, our industry will be called upon to a greater and greater degree to recycle various products presently in the waste stream. This is already becoming very evident in the Northeast where there are governmental mandates of using certain percentages of recycled material in with the natural material presently being sold. It is imperative that we improve our understanding of the items that affect the long-term performance of products containing these

recycled materials before their installation, so that they can be adequately addressed.

Cost

The estimated cost is \$450,000 over 3 years.

PROBLEM 131: SOIL-GEOSYNTHETIC INTERACTION BEHAVIOR

Geosynthetics are increasingly being used in the design and construction of transportation facilities. However, in many of these applications, particularly in reinforced retaining walls and embankments of soft ground, the mechanism of interaction between the soil and geosynthetic is not well understood. Preliminary model studies indicate that there are several parameters which affect interface properties, but it is difficult to generalize these properties for design purposes. This makes economical and safe designs difficult and unreliable.

Objective

Conduct research in both the short term and long term behavior of geosynthetics in realistic soil reinforcing systems and environments. The actual interface characteristics of geosynthetics in contact with real soils, rocks, aggregates, waste materials, etc., should be quantified. This involves studies of soil-geosynthetic friction, stress-strain behavior, and the creep response of geosynthetics. Proper modeling of the soil-geosynthetic system and measurement of stress-deformation-time characteristics during loading is important. Realistic analytical model or models which account for these characteristics would be developed.

Key Words

Geosynthetic, geotextile, analytical modeling, waste interaction, laboratory simulation.

Related Work

Some research is underway on these topics at a number of universities (Oregon State, Purdue, Georgia Tech, Louisiana State, Drexel, to name a few) and private organizations (STS Consultants, Ltd.) in the U.S. Some research on this has been done in the past by CALTRANS, but few other state agencies are involved.

Urgency

Very high priority. The continued use of geosynthetics in stabilization and reinforcement applications is impeded by this lack of information. New products are continually being developed, including very high strength composites and geogrids. In critical situations, expensive full scale test sections are the only way to verify design procedures. While such tests are extremely valuable, the design process could be greatly improved and be made more economical if soil-geosynthetic interaction was fully understood.

Cost

The estimated cost is \$400,000 over 3 years.

PROBLEM 132: IN-SITU MEASUREMENT AND INTERPRETATION OF SOIL PROPERTIES—KNOWLEDGE BASED EXPERT SYSTEM DEVELOPMENT

There currently exists a number of in-situ soil tests which are being used to evaluate engineering properties. The numerous advantages of these tests are often offset by the fact that existing test interpretation techniques are based more on empirical correlation than upon theory. In many cases it is extremely difficult to assess the actual stress strain response of soil and thus not possible to include these characteristics in the interpretation scheme. A review of the available data reveals that cone penetration test (CPT) and dilatometer test (DMT) are the most valuable candidates for extensive use in transportation geotechnology from the viewpoint of practicality, economy and versatility. Vast amounts of local and mostly semi-empirical correlations concerning soil classification, soil strength/stability and compressibility do exist, but have not yet been comprehensively analyzed, cross correlated with theory, conventional testing methods and/or each other.

Objective

To develop better in-situ estimates of the design parameters required for identification, stability, and settlement analyses of both foundations and earth slopes. This research should involve both natural deposits, and samples prepared in laboratory calibration chambers. A knowledge-based expert system should be developed to cross-correlate and manage the data, self-updating itself with future additional input information.

Key Words

In-situ tests, CPT, DMT, soil strength, compressibility, stability, classification, expert system analysis.

Related Work

A number of independent research projects concerned with experimental and theoretical aspects of a wide variety of in-situ testing methods are active in US (UC, Texas A&M, LSU, UF, Purdue, MIT, UBC) and Europe (Oxford U., NGI, ENEL, Groenoble U). Calibration chamber testing has been more extensively pursued in Europe, (UK, France, Italy, Norway), and to a less degree in US (UF, VPI). Knowledge based expert system development, although widely used in other fields, is only recently been introduced into soils related work.

Urgency

Reduction or total elimination of disturbed/undisturbed soil sampling and many strength/deformation tests, utilized in answering geotechnically oriented problems of transportation facilities will result in great savings. To achieve this goal a good number of DOT's are turning into in-situ testing methods. It would thus appear that a better understanding of the geotechnical parameters provided by two of the most promising candidates (i.e., CPT and DMT) of these methods, together with a "smart" data correlating and managing expert system is timely.

Cost

The estimated cost is \$250,000 over 2½ years.

PROBLEM 133: UNIFIED APPROACH TO INTERPRETATION OF IN-SITU TESTING

Current methods for interpreting the results of in-situ tests (cone penetration, standard penetration, vane shear, full-displacement pressuremeter, piezocone, flat dilatometer, stepped blade, spade cells) in soils utilize a different theoretical model for each of the different tests. Common theories invoked for this purpose include: limit equilibrium, plasticity, elasto-plastic models, cavity expansion, finite elements, strain path method, and flow field solutions. In addition, an overabundance of empirical approaches have been developed as well. The consequence is that the interpretation of soil properties by practicing engineers often leads to improper usage, inconsistent results, confusion, and uncertainty in assessing the ground.

Objective

Since each of the aforementioned in-situ tests results in similar high-disturbance effects upon insertion, it should be intuitively expected that a single theory could be used to quantitatively describe all of these tests. Possibly, several of the theories are capable of this task. Several series of calibration chamber tests on laboratory soil deposits can be directed at investigating the interrelationships between the in-situ test devices. Numerical and analytical modeling can be applied to the results of these controlled-environment tests. In addition, the models can be calibrated against field and laboratory data already obtained from a number of well-established and well-documented international experimental test sites.

Key Words

Test Interpretation, In-Situ Testing, Calibration Chambers, Soil Properties, Constitutive Modeling, Numerical Simulation, Theoretical Soil Mechanics.

Related Work

Pursuit of unified-theory approaches have been initiated at Massachusetts Institute of Technology and Georgia Institute of Technology. Calibration chamber tests investigating different in-situ devices are underway at Clarkson University, Louisiana State University, and Virginia Tech. A recent NSF Workshop at University of New Hampshire (1988) has cited at least 77 potential locations for designation as one of the few U.S. National Geotechnical Test Sites for experimentation. Both FHWA and NSF have allocated funding for the latter.

Urgency

High priority. Continued use of mixed bag of correlations and methodologies results in scattered and varied interpretations. Consequence is that geotechnical consultants choose lower bound (or upper bound) of solutions, resulting in unnecessary overconservatism or unsafe underconservatism, depending upon the particular situation (permeability characterization, foundation evaluation, embankment construction, etc.).

Cost

The estimated cost is \$200,000 over 2 years.

PROBLEM 134: EVALUATION OF SOILS AFTER TREATMENT BY GROUND IMPROVEMENT TECHNIQUES

Most of the correlations for soil properties from in-situ techniques such as the SPT, CPT, PMT, etc., have been determined from either laboratory tests on undisturbed samples or in a few cases, full scale field performance. When these devices are used to evaluate sites which have been treated by soil improvement techniques, the old correlations are necessarily used. There is some evidence that these correlations may be inappropriate for treated ground, apparently because of modifications to the soil structure caused by the treatment. There is a need for research to either verify that the present correlations are reasonably correct or to develop new correlations.

Objective

To verify and/or develop new correlations for important soil properties as determined by various in situ techniques in ground which has been treated. These devices are either commonly used for in-situ tests or geophysical tests such as cross-hole dynamic tests.

Key Words

Ground modification, in-situ soil evaluation, geophysical testing, dynamic testing, laboratory testing.

Related Work

There has been some limited research in this area at some universities (Florida and California) and private organizations (GKN, Inc.).

Urgency

Urgent because of the potentially unconservative nature of uneconomical use of existing correlations.

Cost

The estimated cost is \$450,000 over 3 years.

PROBLEM 135: PREDICTION OF AXIAL CAPACITY OF FRICTION PILES BY IN-SITU TECHNIQUES

Present trend of US DOT's is to emphasize in-situ testing and more particularly CPT, as demonstrated by previous or pending purchase of fully equipped CPT vehicles and related equipment by several DOT's, and

more particularly, Florida, California and Louisiana DOT's.

DOT's and FHWA are aware of the need to also improve analytical capabilities with regard to the ability to predict pile capacity and behavior with more confidence. FHWA funded large pile test programs at the University of Houston in over-consolidated clays and in San Francisco in medium dense sand. As regards the latter, ten experts were invited to predict the load capacity, load distribution and load-settlement behavior of a single axially loaded control pile and an axially loaded group of fifty stiffly capped piles of the same design as the control pile. As demonstrated by the results of these predictions (presented at the June 17-18, 1986, Pile Group Prediction Symposium), none of the predictions adequately predicted the observed behavior.

Objectives

■ Demonstrate the use and capabilities of a battery of in-situ tools which can be deployed with a CPT vehicle.

1. Friction cone and piezocone (stratigraphy and engineering properties);
2. Instrumented model piles (pile shear transfer parameters);
3. Dilatometer (in-situ state of stress);
4. Self-boring pressuremeter (in-situ strength and deformation parameters); and
5. High quality sampling (26 and 66 mm samples for confirmation of stratigraphy and cross-correlation with conventional laboratory testing).

■ Develop a data bank for DOT's use in designing friction piles. The data bank will be placed on a microcomputer for cross-correlation and will be an evolving relationship which "self-improves" with the continuous gathering of data.

■ Develop improved and designer oriented.

1. Stratigraphy identification;
2. Classification of soils;
3. Soil parameters determination in-situ;
4. Hydraulic conductivity; and
5. Pile capacity methods.

As regards the latter, the present trend, as also realized by FHWA and state DOT's, is to move away from limit equilibrium methods in favor of load-deformation methods which recognize the deformation characteristics of pile foundations.

Keywords

In-situ tests, CPT, DMT, PMT, instrumented model pile, pile capacity, load-deformation, expert system analysis.

Related Work

There has been a number of recent projects (mentioned above) on "pile capacity prediction". However, the extent of involvement with in-situ testing techniques and development of knowledge-based expert systems have been minimal, if not non-existent.

Urgency

Although the ability of the geotechnical community to characterize a site is improving with the use of in-situ tools such as the CPT, and the ability to implement complex analytical methods has made great strides with the use of computers, pile capacity prediction methods, particularly for friction piles, are lagging far behind. This state of affairs is recognized by both state and federal highway design teams which would make this topic a top priority "Research Need".

Cost

The estimated cost is \$500,000 over 3 years.

PROBLEM 136: IN-SITU DETERMINATION OF GRANULAR SOIL FABRIC

Recent studies have concluded that the concept of "fabric" provides a much more reliable description of the state of granular soils. According to Oda (1978), the fabric for a macroscopically homogeneous sample of granular material should include a measure of the orientation of individual particles (orientation fabric) and a measure that reflects the mutual relationship of individual particles (packing). Previous studies in soil fabrics have concentrated on either numerical analyses or laboratory experiments. Of special interest is that small strain resonant column tests or the shear wave velocity can be used as an indirect but reliable measurement of soil fabric.

It is extremely difficult, if not impossible to obtain undisturbed samples of granular soils. Thus, the above development can not be readily applied to solving geotechnical engineering problems (i.e., liquefaction potential, foundation design ... etc.) unless a practical in-situ testing method can be implemented. Among the possible in-situ testing methods, the seismic cone appears to be the most promising. The cone tip resistance is known to be influenced by the void ratio and in-situ mean normal stress. Void ratio is strongly related to the average coordination number (one of the fabric parameters) in a granular mass. The added seismic capability provides shear wave velocity measurements in the vertical plane. However, to fully establish the fabric parameters, it is necessary to measure the shear wave velocity in the horizontal plane which has not been reported.

Objective

The objective of this research is to develop a practical technique to characterize granular soils in terms of fabric parameters. This should include laboratory experiment in a calibration chamber and field verification.

Key Words

In-situ tests, SCPT, granular soils, bearing capacity, liquefaction.

Related Work

Studies that relate shear wave velocity to stress anisotropy in granular soils have been conducted at the University of Texas. Research work on the relationship between shear wave velocity and soil fabric has been done at Cornell and now continued at Old Dominion University.

Urgency

Urgent because of the crude nature of the current practice in characterization of granular soils

Cost

The estimated cost is \$300,000 over 3 years.

PROBLEM 137: ENGINEERING CHARACTERIZATION AND DESIGN METHODOLOGIES FOR WEAK ROCK AS A TRANSITIONAL MATERIAL BETWEEN SOIL AND STRONG ROCK

Weak rock is present near the ground surface over large areas of the U.S. Engineering property characterization methods vary across the country, and most design methods are empirically based and locally applied. Attention has been directed in the past to establishing a unified classification basis for clay-shales, but certain aspects of engineering response are poorly defined even for these studied materials. Other weak rock lithologies have been studied more often on a site-specific basis. Design methodologies are far from consistent.

For a unified engineering design concept, engineering characterization of weak rock should be viewed as defining the gap between accepted procedures for soil and rock materials. A systematic study of property changes will be important for rational

design of all civil structures including slopes and cuts, foundations, and underground excavations.

Objectives

1. Conduct a national and international search to identify techniques and tests used for weak rock characterization, and to obtain design methodologies in use.

2. Investigate relationships among weak rock properties in the context of transitional materials, using soil and rock data bases as "end members" in a continuum of geologic material property variations.

3. Critically compare and contrast identified engineering tests and design methodologies. Conduct a testing program for direct comparison of the results of different tests in uniform lithologies.

4. Make recommendations on rational exploration and design approaches to serve as guidance for state and national agencies.

5. Identify weaknesses in the current understanding to serve as foci for future research efforts.

Key Words

Weak rock, rock, engineering properties, classification, strength (tensile, compressive, shear), compressibility, stability design methodology, foundations, slopes, tunnels.

Related Work

A number of research projects in the past have been conducted towards the elucidation of the behavior of clay-shales. The use of a continuum approach in data analysis has not been attempted, and should yield immense rewards.

Urgency

Inconsistencies and uncertainties lead to limited understanding and conservative design. The development of an integrated set of recommendations for exploration, testing, and design in weak rock will result in increased economy and truly engineered design.

Cost

The estimated cost is \$400,000 over 3 years.

A2L03 COMMITTEE ON PHYSICO-CHEMICAL PHENOMENA IN SOILS

PROBLEM 138: BIOREMEDIATION FOR TRANSPORTATION INDUSTRY CLEAN-UPS

Fuels, lubricants and solvents handling are mainstay activities in the transportation industry. Wherever these materials have been, or are in use, leaks, spills, and other uncontrolled releases of these compounds into soil and groundwater are frequent. Most of these sites pose significant environmental consequences and require remediation. While options for remediation abound, the objectives for remediation remain to clean-up the site, at a minimum cost, in the most rapid time frame. For hydrocarbon compounds such as fuels, lubricants and solvents, bioremediation offers a methodology to accomplish these ends. A wealth of information regarding bioremediation exists; however, additional knowledge (particularly in terms of applicability to specific compounds and mixtures, field conditions and field performance) is required. Specific contaminants (chlorinated compounds) may naturally degrade into more toxic compounds (vinyl chlorides) and require modification of normal bioremediation approaches. A greater challenge exists to make the transportation industry aware of the potential role for bioremediation of dominant contaminants in the industry's sphere of operations. With cost frequently a driving consideration, the U.S. Environmental Protection Agency is encouraging innovative technologies and risk based corrective actions. To best apply remedial funding, the EPA has embraced a defensible approach toward intrinsic remediation, or natural attenuation.

Objective

The overall objective is to make the transportation industry aware of the potential for bioremediation of contaminated sites and to provide the industry with a ready reference regarding bioremediation techniques, its applicability and cost.

The following intermediate objectives are in support of this objective:

1. Identify the magnitude of hydrocarbon contamination in the U.S. transportation industry. Breakdown the sites into: Highways, Railways, Shipping, and Air transport.

2. Summarize and characterize bioremediation techniques that are currently available. This includes breaking them into intrinsic/monitoring treatment, in situ treatment and ex situ treatment techniques.

3. Develop an applicability scheme. The deliverable will include a quick reference chart or

tables for transportation industry personnel to assess which bioremediation approach is best suited to their contaminant, site conditions and project constraints. This may also include software for AI-assisted bioremediation approach selection. The following elements should be included in the applicability evaluation.

- a. Hydrocarbon waste characterization—LNAPL vs. DNAPL, chlorinated, types of compounds, dissolved vs. separate phase vs. gaseous, unsaturated zone vs. capillary fringe vs. saturated zone.

- b. Hydrogeology—depth to water table, air/water/separate phase permeability, geochemistry, porosity, bulk density, etc., grain size, blow counts (ease of drilling),

- c. Site use and access—paved, traffic (drilling safety), engineered subgrades (hard to drill, etc.), downgradient water supply, downwind receptors, and

- d. Microbiological potential—oxygen versus anaerobic, nutrients, moisture content, toxic concentrations, any characterized microorganisms, microcosms, etc.

4. Develop a program for disseminating the bioremediation technology selection information to federal, state and local transportation authorities, their consultants and contractors.

Related Work

There is abundant activity in bioremediation research ongoing throughout the academic community and some private work as well. These efforts are supported by a variety of sources including the National Science Foundation, U.S. Environmental Protection Agency and the U.S. Department of Defense. All of these efforts are important to assure the success of bioremediation. Most are aimed at a specific contaminant or site conditions or other problem of narrow focus. None of the activities (to this writer's knowledge) focus on the broad spectrum of transportation industry contaminant challenges.

Urgency

This is an immediate issue for the transportation industry. Every agency, public and private, involved in the transportation field, is faced with remediating contaminated sites sooner or later. Bioremediation represents an existing tool for performing some of these remediations and it may very well represent the

most effective, least costly and speediest technique for doing so. Responsible agencies who delay the initiation of remediation projects face ever increasing costs not only from the ever increasing inflation but also from a potentially expanding plume of contaminated soil/water. Getting the knowledge of bioremediation into the hands of transportation industry personnel and a tool for selecting and prescribing the best technique will go a long way in holding down costs for remediation projects.

Cost

This project is estimated to require \$300,000 to complete within 3 years.

PROBLEM 139: CONTAMINANT EFFECTS ON SOIL PROPERTIES

Contaminated soils are common place in the transportation industry—pipeline leaks and refueling spills are merely two examples of countless possible scenarios by which soils become contaminated. Clean-up of the contamination is always a concern, but another concern that may be more immediate is knowledge of the effects that contaminants may, or may not, have on the engineering properties of the soil being contaminated. At the 1992 TRB Annual Meeting, several highly successful sessions on the engineering properties of primarily waste materials were convened (TRR No. 1345); however, the information presented does little to address the potential for change in soil/rock properties as these materials move from a clean state to a contaminated one. If strength, compressibility or permeability of earthen materials are going to change with respect to becoming contaminated, than it is of paramount importance to be able to anticipate the changes and incorporate them into designs or analyses of transportation facilities.

Objective

The main objective is to determine if transportation industry contaminants should be a concern for geotechnical designs and analyses of facilities.

The following intermediate objectives are in support of this objective:

1. Identify the key transportation industry contaminants, likely to be soil/rock borne.

2. Identify the effects of the contaminants on soil/rock properties including but not limited to Shear Strength, Compressibility, Permeability, Creep, Corrosion.

3. Evaluate the potential impact on service life of transportation facilities due to changes in soil/properties resulting from contamination.

Related Work

TRB served as the focal point for research on physicochemical properties of soils beginning in the 1950's and extending into the late 1970's. Much of the knowledge generated through these efforts are directly and indirectly applicable to our understanding of the role contaminants play in impacting soil properties. About 1980 or so, focus shifted to "geoenvironmental" properties of soils and these efforts centered around groups like the U.S. Environmental Protection Agency and other environmentally oriented groups. Research focused on landfills and waste containment not on engineering properties of soils and rock which might have greater bearing in the transportation industry. The knowledge gained through both these focused efforts can and should be brought to bear on the current objective—to determine if transportation industry contaminants should be a concern for geotechnical designs and analyses of facilities.

Urgency

There are several failures of waste-related facilities due to contamination subsequent to construction. These are primarily manifested in excessive permeabilities; however, there are a few cases of mass-movements (slope failures, slips). The latter are more likely to be examples of manifestations that greatly impact the transportation community. Although none of these directly involved the transportation industry, as the industry expands and encompasses more lands and greater activities, there becomes ever increasing probability that lack of consideration for the impact that contamination has on soil/rock properties (especially in the long term) will result in economic losses for the industry. Thus, while the urgency is not immediate, it is none the less growing.

Cost

This project is estimated to cost \$300,000 to complete within 3 years.

A2L04 COMMITTEE ON FROST ACTION

PROBLEM 140: EFFECTIVENESS OF LOAD RESTRICTIONS

Load restrictions are commonly used to limit pavement damage on thaw weakened roadways. However, load restrictions cost the public by reducing the load carried by a single truck. Rarely, load restrictions eliminate damage. The overall cost of load restrictions is not understood.

Objective

The objective of this study is to better understand the cost of load restrictions to the public and the effectiveness of load restrictions. Individual objectives are:

1. Establish the effectiveness of load restriction in reducing pavement damage.
2. Estimate the cost of load restrictions to the public.
3. Relate the effectiveness and cost to the public.

Related Work

Many agencies have load restrictions policies and procedures. In most instances, these policies have been in use for many years. However, few agencies have reviewed the effectiveness of their load restriction program.

Urgency

Many of the load restriction policies may unduly cost the public in increased transportation. In other instances, the load restriction policy may not be adequately protecting the roadway system. By gaining a better understanding of the cost of load restrictions and their effectiveness, agencies can revise their policies to maximize protection while minimizing the cost to the users.

Cost

The estimated cost to complete this research is \$300,000. The anticipated duration of this project is 2 years.

PROBLEM 141: MECHANISTIC DESIGN OF PAVEMENTS IN SEASONAL FROST AND PERMAFROST AREAS

Damage to pavements in seasonal frost and permafrost areas may vary widely from one week to another and from year to year due to extreme variations in the strength of the supporting layers caused by freezing and thawing conditions. As a result of these changes in strength, the accumulation of traffic-associated damage increases dramatically during periods of low-strength. The 1986 AASHTO Guide for Design of Pavement Structures recommends using the resilient modulus of each layer to determine the required structural thickness. The Guide contains an overall concept for the design of pavements in seasonal frost areas, but does not provide detailed guidance.

Objective

The general objective of this research is to develop a detailed mechanistic design procedure for pavements in seasonal frost and permafrost areas. Individual objectives are:

1. Develop a method for estimating changes in moisture contents and temperatures with depth and time. This objective will allow computation of the resilient modulus of supporting soils with time.
2. Apply linear or, preferably, nonlinear layered elastic models to compute stresses and strains at critical positions in the pavement system.
3. Develop a data base containing changes of strength of a variety of soils in frozen, thawing and recovered conditions
4. Apply, refine or develop damage models for flexible and rigid pavements in cold regions. Fatigue relationships which have been developed for asphalt concrete pavements not subjected to temperatures below about 40° F may not be applicable to colder temperatures.

Related Work

CRREL is developing a procedure that follows these general guidelines. Supporting this development are the Corps of Engineers, the Federal Aviation Administration and the Minnesota Department of Transportation. The Alaska Department of Transportation and Public Facilities and many of the Scandinavian countries are developing similar procedures. The Strategic Highway Research Program

(SHRP) is embarking on the study to obtain field data to quantify changes in pavement strength in seasonal frost areas. SHRP does not plan to develop a related design procedure for seasonal frost areas, however.

Urgency

There is no coordinated program to develop design methods for pavements in seasonal frost and permafrost areas. This causes some duplication of effort, but also unfortunately, results in inadequate data in other areas of development. The procedure developed under this research will be widely used by state DOT's and federal agencies.

Cost

The estimated cost of the project is \$500,000 for the duration of 3 years.

PROBLEM 142: CHANGES IN PAVEMENT STIFFNESS INDUCED BY FROST ACTION

Moisture changes and other effects induced by freeze-thaw cycles can significantly alter the strength and stiffness properties of flexible pavement layers (notably the unbound base course and subgrade soils). These effects can markedly change the pavement performance. The 1986 AASHTO Guide for Design of Pavement Structures can accommodate, to some extent, such seasonal material property changes. For existing pavements, knowledge of these seasonal changes are needed to assess the requirement (or lack of) for load limits. The problem is essentially a lack of knowledge on how the resilient moduli of flexible pavement layers change due to freeze-thaw effects and how to best estimate these changes.

Objective

The general objective of this research is to determine methods for characterizing the effects of frost action on the stiffness of unbound base courses and subgrade soils. The specific objectives are:

1. Determine and describe current laboratory and field procedures for evaluating the stiffness of flexible pavement layers.
2. Develop new procedures, as needed, to determine the stiffness of pavement layers in all conditions (frozen, thawed, etc.) The primary emphasis is expected to be on nondestructive field testing and appropriate analysis (such as backcalculation of moduli).

3. Develop, if possible, predictive models of layer stiffness (moduli) in terms of readily measured soil properties.

4. Validate the stiffness models by means of controlled laboratory and field tests.

5. Couple the stiffness models with pavement response and performance models for use in *design, evaluation, and operation* (such as the need for load restrictions) of pavement structures affected by frost action.

6. Illustrate how frost action can influence pavement performance for various types of pavement structures in various locations (climates).

7. Develop an initial data base of layer moduli for various pavement types and conditions (frozen, thawed, etc.).

These objectives can be best accomplished within the framework of two or more research studies.

Related Work

Frost Research in Progress

1. The FHWA has issued several RFP's recently which can contribute to the proposed research (such as determination of *in situ* layer moduli, etc.).

2. The FHWA has contracted with the Washington State Department of Transportation to develop a training videotape on conducting laboratory triaxial resilient moduli tests.

3. Prior work in Alaska, Minnesota, Washington State, Pennsylvania, New York, and Alberta on field sites and seasonal material changes is important and will assist in focusing the research.

4. Both at CRREL and various universities, such as the University of Illinois, Cornell, Oregon State and the University of Washington (to name only a few), laboratory triaxial tests and NDT/backcalculation techniques have been used to determine seasonal stiffness values. This information will be extremely helpful to the proposed research.

Key Words

Frost action, freeze-thaw, thaw weakening, resilient modulus, soil stiffness, load restrictions, load limits, pavement response, pavement performance.

Urgency

There is no widely accepted method to accurately account for the significant reduction in pavement layer stiffness due to frost action, and hence there is a critical need to help agencies determine seasonal

moduli for pavements in various conditions (frozen, thawed, etc.). Such moduli and associated pavement analysis techniques are urgently needed to improve *pavement design, evaluation, and operation* practices in seasonal frost areas.

Cost

The estimated cost is \$350,000 over 3 years.

PROBLEM 143: MEASUREMENT OF MOISTURE CONTENT AND/OR MOISTURE SUCTION IN SOILS

The moisture content of solid influences many soil properties including the thermal conductivity, the volumetric heat capacity, the latent heat of fusion, the resilient modulus, the compressive strength and the hydraulic conductivity. No equipment exists today which can be installed beneath pavements, behind retaining walls or in soils related to other transportation facilities which will reliably measure the moisture content or soil moisture suction for several years. A variety of devices are available, but none maintain their calibration for a reasonable period of time, especially when subjected to freezing and thawing conditions.

Objective

The overall objective of this research is to develop a device which can be used to measure the moisture content or soil moisture suction of a variety of soil types over a wide variation in moisture contents in freezing and thawing conditions.

Other related objectives of the effort include, minimizing the size of the device, developing a procedure for calibrating the device and establishing the reliability, accuracy and repeatability of observations from the device.

It is desirable, but not necessary, that the device will be small enough to be installed in two-inch diameter, or smaller, laboratory soil samples as well as in field sites.

It is most desirable to measure moisture suction with the device, but a device which will measure moisture contents accurately is acceptable.

The device should measure the moisture content of a variety of soils, from coarse sands to highly plastic clays within an accuracy and repeatability of + or - 2.5 percent by volume. If pore pressures are measured, the sensitivity and accuracy should be + or - 10 cm of water for pore pressures less than 1000 cm of water and + or - 20 cm of water above that level.

It is also desirable, but not necessary, that the device be capable of responding to rapid transient changes such as those resulting from vehicular loadings. This will be applicable to devices that measure pore pressures.

These objectives can be accomplished with one or two research studies.

Related Work

The Federal Highway Administration, the Strategic Highway Research Program, the Corps of Engineers, the Minnesota Department of Transportation, and several other state departments of transportation are installing instrumentation in pavements to monitor pavement performance. A variety of moisture sensors have been installed by this group, but none of the devices are expected to provide reliable data for more than a few months. No data have been published by any of these projects.

Urgency

Although the agencies listed above have installed moisture sensing devices, none expect substantial success in the measurement of moisture contents or moisture suctions. None of these agencies have a current project to develop an improved device. The accuracy of the installed sensors is uncertain. The fact that a wide variety of equipment has been used indicates that no one piece of equipment is widely accepted. In the next few years, many more SHRP test sections will be instrumented and many more DOT's will install equipment to quantify the behavior of pavements when validating the use of mechanistic design methods.

Cost

The estimated cost of this project is \$400,000 over 4 years.

PROBLEM 144: DESIGN OF PAVEMENTS FOR RESISTANCE TO FREEZE-THAW DAMAGE

Accumulated fatigue and rutting damage to asphalt pavements from freeze-thaw conditions may vary widely from day to day and year to year, due to the extreme temporal variations in the strength of the supporting layers. As demonstrated by the AASHTO Road Test, nearly all load related damage can occur in the few days or weeks it takes for thawing and strength recovery of the unbound layers in a typical pavement structure. The latest AASHTO Guide for Design of

Pavement Structures recommends use of the resilient modulus concept with "appropriate" values for each layer, in determining the required layer thicknesses for pavement, base and sub-base. However, details are lacking on how to rationally select appropriate modulus values for frozen and thawing layers in a partially thawed, saturated pavement structure in which drainage of water is usually blocked by underlying frozen soils.

No accepted laboratory procedures exist for the routine testing of soils to determine their probable stress/modulus relationships. Finally, field deflection test data from typical pavements, taken at times of active thawing and maximum strength losses, is very rare and not well correlated to material properties. In the absence of good information on rational design procedures, overly conservative design assumptions and material specifications are commonly used, which often increase project costs.

Objectives

The primary goal is the development, and acceptance by AASHTO, of a rational seasonally adjusted mechanistic design procedure for flexible pavements in areas which experience significant freezing and thawing on an annual basis.

Other objectives are to:

1. Develop field methods for the measurement of resilient modulus values based on back-calculations from FWD test data in recently thawed and thawing pavement structure layers and relate these modulus values to those of the same layers in the subsequent fully thawed, drained and reconsolidated state. Measure field moisture contents at the times of field tests through repeated borehole sampling or buried moisture sensor methods.

2. Develop a data base on the actual measured changes in resilient properties of pavement layer materials from freezing and thawing; then relate these changes to the soil types, gradations and moisture content and availability factors for use by others in selecting appropriate modulus values for frost design purposes.

3. Develop new or refine existing damage models for flexible pavements undergoing seasonal thawing, to account for the low modulus of thawing structural layers, the presence of shallow, underlying, rugged layers of frozen ground and the low resistance to fatigue of asphalt concrete at the typically low temperatures during mid-winter thaws or spring thaw events.

4. Apply elastic response analysis methods to actual road segments where field modulus test data was taken during thawing periods, and compare predicted performance and damage with actual

measured pavement distress. Then, adjust the analysis models as appropriate to match predictions to reality.

Related Work

The Minnesota DOT, in its MinnRoad Test Program, has initiated a site and soil specific study of the seasonal variations in resilient behavior of selected pavement types. The SHRP seasonal GPS pavement study site program has a goal of measuring freeze thaw depths, moisture contents, frost heaving and resilient field responses to load by FWD testing during all months of the year, which will provide a start on a data base. However, the long time between FWD tests (monthly) may miss the thaw weakened period. Finally, CRREL has an overall goal of developing an elastic analysis procedure for seasonal damage analysis of military roads and airfields.

Urgency

Existing SHRP GPS and SPS study sites are present and usable in most states and are a valuable resource in which much of the necessary field sampling work and pavement and soil property and thawed modulus testing work has been done and recorded. However, the present SHRP GPS data base, which could be a very valuable asset, is useless for the required work on this proposed study unless supplemented by further and more intensive FWD test data. *Unless the proposed studies are initiated quickly, the SHRP sites will all be reconstructed or dropped from ongoing data collections, and the value of the data base will be lost.*

Pavement design analysis work for seasonal freezing and thawing conditions is a primary activity in most of the U.S. and Canada. Improper designs cost millions each year in early damage or overly costly construction. The actual measurement of springtime strength levels for use in such pavement design analyses is almost non-existent in practice. Rather, engineers continue to apply conservatism or to develop insufficient pavement designs due to the present lack of good and reliable data or of accepted methods of design for seasonal variations in roadway strength.

Cost

Study costs are totally dependent on the size of the initial test and measurement program. Objectives 1 and 2 (above) could be accomplished with a focus on existing SHRP sites, provided the work is initiated quickly.

A budget of \$500,000 to \$1,000,000 would provide for the inclusion of enough specific site test

data to permit work to begin on the other project goals by providing a good data base. The initial work would require intensive FWD tests at each site at least weekly during the thawing periods, followed by use of existing back-calculation methods to determine the changes in resilient response properties over time.

A time period of 3 to 4 years will be needed, depending on the number of available FWD test trailers and the distances between test sites. It is critical to arrange frequent visits to test each site during peak thawing periods at various thaw depths.

A2L05 COMMITTEE ON ENGINEERING GEOLOGY

PROBLEM 145: ROCKFALL PROCESSES AND MITIGATION

Rock fall continues to be a major hazard along transportation facilities in mountainous areas where driving lanes can be blocked and motorists injured or killed. Computer-aided kinematic models permit reasonable predictions of movement patterns and travel distances as rocks bounce and roll down rock faces and talus slopes. Field measurements of typical rockfall conditions are needed to provide an empirical basis for predicting general rockfall behavior in high-risk zones. Additional research is needed to determine with improved confidence the areas where rock falls originate, and to demonstrate the need for rockfall management and its effectiveness.

Objectives

The objectives of this research are as follows:

1. To provide field measurements of typical combinations of slope geometry, rock type, climate and rockfall records for areas of recurrent rockfall problems.
2. To develop improved empirical predictions of rockfall behavior based on records and observations.
3. To use these data to delineate hazardous areas and provide guidance for prioritizing hazard areas for rockfall mitigation techniques.
4. To use these data to evaluate the effectiveness of alternative rockfall mitigation techniques.

Key Words

Rockfall, roadway hazards, management.

Related Work

Subcommittee A2L05(1), Subcommittee on Rock-Fall Management, was formed in 1993 with a three-fold purpose: (1) share existing technology among DOTs, university researchers, rockfall mitigation manufacturers and consultants; (2) participate in developing new technologies; and (3) assist in applying the technologies to rockfall management. Several DOTs have conducted significant rockfall hazard research and rockfall management is becoming a programmed function. However, no clear national direction or precedent exists to guide these efforts.

Urgency

Comprehensive programs to delineate rockfall hazard areas are available in very few states. Those states with hazard delineations need methods to prioritize the areas so that the most hazardous areas may be mitigated first. Several rockfall hazard mitigation techniques are available; research is needed to evaluate the effectiveness of these techniques and to develop guidelines to assist Departments of Transportation in selecting the optimum techniques for specific slopes.

PROBLEM 146: ROCK SLOPE RATING PROCEDURE INCLUDING LIFE CYCLE OF ROCK REINFORCEMENT

Many rock slopes along major highways have been in existence for 25 or more years. Design of a number of these slopes included rock bolts and other types of mechanical reinforcement. A number of other slopes were designed without reinforcement, but performed poorly and were improved by installing reinforcement. Inventories of rock slopes are needed to assist Departments of Transportation in rating the conditions of rock slopes in general, and those with reinforcement in particular.

Objectives

The objectives of this research are as follows:

1. To inventory and review slope rating systems used by Departments of Transportation with particular emphasis on how rock reinforcement is described.
2. To synthesize the descriptions of rock reinforcement so that life cycle information might be extracted.
3. To summarize the procedures used by those DOTs that have had to replace rock reinforcement elements in slopes where performance was starting to deteriorate.

Key Words

Rock slopes, performance, rating, reinforcement, life cycle.

Related Work

Subcommittee A2L05(1), Subcommittee on Rock-Fall Management, is evaluating the effectiveness of rockfall mitigation techniques, many of which are some form of reinforcement. Committee A2K02, Committee on Transportation Earthworks, listed two related problems in Transportation Research Circular 417: Problem Number 128, Design Methods and Procedures for Rock Slope, and Problem Number 129, Investigation of the Effectiveness of Horizontal Drains.

Urgency

The current need to maintain and upgrade transportation infrastructure is extensive. Prioritizing activities is desirable because of limited availability of funds. Rating procedures provide a rational basis to assist in this prioritization.

**PROBLEM 147: APPLICATION OF
GEOSTATISTICAL METHODS TO IMPROVE
THE INTERPRETATION OF SUBSURFACE
DATA**

Projecting the continuity and characteristics of soil and rock materials between data points represented by borings continues to be critical as funds available for exploration decrease and liability exposure for subsurface interpretations by engineers increases. The use of statistics and probabilistic methods in geotechnical engineering is relatively common. Statistical techniques such as kriging and randomization have been applied in the minerals industry to more realistically estimate variations between borings. These techniques probably provide a rational basis for computer-aided interpretation of soil layering and/or selective properties between discreet points in borings.

Objectives

The objectives of this research are as follows:

1. To review existing geostatistical techniques to identify methods with potential applications for subsurface exploration interpretations.
2. By use of demonstration projects, to evaluate limitations and suitability of the methods to specific geotechnical data needs, e.g., estimating material quantities and physical properties.

Key Words

Geostatistics, subsurface interpretation.

Related Work

A session on Methods of 3-D Subsurface Characterization was held at the 75th Annual Meeting of TRB. Applications of geostatistics in the mining field are available, but no current research to demonstrate applications of these techniques in the transportation industry is known.

Urgency

The need for methods to support engineers interpreting data between borings is increasing as funds available for exploration decrease and the public's tendency to litigate increases.

**PROBLEM 148: APPLICATIONS AND
LIMITATIONS OF PROBABILISTIC METHODS
IN EVALUATING RISKS ASSOCIATED WITH
NATURAL PROCESSES**

Natural processes commonly are hazards along transportation routes. Design and maintenance philosophies for dealing with flood hazards are based on the probability of occurrence of damaging events. Slope movements, particularly earthquake-induced movements, can cause extensive damage, but the probability of occurrence usually is small. The extent to which probabilistic methods may be valuable tools in design and maintenance is unevaluated.

Objective

The objective of this research is to evaluate applications and limitations of probabilistic methods in assessing risks associated with natural processes.

Key Words

Probabilistic methods, natural processes, hazards, risks.

Related Work

Several papers addressing this issue were published in *Transportation Research Record 1288*. Useful research is being carried out currently in the field of dam safety. Some research was done recently regarding safety of

natural gas transmission pipelines. The application to other aspects of transportation is unknown.

Urgency

The current need to maintain and upgrade transportation infrastructure is extensive. Prioritizing activities is desirable because of limited availability of funds. Probabilistic methods may be a valuable tool to assist in this prioritization.

PROBLEM 149: EARTHQUAKE GROUND MOTION AT BRIDGE SITES

Research sponsored by the National Earthquake Hazards Reduction Program will produce a set of new ground motion maps for the United States in 1997. These maps will show the distribution of ground motion that has 10 percent and 2 percent probability of being equaled or exceeded in a time period of 50 years. These maps are intended to provide the basis for an updated building code which includes multiple performance objectives. Highway structures, particularly bridges, are critical facilities which will be depended upon during the emergency response phase of earthquakes and other disasters. Ground motion at bridge structures estimated from these probabilistic maps needs to be put in context of the deterministic maximum ground motion that can reasonably be expected.

Objectives

The objectives of this research are as follows:

1. To inventory each state DOT and Geological Survey to determine if maximum earthquake ground motion maps have been developed.
2. To summarize information regarding the maximum earthquake ground motion to assist DOTs in evaluating the probabilistic ground motion maps that will be available in 1997.

Key Words

Earthquake, ground motion, probabilistic, deterministic, maximum, bridge sites.

Related Work

The states of California and Nevada have developed maps of deterministic maximum earthquake ground

motion. Other states have not, as far as is known at this time. The probabilistic maps are being developed by seismologists at the US Geological Survey.

Urgency

Damage to bridges in the Loma Prieta (1989) and Northridge (1994) earthquakes have drawn attention to the importance and vulnerability of bridges. The concept of multiple performance objectives, the need for DOTs to have dependable bridges, must be put in context for comparison to the probabilistic ground motion maps in 1997.

PROBLEM 150: EARTHQUAKE-INDUCED GROUND DISPLACEMENT AND DAMAGE POTENTIAL

The magnitude of earthquake-induced vertical and horizontal displacements is difficult to estimate, and locations of liquefaction-induced ground displacements cannot be predicted with confidence. Nearby sites seemingly having similar soil properties can differ greatly in settlement or lateral spread movements. Factors such as stratum thickness, lateral variations in sediment properties, grain size characteristics, and layering details all are relevant, but of unknown influence. A need also exists to develop relatively straightforward criteria that can be used by the practicing engineer to assess whether liquefaction-induced ground displacements at a site might be sufficiently large to warrant a more costly, detailed analysis.

A need also exists for post-earthquake examination of landslides (nonliquefaction related) to confirm existing models or develop new models for predicting distance of movement. Few case history studies are available which address the validity of currently used models for estimating landslide displacement.

Objectives

The objectives of this research are as follows:

1. To develop more realistic models for estimating settlements caused by liquefaction.
2. To develop more realistic models for estimating lateral displacements caused by liquefaction.
3. To develop simple techniques for evaluating if liquefaction-induced damage potential exists.
4. To evaluate the validity of currently used landslide displacement techniques.

Key Words

Earthquake, ground failure, damage, prediction.

Related Work

The Earthquake Engineering Research Center has sponsored a research project to evaluate potential liquefaction-induced damage at bridge sites. Federally funded research has focused on the role of geologic factors in determining where lateral spread movements took place in the 1811-1812 New Madrid earthquakes.

Landslide data have been collected for the 1989 Loma Prieta and 1994 Northridge earthquakes. Analysis and synthesis of these data continues.

Urgency

The potential for earthquake hazards is only now beginning to be recognized for many parts of the country. Many engineers are having to make decisions for situations using analysis procedures that are unproven.

PROBLEM 151: SHORT- AND LONG-TERM REMEDIAL SOLUTIONS FOR GEOLOGIC CONDITIONS ON LOW-VOLUME ROADS

Low-volume roads comprise more than 90 percent of the world's transportation system. The extent of these roads and the perceived lesser importance because of the low traffic volumes contributes to a difficult funding problem for designers and operators of low-volume roads. Geologic conditions along low-volume roads often are major factors in cost and reliability. Technological advances in slope stabilization and other areas can provide useful tools in remedial design. Examination of existing geologic conditions and subsurface investigations can aid in selecting economically feasible designs.

Objectives

The objectives of this research are as follows:

1. To review existing technology in the design of low-volume roads.
2. To characterize the variety of geologic factors affecting siting, design, construction, and maintenance of low-volume roads.
3. To identify opportunities for improvements in efficient siting, design, construction, and maintenance of low-volume roads.

Key Words

Low-volume roads, geologic factors, site selection, design.

Related Work

A technical session is planned for the 1998 Annual Meeting of the Transportation Research Board. This session will be cosponsored by the Committee on Engineering Geology (A2L05) and the Committee on Low Volume Roads (A5002).

Urgency

Low-volume roads continue to be a challenge because of the demand for dependability and the decrease in available funds for siting, design, construction, and maintenance. Repair of hurricane damage in 1995 to low-volume roads in the eastern Caribbean Islands currently is being considered. Animal trails in parts of Africa, and elsewhere in the world, that are now major thoroughfares will become low-volume roads in the near future.

PROBLEM 152: RISK ANALYSIS BASED ON EXISTING DEPARTMENT OF TRANSPORTATION EARTH SCIENCE DATA

Much valuable detailed geologic and geotechnical information presently exists in the files of state DOTs. The development and availability of techniques for efficient and rapid management of spatial data provide an opportunity for moving toward analysis and reduction of risks caused by or related to geologic and geotechnical conditions.

Risk analysis results are expressed in terms of probability of processes operating at potentially damaging intensities and the anticipated performance of facilities (fragility) phrased in terms of dollar-value loss. Geologic and geotechnical information have been developed during planning, design, construction, and maintenance operations at DOTs. Research is needed to develop systematic procedures to recover pertinent data and analyze it so risk exposure can be understood. Understanding risk is needed so DOTs can formulate plans for risk reduction to prioritize maintenance and limit liability.

Objectives

The objectives of this research are as follows:

1. To develop procedures for cataloging existing geologic and geotechnical data in DOTs' files.

2. To develop procedures for evaluating the data for predicting conditions that could represent hazards for motorists.

3. To develop procedures for delineating hazardous areas and prioritizing them for risk-reduction maintenance.

Key Words

Existing earth science information, hazards, risk reduction.

Related Work

Several states currently have programs for evaluating areas where rockfall may be a hazard, but no states currently have programs for systematically documenting and evaluating all hazard areas. Current rockfall management programs will provide a useful framework for developing procedures to deal with

hazards from all geologic and geotechnical conditions. Many state DOTs in use geographic information system (GIS) technology in some way. GIS provides an efficient tool for management and manipulation of spatial data.

Urgency

Comprehensive risk-reduction programs do not exist in any DOT. Liability suits filed against a DOT for damage or injury caused by geologic or geotechnical conditions could be defended better if the DOTs could demonstrate that risk-reduction programs had been formulated and that priorities had been set. To formulate sensible comprehensive risk-reduction programs, all potentially hazardous conditions must be identified, characterized, and prioritized. The proposed research will develop procedures for using existing data to accomplish this objective.

A2L06 COMMITTEE ON ENVIRONMENTAL FACTORS EXCEPT FROST

PROBLEM 153: MECHANISTIC MODELING OF UNSATURATED GEOMATERIALS IN PAVEMENT SYSTEMS

Mechanistic modeling of flexible and rigid pavements can account for stresses and strains induced by wheel loads under a variety of conditions. In the currently used mechanistic modeling of flexible pavements, either the finite element method (FEM) or multi-layered elasticity (MLE) approach is used to model the structural response of pavements. These methods often have provisions to include Resilient Modulus (RM) values measured using the current AASHTO specifications in a linear or nonlinear fashion in the analysis. However, all the components of a pavement system are still treated as single phase, elastic material. In reality, all the geomaterials (aggregates used in bases and subbases and the subgrade) in a pavement system are three phase (solid skeleton, pore water, and pore air) materials exhibiting highly nonlinear, elastoplastic, stress-strain behavior. These three phase geomaterials are referred to as unsaturated geomaterials.

If it is possible to properly characterize the three phase and the nonlinear behavior of geomaterials found in the pavement systems, then an improved mechanistic modeling of pavement systems can be performed. The results from these improved mechanistic modeling can then be combined with a pavement distress model such as a fatigue cracking model or a rutting model, as currently done, to obtain realistic performance of pavement systems.

Objectives

The objectives of this research are as follows:

1. To develop an improved mechanistic model for pavement systems by incorporating the recent advances in fundamental characterization of three phase behavior and elastoplastic constitutive modeling of porous media (unsaturated geomaterials) within a FEM framework.

2. To validate the improved mechanistic model by comparing the predictions against test results obtained on instrumented scaled laboratory pavement systems subjected cyclic loading.

Key Words

Mechanistic model, unsaturated geomaterials, elastoplastic behavior, finite element method, pavement systems, cyclic loading.

Related Work

Work on fundamental characterization of three phase material is being performed by the University of Saskatchewan, the University of Oklahoma and several other institutions. Several elastoplastic constitutive models for geomaterials, under static and cyclic loading, have been developed by researchers in the U.S., Canada, Japan, and Europe in recent years.

Urgency

With the deteriorating U.S. highways and increased truckloads being applied to these highways following NAFTA and other factors such as the improvements in mechanical design of trucks, it is of utmost importance to characterize the behavior of pavement systems as realistically as possible. The better characterization of the behavior of the pavement systems will lead to better scheduling of maintenance of these systems and a longer life span.

Cost

The estimated cost of this research is \$200,000 with a 2-year duration.

Implementation

AASHTO should take the lead in implementing the findings from this research through specifications and distribution of the resulting mechanistic model by setting up a World Wide Web homepage.

Effectiveness

The implementation of findings from this research will lead to better characterization of the behavior of pavement systems. This in turn will lead to better scheduling of maintenance and a long life span for these pavement systems.

A2M03 COMMITTEE ON INTERMODAL FREIGHT TERMINAL DESIGN AND OPERATIONS

PROBLEM 154: FINANCING AND IMPROVING HIGHWAY ACCESS TO U.S. INTERMODAL CARGO HUBS

Large U.S. seaports and common-user truck/container freight yards are facing acute congestion access problems. The ISTEA legislation promotes numerous issues including intermodal efficiency, congestion management and remediation, and innovative public/private ventures to finance intermodal transportation projects. Responding to these objectives of ISTEA has been an ongoing effort within the freight community, which has actively sought ISTEA funding for improving highway access to high volume intermodal freight projects. While ISTEA has allowed for some funding of freight mobility enhancement projects, worthy projects far exceed the finite pool of public dollars. DOTs and MPOs in states with key seaports or inland cargo hubs must grapple with strategies to facilitate the flow of international commerce. A recent TRB study indicates that 50 percent of the major U.S. ports report serious congestion delays at the terminal, and this flow of international commerce is expected to triple over the next three decades.

DOTs and seaports have a shared responsibility to efficiently move commercial freight. Assessing the combined expertise available with electronic highway toll tags and intermodal freight identification tags presents an opportunity to examine electronic traffic tracking devices as a step toward possible tolling projects at cargo hubs. This non-barrier user-fee assessment could be collected without further escalating congestion delays at freight terminal gates. Revenues generated could be used to match or offset construction of dedicated freight corridors into cargo terminals.

Objective

A pilot investigation into freight terminal access fees could assess an innovative public/private strategy to offset the sharply escalating costs of accommodating peak traffic demands for cargo hubs.

Key Words

Intermodal planning, toll facilities, administration, financing, design.

Related Work

There are some related research projects under way, but none that directly address tolling options at freight hubs. They are as follows:

- 1988 Highway Financing Briefs looks at tolls, taxes and impact fees;
- 1986 NCHRP Project 214: *Public Private Partnerships for Financing Highway Improvements*;
- 1992 NCHRP Project 2024 (7), *Alternative to Motor Fuel Taxes to Improve Surface Transportation Improvements*;
- 1993 NCHRP Project 830, *Characteristics and Changes in Freight Transportation Demand*;
- 1993 NCHRP Project 831, *Long-Term Availability of Multimodal Corridor Capacity*;
- 1993 Synthesis Project 2502, *Methodologies Associated with Freight Planning*;
- 1993 Synthesis Project 2511, *Toll Plaza Design*; and
- 1993 TRB *Special Report 238: Landside Access to U.S. Ports*.

Urgency

This is a high priority project that would provide a tool directly applicable to the creation of statewide intermodal management systems mandated under ISTEA. This investigation presents a viable strategy that would collect and leverage user fees at point-of-user impact. Technologies to assess and collect toll fees are readily available. It is likely that the institutional arrangements and the market application strategies would present the larger challenge, therefore, the problem statement investigation would include the following elements:

- Survey of relevant research and practice;
- Determination of possible hub facilities for study;
- Analysis of traffic flows at selected hubs;
- Assessment of acceptability and barriers to application;
- Preliminary assessment of associated costs and benefits;
- Examination of administrative approaches; and
- Technical application issues.

Cost

\$300,000 for the described scoping study.

User Community

Those audiences that may benefit include American Association of Port Authorities (AAPA), AASHTO, FHWA, MARAD, state DOTs, and MPOs.

Effectiveness

This study could examine a possible option to help support the nation's financially pressed seaports that

serve as gateways for commercial and military cargoes. The enormous sophistication in ship capacity, and rapid deployment of cargoes to accommodate just-in-time (JIT) logistics, demands seamless accommodation of increasing peak traffic flows through cargo ports. Innovative funding strategies must be examined to keep pace with escalating infrastructure improvements that complement national economic competitiveness. In addition to the potential generation of funds for infrastructure improvements, user fees could secondarily serve as a mechanism to regulate access demand to load centers at peak congestion periods. This research responds to the public/private partnership advocacy outlines in ISTEA.

A2M04 COMMITTEE ON RAIL TRANSIT SYSTEM DESIGN

PROBLEM 155: RECOMMENDED STRATEGIES FOR THIRD RAIL DE-ICING

Many rail transit systems rely on third rail for supplying power for its operations. Snow, sleet and freezing rain can adhere to the third rail and inhibit contact with the power collection shoes on the rail vehicles. The resulting loss of power can cause trains to become stranded on the line. Newer vehicles with their computer regulated consumption of power are more susceptible to problems than older vehicles. Research is needed to provide a recommended practice for transit systems to mitigate the effect of snow and ice, particularly with newer vehicles.

Objective

The research should develop a recommended practice for transit systems to mitigate the effects on service of snow, sleet and freezing rain. At a minimum, the report should examine the various methods, evaluate how they work, their efficiency and comparative cost analysis, and develop a recommended approach that transit properties could follow.

Related Work

1. *Transit System Third Rail De-icing by Radio Frequency Induction*, C. A. Waller and W. B. Berry, University of Notre Dame and R. L. Kleinman, ElectroCom Automation, Inc. 1991.
2. *Proprietary Product Literature for Third Rail Electric Heaters*.

Urgency

The impact of this research will be immediate and could save millions of dollars spent in winter operations. It could also help provide better transit service during winter weather thus boosting ridership.

PROBLEM 156: VIBRATION MITIGATION ALTERNATIVES TO FLOATING SLAB

Often transit route alignment takes the tracks too close to houses, office buildings, hospitals and similar structures where transit induced ground-borne noise and vibration can reach unacceptable levels. Traditionally, direct fixation track on floating slab has been accepted as the most effective mitigation method available regardless of the desired mitigation levels. Though effective in

reducing transmission of ground-borne vibration, floating slab is highly capital intensive to build and maintain. Alternate mitigation measures less expensive to build and easier to maintain and yet effective for smaller range of vibration reduction than floating slab, may be the appropriate mitigation in such cases where a large reduction in vibration in certain frequency ranges, such as is possible with floating slab, is not necessary. Research is needed to identify and prove out those alternatives.

Objective

The research should culminate in identifying several ground-borne vibration mitigation methods that are cheaper to build and easier to maintain than floating slab. The research reports should include, at a minimum, a description of the alternative methods of mitigation, how they work, their efficiency and comparative cost analysis.

Related Work

Proprietary literature on Low Vibration Track, Cologn Egg, and DS-ISO-RAIL concept are available.

Urgency

The impact of this research will be immediate. Savings in capital cost could run into millions of dollars depending on the length of floating slab installation that can be avoided each year.

PROBLEM 157: TRACK DESIGN IN THE TRANSITION AREA BETWEEN DIRECT FIXATION AND BALLASTED TRACK

Transit owners are experiencing increased maintenance expenditures and a degradation of ride quality at transitions from tie and ballast trackway cross sections to direct fixation trackway. Generally, trackway designs include details and provisions for this transition area of the subgrade and supporting track structure. The present design does not appear to be working as successfully as expected. Additional maintenance efforts are being expended to ensure the transition areas retain the proper profile to ensure an acceptable ride quality.

Transit owners desire design guidelines that assist them in selecting the proper design details ensuring procurement of the proper track materials and

construction details for these transition areas. With reduced federal funding and a heavier reliance on fare box revenues to support maintenance activities, transit owners must ensure their capital investments provide them the greatest life cycle cost benefit and provide the patron the highest ride quality.

Objective

Develop design guidelines, parameters and criteria necessary to enable transit owners to select the appropriate ballasted track design configuration at transitions to direct fixation trackway. These guidelines will be used to develop a tie and ballast track design that provides the best tie and ballast configuration in an effort to reduce long term maintenance and improve ride quality.

Related Work

None identified.

Urgency

As the average age of transit properties increases, properties are beginning to experience degradation of ride quality in the transition areas from tie and ballast to direct fixation trackway. This degradation, if left unconnected, could lead to the failure of rail and fastening components and possibly lead to derailment.

PROBLEM 158: ECONOMIC ANALYSIS OF PREMIUM SPECIAL WORK USAGE ON TRANSIT

During the past ten to fifteen years, major improvements have been achieved in design and fabrication of rail special work. Numerous test installations are in-track or under development by the freight roads and Amtrak.

These include tangential geometry turnouts, swing-nose frogs, boltless braces, and use of premium materials. However, little such research has occurred on transit properties in North America. Most transit properties either continue to use their own decades-old standards, or procure standard AREA devices.

Objective

This research would provide transit operators with the tools to evaluate the payback of using the various premium materials or configurations based on the operating characteristics of their systems. They would be able to evaluate the components available both singly and in tandem to achieve the best payback of cost versus reliability, longevity, and ease of maintenance.

Related Work

Several freight railroads plus Amtrak have extensive test installations of premium special work. In addition, the AAR Transportation Technology Center at Pueblo is testing several configurations. But there is little if any carryover to transit system loadings, geometry, or operating characteristics.

Urgency

Most, if not all, rail transit properties in North America have moderate to severe budgetary problems. In addition, reliability and comfort of service are major factors in keeping and building ridership. This research would aid in selecting special work configurations which would enhance both economic and reliability issues. Also, the use of swing-nose and spring frogs would offer the potential for noise reduction, thus addressing community concerns about that important environmental factor.

A2M05 COMMITTEE ON GUIDED INTERCITY PASSENGER TRANSPORTATION

PROBLEM 159: SAFE EGRESS FROM HIGH-SPEED GROUND TRANSPORTATION (HSGT) SYSTEMS UNDER EMERGENCY CONDITIONS

Significant portions of new HSGT systems may be elevated or go through tunnels. The location of the HSGT vehicle and guideway affects the safety of passengers during an emergency evacuation. Stopping areas must be long enough and wide enough to allow immediate egress of all passengers from a crowded train. The absence of a safe means of leaving the vehicle and the inability of emergency response personnel to reach or evacuate passengers may cause injury or aggravate existing injuries. A stop at a location over an inaccessible area such as an elevated segment over a swamp or a lake could prevent or delay evacuation of passengers and crew from the vehicle. Additionally, a stop on a steep curve may present difficult or dangerous conditions for passengers to exit onto the sloping guideway. This is particularly true if the guideway condition is icy or snow-covered.

Objective

The objective of the research is to evaluate the effectiveness and impact on the vehicle/guideway design of walkways, railings, platforms with ladders or other such means to assist evacuation such as chutes or rope arrangements. Consideration must be given to access by emergency response organizations, emergency lighting, ventilation, communications and support equipment (i.e., access tools, fire extinguisher). The special needs of elderly and disabled passengers must be addressed.

Related Work

- German Transrapid Development.
- FRA and VNTSC reports and projects on safety of high-speed rail and maglev trains.
- VNTSC Report DOT-VNTSC-FRA-93-23, December 1993, Titled "Safety of High Speed Guided Ground Transportation Systems, Emergency Preparedness Guidelines," by Stephanie Markos.
- FRA/Industry Working Group on Rail Passenger Car Safety Standards and Emergency Preparedness to issue a report by the end of 1996.
- FRA/NIST Fire Safety Work.

Urgency

High priority.

PROBLEM 160: HIGH SPEED RAIL AND MAGLEV VEHICLE INTERIORS

In order to ensure the future usefulness of maglev and high-speed rail systems in the United States, it is essential to insure that the safety level afforded by such systems equals or exceeds that of other high-speed ground transportation systems worldwide. It is imperative that occupant safety be granted a high priority. The construction of maglev and high-speed rail vehicle interiors will be critical to occupant safety. Thus every effort must be made to maximize the safety of the vehicle interiors.

Objective

Consideration should be given to establishing guidelines and standards pertaining to performance and safety standards (flammability, smoke emissions, toxicity, etc.) for passenger seating, applications and types of materials, retention of items of mass, and requirements for onboard emergency equipment. Although these restrictions need not stipulate emergency condition procedures regarding occupant egress, it would be well to consider standards aimed at requiring all operators to have such procedures in place.

Related Work

There is already much work under way in fulfilling this research need. The FRA/Industry Rail Passenger Safety Standards Working Group and the FRA/NIST Fire Safety work in particular are directly relevant.

Urgency

High priority. High speed rail and maglev system design parameters will require the implementation of appropriate safety standards in advance of their implementation to avoid potentially costly redesign.

PROBLEM 161: OVERALL HSGT SYSTEM SAFETY RISK ANALYSIS

Several recent USDOT-sponsored research studies have analyzed various aspects of HSGT system safety, such as train collision avoidance and accident survivability, vehicle crashworthiness, human factors, advanced braking concepts, shared right-of-way, and the effectiveness of various intrusion barrier designs. The

FRA is also currently supporting several demonstration projects around the country to investigate ways of improving the safety of high speed rail/highway crossings at grade and ways of achieving positive train separation. To date, however, no comprehensive HSGT system safety risk analysis has been undertaken, which ties together all the various safety aspects of this mode at a systemwide level. No consensus as to the acceptable level of risk exists, particularly regarding "corridor" risk vs. level of train control and the impact of positive train control or grade crossing risks vs. speed, for example.

Objective

What is needed is an overall risk analysis that quantifies safety of various HSGT technologies including "Accelerail," Very High Speed Rail (VHSR) and Maglev. This would pull together the various disparate subsystem safety analyses into a combined system-level evaluation. Building on the subsystem-level analytical studies performed to date, the overall study should assess the relative safety of various proposed HSGT technologies, and identify what factors are most important to achieving an acceptable level of safety.

The overall safety of currently proposed "pre-HSGT" and "accelerail" type services should also be evaluated to help policy makers decide the merits of various alternative technological approaches to providing HSGT service in candidate corridors around the U.S. The risk related to rail/highway crossings at grade, in particular, should be closely analyzed to determine how risk increases with train speed and/or frequency at such crossings. The safe threshold speed for HSR operations above which grade crossings should either be closed or separated should be determined.

Related Work

All of the recently completed FRA-sponsored HSGT safety studies provide useful background and subsystem level safety analyses. The grade crossing protection demonstration results should be integrated into the overall risk assessment study.

Urgency

High priority.

PROBLEM 162: TRACK GEOMETRY, INSPECTION, AND MAINTENANCE PRACTICES

Existing federal track safety standards are not suitable for application to high-speed rail systems in the United States for several reasons:

- Existing standards were intended as a compromise approach to accommodate the very broad unit heterogeneity of the freight and passenger car fleet in the U.S. This is evident in terms of vehicle design/performance characteristics and the widely varying states of vehicle maintenance.

- For the most part, current track safety standards are empirical, having been based on "best practice" concepts, developed by the independent railroad companies over the years, for train operations seldom exceeding 45 m/s (100 mph). There is little rational analysis supporting these standards, which rules out any attempt to extrapolate contemporary experience to the high-speed train operating regime.

- HSR geometry standards for operations to 89.4 m/s (200 mph) abroad are also empirical with each railway having its own version of a standard. The differences between the various foreign railway standards may be attributed to measurement methods.

There is a distinct division of opinion in the U.S. rail research community as to whether it is technically feasible to proceed at once with the development of generic high-speed track safety standards that would be universally applicable to all possible candidate systems. There is a substantial belief that there first must be accumulated a body of knowledge on site-specific experiences built up over some years of operating foreign-origin systems in the U.S for the purpose of providing guidelines for the creation of the generic version. If this is a valid assumption, the production of versatile, generic domestic HSR track safety standards may not be likely for many years.

Objective

Develop recommended safety standards for construction, inspection, and maintenance of HSR track. Performance standards are preferable. In the event that pure performance standards may not be achievable, a given performance standard may have to be expressed parametrically in terms of design constituents. Examples of various design parameters are modulus, lateral resistance, spacing, spiral design, fastener holding force, and so forth for given lateral and vertical wheel forces on the rail.

Related Work

FRA has been approaching this issue from two directions: revision of CFR Title 49, Part 213, known as the FRA track standards, and development of a matrix of standards (including track), referred to as "Rules of Particular Applicability." The latter concerns site-specific high-speed guided ground vehicle operations in the U.S., which currently are based on foreign technology.

Performance standards, particularly concerning track geometry and mainly reflecting foreign practice, are being evolved in the second activity.

There is testing planned using instrumented wheelsets on inspection car 10002 that will allow comparison of ride quality with track geometry. Analytical techniques need to be developed to evaluate and interpret the results. (At very high speeds, track geometry affects ride quality well before there is a safety concern.) Results of the testing program will help the track research community to understand high-speed track/train dynamics better and should be helpful in developing new standards.

Urgency

High priority.

PROBLEM 163: INTERCITY PASSENGER TRANSPORTATION LIFE CYCLE COST/BENEFIT ANALYSIS

Some attempts to justify public expenditures on intercity rail transportation have taken the approach of first projecting the purely financial results and then estimating the magnitude of public benefits. Often there is a financial shortfall. Since the public sector must usually cover the shortfall, the question becomes what this expenditure on the shortfall "buys" in terms of public benefits. French and German studies have made a distinction between "commercial rate of return," which takes into account only revenues and costs accruing to the provider of service, and "social rate of return" which includes benefits and costs to the public at large. Highway investment analysis must be done purely from a public benefits standpoint because no new revenues except for gas taxes will typically accrue to the provider of the service since there are usually no tolls involved.

A great variety of benefits are often considered in the analysis and these are quantified in varying degrees. Some of the benefits, such as employment impacts or increased real estate values, are arguably offset by changes in the opposite direction in locations not served by the new facility. Also it can be argued that some such benefits simply reflect the capitalization of transportation benefits which may already have been counted elsewhere in the analysis. At the same time others have argued that often a new transportation facility, particularly one that represents a dramatic decrease in the time or cost of travel can lead to unforeseen impacts in productivity of business sectors that use transportation or in non-business travel, with repercussions in the entire economy. Some of these effects are not captured by transportation/economic models currently in use.

There is a mistaken impression that all highway and aviation infrastructure improvements are paid for by

the user. Hopefully, this research effort will generate a product that dispels this notion.

There is a need for research to develop a framework for benefit/cost analysis of intercity passenger transportation investments, to identify the categories of benefits and costs to be considered, and to quantify the physical quantities and value per physical unit. This includes the total life cycle costs and benefits attributable to different modes (highway, rail, air) including direct and indirect socio-economic benefits for use in planning for expansion and/or development of new intercity passenger transportation systems. Environmental impacts, net plus or minus, need to be quantified in economic terms and included in the framework.

Objectives

The objectives of this research are to:

1. Develop an appropriate multi-modal framework for incorporation of benefits and costs (including environmental benefits and costs) associated with the implementation of new intercity passenger investments, with emphasis on high-speed ground transportation. The framework should:

- Identify categories of benefits and costs.
- Identify specific benefits and costs within each category.
- Identify potential overlaps or double counts.
- Specify a method for how the benefit and cost information must be integrated and presented to facilitate implementation decisions.
- Include consideration of benefits or impacts among all modes and effects on the overall economy and on land use patterns.

2. Identify possible mechanisms for introducing a new mode or upgrading an existing under-utilized mode, based on savings achieved by reducing the need for future capacity expansion in other modes or extending another mode's economic life.

3. Develop a data base of information that can be used to quantify and, where possible, monetize benefits and costs for use in the analysis of intercity passenger transportation systems and in the NEPA review process.

Related Work

In August 1993, the Federal Railroad Administration's Office of Policy prepared an annotated bibliography of papers and reports on the measurement, mitigation and costing of the environmental externalities and social costs of transportation systems that lists current research underway in areas related to this need.

The recently completed Commercial Feasibility Study developed a framework for the passenger rail mode which could be incorporated in the overall framework.

Swedish R&D in this field by Lars Hansson (The Swedish Approach to Multi-Modal Transportation Planning) is a worthwhile reference source.

The Federal Transit Administration's "Major Investment Study" methodology probably comes the closest to meeting the objectives of this research. Yet a

suitable framework specifically addressing intercity passenger transportation investments does not exist.

Urgency

There is an urgent need for this research as input to future federal legislation on intermodal efficiency (ISTEA-II).

A2M06 COMMITTEE ON RAILWAY MAINTENANCE

PROBLEM 164: IDENTIFYING AND MODIFYING THE INFLUENCE OF SUBGRADE ON TRACK MAINTENANCE REQUIREMENTS

Subgrade is the platform on which the track superstructure, ballast and sub-ballast are placed. Subgrade stability is thus expected to have a significant influence on ability to maintain track geometry. There are also indications that the stiffness of the subgrade affects the life of the track components such as rails, ties, and ballast. Thus the required amount of track maintenance and the associated costs are expected to be related to subgrade conditions. However, this relationship has not been adequately established, nor has the effectiveness of means to alter the subgrade effects been adequately determined. These means include modifying the subgrade or modifying other track components.

Objective

Establish the relationship between subgrade conditions and track maintenance requirements. Determine feasible means to alter the adverse effects of subgrade to reduce maintenance costs.

Key Words

Subgrade stability, subgrade stiffness, maintenance costs, track geometry.

Related Work

Valuable information on this topic is being obtained on the FAST track at the Transportation Technology Center in Pueblo, Colorado. However, little related work has been done on revenue track.

Urgency

This topic has received little attention in the past, but it could have a big effect on track maintenance costs. Increasing pressure on maintenance budgets makes it a high priority topic to investigate.

Cost

\$1,000,000 to \$5,000,000 minimum

User Community

FRA, AAR, individual railroads

Implementation

Reports, papers, workshops, presentations, AREA manual.

Effectiveness

Improve economy and safety of railway operation.

PROBLEM 165: IMPROVED NON-DESTRUCTIVE EVALUATION OF IN-PLACE CONDITION OF TRACK COMPONENTS

As railroads develop and implement performance based track inspection methods (such as gage restraint standards), the need to determine which components are to be replaced will become more critical. Performance based inspection will locate weak sections but do not necessarily identify which specific components have failed or are not up to standards. Additional inspection must be performed to determine which components are to be replaced. In some cases the visual condition of a component such as a wood crosstie, does not indicate overall strength or internal decay.

Non-destructive methods of inspection to identify individual component that should be replaced is a research need. Use of other technologies which have undergone recent advance and can be applied to the railroad environment should be investigated. Examples include the use of radar to inspect tie conditions.

Objective

Evaluate other technologies that can be utilized to inspect in place track components. Determine physical properties that affect performance, and would result in components being replaced.

Key Words

In situ inspection, non-destructive inspection, performance standards

Related Work

Ongoing railroad industry performance based standards for track inspection.

Urgency

As personnel with expertise in track inspection are tasked to perform more work, the need to supplement with alternative technologies increases. In order to better implement performance based standards which have the potential of inspection long lengths of track rapidly, in the field personnel need better means of determining exactly which track components need replacing, as visual indications are not always sufficient.

Cost

For each technology ~\$250,000 for proof of concept and ~\$1 million for product development.

User Community

AAR, AREA, FRA, RPI, REMSA, individual railroads

Implementation

Would be implemented gradually to first supplement then eventually replace hand or visual inspection to determine which ties or other components are selected for replacement.

Effectiveness

Will improve economy of track maintenance by ensuring components are replaced only if they are actually not capable of performing as required. Thus, for example, ties that look bad but are actually strong remain in track.

**PROBLEM 166: DEVELOPMENT OF
PREDICTIVE TRACK MAINTENANCE MODELS
WHICH UTILIZE FIELD DATA**

A shrinking work force in many engineering departments coupled with limited budgets for maintenance and rehabilitation (M&R) necessitates the need for effective planning models. A key management objective is to determine when, where, how much, and how best should M&R be accomplished. However, models do not exist that are sensitive to such variables as operating speed, annual tonnage, axle load repetitions, and climatic conditions. The models should utilize information that is routinely collected such as geometry car, rail flaw, and inspection report data.

Objective

The objective of the research is to develop a family of predictive M&R planning models. The models would be

used to determine M&R needs in future years based on differing strategies and scenarios. Accordingly, they would be sensitive to key variables such as annual tonnage, expected axle loads, desired FRA class, etc. Different models should be developed for component groups such as ties, turnouts, ballast and subgrade, etc. as well as interactive composite models that integrate the component group models.

Key Words

Predictive models, track maintenance, maintenance planning, maintenance management, track management.

Related Work

General models exist to help plan tie renewal and rail replacement projects. Also, some railroads, organizations, and consultants/vendors have developed models for predicting component life and/or various economic models for planning M&R. However, applicability is limited based on the assumptions and data used in the development. Most recent effort have been directed towards heavy haul traffic, but low volume lines have been virtually ignored. Much work still remains.

Urgency

This suggested work has high relevance within the railroad industry. The development and implementation of these models could reduce track safety problems, and help ensure that limited M&R resources are allocated effectively.

Cost

\$1,500,000

User Community

The user community includes all public and privately owned railroads, including military and industrial track networks as well as such organizations as the FRA, AAR, and ASLRA.

Implementation

The models should be made available to all railroads for use on an optional basis. Distribution could be made through the FRA, AAR, ASLRA and military. Training courses on use could be sponsored regionally through those same organizations.

Effectiveness

The societal impact are twofold; economic viability of the railroad industry and safety for railroad personnel and the general public (train passengers and those living and working near railroads).

PROBLEM 167: MECHANISMS OF BALLAST DETERIORATION AND METHODS OF PREDICTING BALLAST LIFE

Recent research has shown that ballast breakdown is a major cause of ballast fouling leading to deterioration of track performance. However the mechanisms of ballast degradation are not understood. Repeated load, impact and vibration forces from traffic and environmental induced forces cause breakage and abrasion. However the linkage between the character of the forces and the resulting amount and nature of degradation has not been established. Fatigue of the rock particles may be a factor but this has not been investigated. How the fouling process develops beginning with clean ballast until it is at the end of its life has not been established. For these reasons means to predict the relative life of ballast in track are very limited. As a result an accurate economic assessment of ballast alternatives is not possible.

Objective

Determine the mechanisms of ballast breakdown in track in relation to the various causes and the ballast particle properties. Establish tests for reliably measuring ballast life.

Key Words

Traffic loads, impact, vibration, fatigue, breakage, abrasion.

Related Work

Field studies have been conducted to define the sources and causes of ballast fouling. Attempts have been made to simulate in laboratory tests on ballast some of the load conditions in the field. Petrographic studies have been performed to assess the connection between rock properties and performance in index tests. Field tests to measure the rate of ballast breakdown with traffic are in progress. However, a lot more work is needed to achieve accurate prediction of ballast life.

Urgency

The cost of ballast and related maintenance are substantial and reoccurring. Thus there is a considerable

economic benefit to be gained from an improved ability to predict ballast life. The potential cost savings make this a high priority item.

Cost

\$2,000,000 to \$5,000,000 minimum

User Community

FRA, AAR, individual railroads

Implementation

Reports, papers, workshops, presentation, AREA manual.

Effectiveness

Improve economy of railway operations.

PROBLEM 168: DETERMINE WHEN TO CLEAN OR REPLACE BALLAST

As ballast deteriorates through breakdown and other causes of fouling its ability to perform its functions decreases, and track maintenance costs increase. Eventually cleaning or replacing is needed. The maintenance engineer needs a means to assess the condition of ballast in track combined with guidelines for determining whether to clean or replace the ballast. This will permit better utilization of maintenance budgets by carrying out these operations at the optimum time.

Objective

Develop procedures for field inspection of ballast to quantify condition. Establish criteria for determining whether to clean or replace ballast.

Key Words

Maintenance, ballast deterioration, ballast cleaning, ballast replacement.

Related Work

Studies have been initiated to establish ballast fouling limits based on drainage requirements. Work has yet to be done on defining limits based on ballast mechanical behavior. Preliminary tests have been made to evaluate the use of nuclear devices for monitoring the degree of ballast fouling.

Urgency

Better use of maintenance funds would result from improved procedures for determining ballast cleaning/replacing needs.

Cost

\$1,000,000 to \$4,000,000 minimum

User Community

FRA, AAR, Individual Railroads

Implementation

Reports, papers, workshops, presentations, AREA manual.

Effectiveness

Improve economy of railway operations.

PROBLEM 169: EFFECTS OF HEAVY AXLE LOADS ON BRIDGE MAINTENANCE AND LIFE

The upcoming decision to increase axle loads on rail vehicles translates into higher infrastructure costs. In order to insure that the rates established for moves utilizing these cars correctly reflects these high maintenance costs, the detrimental effects must be quantified.

Objective

Assess the detrimental effects on bridges caused by 125-ton or higher car traffic, to predict increased bridge maintenance requirements and remaining bridge life.

Key Words

Bridge fatigue, bridge type.

Related Work

Much of the related work focuses on steel bridges. Timber bridges now require attention.

Urgency

Due to the number of railway structures over 75 years old that are still utilized for daily mainline service, it is imperative that their remaining life and future maintenance costs in consideration of heavier loadings being predicted. Major structure replacements involve substantial capital costs which must be planned for to insure the financial welfare of the railroads.

Cost

\$500,000

User Community

American Railway Engineering Committee 15, Steel Structures;
American Railway Engineering Committee 8, Concrete Structures;
American Railway Engineering Committee 7, Timber Structures;
Association of American Railroads Research & Test Department;
Class 1 Railroad Chief Engineers; and
International Heavy Haul Railway Conference.

Implementation

Being able to predict bridge maintenance costs and life in relation to structure loading would provide valuable information to railways. Life cycle bridge costs could be predicted and policies for bridge utilization and replacement could be better planned. Computer bridge loading assessment models could provide output for various bridge configurations.

Effectiveness

The ability to evaluate increased axle load effects on bridge maintenance and life would provide railway officers with a tool to assess various operating strategies that could take into account bridge costs.

PROBLEM 170: IMPROVED UNDERSTANDING OF RAIL PERFORMANCE AND BEHAVIOR

Changed operating conditions including increased axle loads, the use of lubricants, as well as adverse operating conditions contribute to the degradation of rail or to extending the life of rail. Technology is now available to instrument specific track locations cost effectively to assess the mechanisms contributing to problems.

Similarly data on specific failures are available to attempt to understand these failures and correlate them with specific conditions.

Objective

The overall objective is to better understand rail performance and behavior. More specifically the following areas could be addressed:

- Quantify the desirable benefits of lubrication in terms of minimizing wear by “contaminating” the interface between rail flange and rail; and reducing friction to minimize fuel consumption.

- Assess the mechanisms contributing to rail migration (unidirectional traffic, steep grades, etc.)

- Develop relationship between increased rail fractures and increased tensile forces in winter and the subsequent increase in rail failures.

Key Words

Rail performance, rail behavior, lubrication, wear, energy, fuel consumption, performance, friction, migration, fracture, failure, rail stress, rail neutral temperature

Related Work

Ongoing work on wear, and measuring the friction coefficient of lubricants and how it changes with the concentration of the lubricant is relevant to this work.

Urgency

As operating conditions change the need to understand unusual and routine impacts on rail is critical to minimizing life cycle costs including both maintenance and rail replacement.

Cost

~\$500,000

User Community

AAR, FRA, individual railroads

Implementation

Would be used to address location specific problems initially. Ultimately the research would be an important part of track maintenance planning.

Effectiveness

Will reduce life cycle costs of rail.

PROBLEM 171: EFFECTS OF SEASONAL FROST ACTION IN RAILWAY SUBGRADES ON THE MAINTENANCE OF TRACK GEOMETRY

In seasonal frost areas, such as the “northern tier” states in the United States, and the southern portions of Canada, the railway track structure may be seriously deformed by heaving due to frost action to the subgrade, and possibly in the ballast and sub-ballast as well. Typically, the magnitude of the heaving is not uniform along the length of the track, thus resulting in a rough track profile. One response is to restrict the speed of the trains over the afflicted portions of the track. However, because the heaving is not uniform, the support from the crossties is not uniform, and as a result, the rails may be seriously overstressed. To restore reasonable support, the portion of the rails over the low or nonheaved ties is shimmed up. This can be done with reasonable success, but it requires extensive effort, and must be repeated at frequent time intervals, perhaps every week, to be effective. When warmer temperatures return in the spring, thawing occurs from the ground surface downward, and the shims must be removed in reverse order until the rail returns to its pre-freezing level.

There is an additional aspect which must be considered, however. During thaw, the subgrade often becomes completely saturated with meltwater which drains very slowly. Thus the subgrade remains in an unstable condition for a substantial time, perhaps two months. Actually, this weakening may apply to all components of the rail support system, depending on how clean the ballast and sub-ballast are.

Objectives

Determine the relationship between track maintenance requirements and subgrade conditions and characteristics during the annual freeze-thaw cycle, and determine how to identify these conditions in the field in an effective and efficient manner. Determine the costs associated with shimming the track (or other comparable methods) and compare those with the costs of replacement of poorly performing sections, thus providing a basis for informed decisions.

Key Words

Frost heaving, annual freeze-thaw cycle, subgrade stability, subgrade stiffness, track geometry, maintenance costs.

Related Work

Considerable research has been done on predicting the amount of frost heaving and the depth of frost penetration as a function of subgrade soil type and the duration and intensity of freezing temperatures as applied to roads and streets. Information is also available on the deflection of a pavement under a standardized wheel load as a function of time following initiation of thaw, for various subgrade types. This technology can be adapted and applied to railway maintenance.

Urgency

Research on maintaining railway geometry under winter conditions has not been given much consideration, but the task is labor intensive, and therefore costly. If these costs could be reduced or eliminated by research, there would be a substantial advantage to the railroads. Refined cost information would improve decision-making.

Cost

\$1,500,000 to \$3,500,000 minimum.

User Community

FRA, AAR, individual railroads.

Implementation

Reports, papers, workshops, presentations, AREA manual.

Effectiveness

Better economic decisions regarding the trade-off between repeated maintenance costs and replacement/reconstruction costs would be possible as a result of this project.

PROBLEM 172: MITIGATION OF RAILHEAD FATIGUE BY IN-SITU RESURFACING OF THE RAILHEAD

Current rail grinding practices aim at recovering an optimal rail profile after the processes of wear and plastic flow have degraded the original rail profile to an undesirable shape. To accomplish the goal of maintaining an optimal rail profile, two problems must be addressed: an optimal rail profile must be defined and an optimal rail grinding schedule must be determined. To date, a consensus has not been reached as to what constitutes an optimal rail profile and what constitutes an optimal rail grinding schedule.

Upon grinding away the surface layer of plastically deformed steel, near-surface compressive residual stresses are reduced, and if enough material is removed, these stresses might be eliminated. Necessarily and concurrently, the subsurface counterbalancing tensile residual stresses will be reduced or eliminated. It is in the subsurface zone of tensile residual stresses that some types of railhead fatigue defects are observed to nucleate and begin growth.

In addition, by grinding the railhead, the action of the wheel-rail contact stresses migrates downward into the railhead. With an appropriate grinding schedule, it should be possible to prevent the steel from cracking in fatigue at every depth below the running surface by exercising much of the material through the depth of the railhead rather than a shallow lens of material at a critical depth. Considering residual stress reduction and critical depth migration, there is a strong possibility that the rail grinding process can be used to mitigate railhead fatigue defect nucleation.

Objective

To eliminate one cause of train derailments.

Key Words

Derailments, Fatigue Cracks, Rail Grinding, Rail Wear

Related Work

The AAR and some member railroads are conducting full-scale rail grinding experiments in revenue service and through FAST. These tests are focused on rail profile optimization and on controlling wear damage.

Urgency

As cleaner rail steels are implemented, the occurrence of fatigue-crack related train derailments should decrease. However, the phenomenon of metallic fatigue under rolling contact cannot be eliminated with metallurgical improvements; it can only be postponed. This research potentially motivates both a new rail design and a new rail maintenance philosophy aimed at eliminating fatigue-crack related derailments.

Cost

\$3,000,000

User Community

FRA, AAR, Individual Railroads

Implementation

Presentations, Research Reports, Journal Articles, AREA Manual

Effectiveness

Eliminating sources of train derailments in general has important societal impacts, particularly if the incidents of hazardous material spillage can be reduced. Measures of effectiveness will be evident in two ways: fewer fatigue cracks being detected during routine track inspections and fewer train derailments attributed to catastrophic fatigue crack propagation.

PROBLEM 173: DETERMINING THE IMPACT OF PERFORMANCE VARIABILITY ON CONSTRUCTION SCHEDULE AND COST

Construction and maintenance operations involve the coordination of labor, materials, equipment and tools to achieve a desired cost and schedule objective. However, construction is performed in an uncontrolled environment, subject to unique conditions related to environment, location, topography, and climate. In addition, labor productivity and skill level is highly variable. It is important to develop a methodology to accurately predict cost and schedule performance while recognizing the inherent complexity and variability in all construction processes. Without such a methodology, it is not possible to predict contractor performance with any degree of certainty. As a result, companies engaged in construction and maintenance operations are accepting the risk that their cost and schedule objective (or constraints) will not be met satisfactorily.

To minimize such risk, it is important to construct a management planning tool that can be used to predict contractor performance. It is desirable to know the range of cost the construction process may have. Similarly, it is desirable to know the probable duration for successfully completing the project. If such performance measures could be accurately predicted, it would permit managers to make decisions with quantitative data rather than relying on speculation, intuition or historical precedent. Too often, important management decisions are predicated on assumptions regarding construction cost and schedule that ultimately prove to be erroneous. Management must be able to quantify the variability inherent in construction processes in order to make intelligent, proactive decisions.

Objective

The objective of this research is to create a methodology for accurately predicting the cost and schedule

performance for construction operations which commonly occur in the railroad industry. Additionally, this research will provide a means of quantifying the cost and schedule impacts of proposed changes to the planned construction methodology. It may be useful to know the ultimate consequence of changes to crew composition, equipment selection, or work methods. Quantitative answers to "what if" questions can be provided. What if we work one crew overtime versus working two crews simultaneously? Such questions can be answered with respect to both schedule and cost. Trade-offs between schedule and cost can be identified for proactive decision making.

Key Words

Process Optimization, Computer Simulation, Productive Analysis

Related Work

The Construction Industry Institute is exploring the use of computer simulation modeling as an analytical tool for quantifying cost and schedule impacts of process change.

Urgency

This research provides a tool for optimizing maintenance and construction dollars and for minimizing operational disruptions resulting from construction related activities.

Cost

\$1,000,000

User Community

FRA, AAR, Individual Railroads

Implementation

Presentations, Research Reports, Computer Software, Workshops

Effectiveness

The ability to optimize maintenance and construction expenditures while minimizing operational schedule disruptions created by construction related activity is beneficial to the industry. Variability and uncertainty inherent in the performance of construction activities can be predicted and minimized.