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Maintenance Research Problem Statements

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MAINTENANCE RESEARCH PROBLEM STATEMENTS

OPERATION, SAFETY, AND MAINTENANCE OF TRANSPORTATION FACILITIES

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Subscriber category

III materials, construction, maintenance

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

Preface

An important function of the Transportation Research Board is the stimulation of research toward the solution of problems facing the transportation industry. One of the techniques employed by technical committees in support of this function is the identification of problems and the development and dissemination of research problem statements. 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 problem statements in this circular represent a composite of efforts by eight of the Group 3, Section C committees. They should not be considered an all inclusive recognition of maintenance research needs but, instead, represent only the problems identified by those committees. Since many of the statements may touch upon the scopes of several other elements of the Board, the circular is being distributed to a wide range of interest areas.

A standard system was not used to establish priority ratings and committee chairmen used different systems. 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 probably created a bias in favor of applied research as opposed to theoretical studies.

While the problem statements have been arranged by contributing committees *this arrangement does not establish recommended priorities*. The ordering of statements under individual committee listings *does* reflect that committee's evaluation or priorities.

Contents

Committee A3C01 - Maintenance and Operations Management

Integration of Maintenance Management System with PMS, BMS and Other Management Systems/Data Bases

Problem: To be effective, maintenance management systems (MMSs) need to be integrated with other decision-support systems and data bases that serve maintenance. Integration is needed to address such fundamental issues as:

- Capital-maintenance tradeoffs
- Optimal allocation of limited funds over time to projects and program elements
- Level-of-service measures and standards tied to quality evaluation and outcomes of maintenance expenditures and activities

These capabilities are not available within the traditional MMS but can be developed using new technology for data acquisition and display of spatial information.

Objectives: Develop a maintenance management and information system (MMIS) that incorporates data available from all transportation information systems. The MMIS should have as its core a stand-along PC or workstation-based analytical procedure with open architecture and provisions for integrated data bases and data interchange standards that can be easily customized to any state. It should permit data entry using advanced data collection and data reduction techniques including a wide variety of sensors, pavement condition and distress identification using video imagery, non-destructive evaluation techniques, electronic clipboards, bar coding, voice recognition, etc. It should have the capabilities of not only traditional MMS, but also address such fundamental issues as:

- Integration of maintenance with pavement and bridge management
- Use of GIS and GPS for spatial data
- Assessment of capital-maintenance tradeoffs
- Evaluation of condition of maintainable elements
- Assessment of alternative levels-of-service standards
- Optimal allocation of limited funds subject to a series of annual budget constraints
- Unique characteristics of different types of maintenance activities typically found in each state.

New software should be developed, tested and evaluated in one or more host states. Organizational and management issues should also be identified and evaluated.

Current Activities: NCHRP Project 14-9(4), "Role of Highway Maintenance in Integrated Management Systems," is currently developing a conceptualization of an idealized MMIS. The conceptualization will include the integration of all the key management systems and data bases that support highway maintenance (maintenance, pavement, bridge, safety, equipment, materials, CADD, and planning management systems and databases).

Urgency: The recent passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) mandates that states and MPOs implement a variety of management systems (bridge, pavement, safety, congestion, and others). With the emphasis on maintenance in ISTEA and the management systems mandated by ISTEA, there is an urgent need for strategies for integrating various databases and decision-support systems that can serve maintenance and determine the optimal mix between capital and maintenance expenditures.

Evaluation of Bar Coding and Electronic Data Interchange for Maintenance Materials Inventory Management and Control

Problem: States and localities with road and bridge maintenance responsibilities must be accountable for the materials they use. The wide variety of materials used in maintenance creates a complex materials management and inventory problem. Bar coding using an Electronic Data Interchange (EDI) can greatly improve the materials inventory, management and accounting process, resulting in large cost savings. Such techniques are used heavily in shipping and receiving by private industry. However, lack of national standards for bar coded maintenance materials and the lack of data interchange standards suitable to support EDI for maintenance materials inhibit adoption by states.

Objectives: Investigate the requirements, feasibility, costs and benefits of using bar codes for materials inventory management, control and accounting by states and material suppliers. If the process is feasible, develop recommendations for national standards for material bar codes and for EDI.

Current Activities: Phase II of NCHRP 14-10, "Improvements in Data Acquisition Technology for Maintenance Management Systems," is investigating the use of bar coding in a cradle-to-grave sign management system beginning with materials purchase and sign fabrication and continuing with sign installation, repair, removal, disposal and reuse. Some states have taken a preliminary look at materials bar coding, but have not developed a full system.

Urgency: Materials management is a large and costly effort for transportation agencies. The potential savings in human resources, time and funds justify an urgent priority for this research project.

Committee A3C04 - Traffic Safety in Maintenance and Construction Operations

Methods to Slow Traffic in Work Zones

Problem: Traffic control in work zones includes advance signing and smooth lane transitions in an attempt to maintain traffic flow with minimum conflict. Unfortunately, when traffic is maintained in this manner, drivers fail to recognize that conditions have changed. The work zone environment, with workers close to traffic, narrower lanes, low shoulders and equipment entering traffic lanes, is less forgiving than non-work areas. The primary safety concerns of highway workers are the speed of traffic through work zones and the drivers' disregard for the employee's safety, as well as their own safety.

Objectives: Determine ways to slow traffic in work zones by using "high tech signing," driver education, publicity and changing roadway geometrics. By reducing speed through work zones, the number and severity of accidents should be reduced, and workers should be less anxious while working next to traffic.
Findings could be incorporated into American Association of State Highway and Transportation Officials (AASHTO) guidelines and the *Manual of Uniform Traffic Control Devices* (MUTCD). The envisioned study should be funded at $200,000 - $300,000 with a duration of 24 months.

Current Activities: NCHRP Project 3-41, "Procedure for Determining Work Zone Speed Limits," is on-going. Texas Transportation Institute has evaluated some speed control techniques.

Urgency: With the interstate system nearly completed, maintenance and rehabilitation of the existing system will increase as highways age and most repairs will be done next to traffic. Therefore, it is important to find ways to improve work zone safety.

Determine the Effectiveness of Variable Message Boards

Problem: Particular emphasis is needed to evaluate the effectiveness of variable message boards (VMBs) in construction zones. At present, motorist's level of comprehension is unknown. Are VMBs more effective with imparting a message than traditional construction signs or are they just a distraction? This knowledge would be beneficial to the traffic engineering profession in providing effective traffic control in construction zones.

Objectives: Determine the effectiveness of VMBs. Improved safety and smoother flow of traffic through construction zones would be the major benefits to understanding the effectiveness of the VMB and tradition construction signs. Traffic Engineers need to know how VMBs contribute to overall travel behavior and safety, particularly in construction areas. The funding level is estimated at $250,000 to $300,000.

Current Activities: Unknown

Urgency: This will have a direct impact on safety and traffic control in construction zones.

Guidelines for the Use of Truck Mounted Attenuators in Work Zones

Problem: Truck mounted attenuators (TMAs) have been recently added to the arsenal of devices and equipment designed to improve the safety of highway workers. Specific guidance is available for traffic control devices, such as signs and barricades, but there is no operational guidelines for the use of TMAs. TMAs have not been crash tested with all the vehicle types on the roadway, i.e., an 36,000 kg (80,000 lb) tractor trailers at 97 km/h (60 mi/h). In addition to

investigating the effectiveness of the TMA, the crash tests should also assess the positioning of a TMA shadow vehicle to minimize the potential negative effects of a catastrophic event.

Objectives: Establish guidelines for the use of TMAs in work areas. These guidelines should include:

- A prioritized list of operations where TMA shadow vehicles should be used (occupancy of the shadow vehicle and type of roadway should be considered).
- A recommended location for the TMA shadow vehicle in relation to the work area or moving operation with due consideration given to the speed and weight of approaching vehicles and weight of the TMA shadow vehicle.
- A recommended weight for the TMA shadow vehicles based type of roadway and traffic mix, speed and volume.

Data should be collected on accidents involving TMA shadow vehicles and compared to accidents involving shadow vehicles without TMAs. All organizations that perform work on roadways will benefit from this research.

Current Activities: The University of Tennessee, Transportation Center has developed guidelines for the use of TMAs in work zones. These guidelines were developed without crash testing.

Urgency: Pennsylvania DOT has recently purchased 256 TMAs. Since the proposed revisions to the MUTCD discusses operational considerations of TMA's, high priority should be given to this topic.

Operational Guidelines for Portable Traffic Signals in Work Zones

Problem: There are no national guidelines for the use of portable traffic signals (PTSs) in construction work zones.

Objectives: Develop guidelines for the use of PTSs in construction work zones. The guidelines should include a list of operations in which PTSs could be used with typical plans depicting PTS location(s). Compare the effectiveness and costs of using a flagger versus PTS with varying traffic, determine the maximum effective length of work zones utilizing PTSs, and determine where pre-time control is preferred over actuated control. All organizations that perform work on roadways will benefit from this research. The findings of this research should be considered for inclusion in the MUTCD.

Current Activities: Unknown

Urgency: Pennsylvania DOT has purchased several PTS units and developed simplistic usage guidelines. The urgency of this research is intermediate.

Rear-End Accidents in Maintenance and Construction Work Zones

Problem: Review of work zone accidents indicates that rear-end accidents are prevalent especially during freeway lane closures. Driver's inattention may be the primary cause for most of these accidents. Passive signing, such as "Watch for Stopped Vehicle Ahead" or "Right/Left Lane Closed Ahead" have not completely eliminating the problem of rear-end accidents in merge or advance warning areas.

Objectives: Determine the nature of rear-end accident problems in work zones especially from the human factors point of view. Review the existing traffic control strategy in areas where rear-end accidents are common. Modify or develop new traffic control devices to reduce the potential for rear-end accidents. Demonstrate the effectiveness of modified or new traffic control devices in the field. The estimated cost of this research is $300,000.

Current Activities: Two studies in this area are "Accident Experience in Construction and Maintenance Zones" at the Ohio State University, and a Kentucky study, "Analysis of Accidents in Construction and Maintenance Work Zones."

Urgency: The priority for this research is high due to the large number of rear-end accidents in work zones.

Committee A3C05 - Pavement Maintenance

Cold Applied Transverse Crack Sealants for Asphaltic Pavements

Problem: A majority of transverse crack sealing materials used for routine maintenance of asphalt

pavements require the use of a double boiler melter. Boilers are fairly expensive and working with hot sealants can be hazardous. If "equivalent" cold applied materials, which do not require special equipment, could be substituted it would reduce start-up costs and make for a safer operation.

Objectives: Develop or identify cost effective, environmentally safe cold applied crack sealants for asphaltic pavements which perform as well or better than hot applied materials. A durable, low cost, cold applied sealant would increase the likelihood asphaltic surfaced pavements would be properly maintained. The skill level of maintenance workers used to make the application could be lowered since the use of specialized equipment would not be necessary. Documented research clearly indicates properly sealed roads last longer and over the long run ride better. The measure of effectiveness would be public perception of better roads at overall lower cost. Effective marketing by producers drawing support from government research efforts would be an effective method of implementation. The estimated cost of this effort is $100,000.

Current Activities: Crack sealing research has tended to concentrate on hot applied materials with some emphasis on emulsions and silicone sealants. However, no specific effort aimed at developing or identifying cold applied materials is evident.

Urgency: High priority, since crack sealing is a widespread maintenance activity involving millions of dollars of work. If durable low cost, cold applied sealants were available they would likely be implemented within a relatively short period.

Analysis of SHRP Maintenance Effectiveness Data

Problem: The Strategic Highway Research Program (SHRP) Maintenance Effectiveness Study (H-101) has developed an experimental design and an analysis plan to determine the effectiveness of preventive pavement maintenance treatments. Treatments have been constructed and will be monitored until they fail. The SHRP contractor will analyze the initial information from the treatments; however, most of the treatments will have been in place no more than 2 years when the SHRP H-101 study ends in late 1992. There is no provision for continuing the analyses of the data.

Objectives: Continue the analysis of the data from the SHRP H-101 (LTPP SPS-3 and LTPP SPS-4) test sections and provide the maintenance community with information on the effectiveness of the preventive pavement maintenance treatments. Results of the analysis should define the effectiveness of each treatment in various environmental regions and under different traffic levels. In addition, it should show the most cost-effective time in the life of the pavements to apply the treatments. A cost-effectiveness analysis procedure should also be developed. A training program should be prepared to allow agencies to train their engineers and supervisor about the results of the analysis. This process should improve the success rate of preventive pavement maintenance treatments, improve the cost-effectiveness of treatments, and help justify requests for preventive maintenance budgets. The audience for this work includes members of AASHTO, the FHWA, and local agency organizations such as APWA, NACE, and RTAP. The estimated cost of this effort is $750,000 over 7 years.

Current Activities: The treatments are in place and the H-101 contractor has developed analysis techniques. The H-101 contractor will complete the initial analysis. No major work is know to be underway to continue this effort after SHRP.

Urgency: Hundreds of millions of dollars are spent on preventive maintenance each year in the U.S. It is immensely important to determine the effectiveness of the preventive maintenance treatments and to determine the most cost-effective time in the life of a pavement to apply these treatments.

Micro-Surfacing Quality Assurance

Problem: Many agencies are currently using micro-surfacing as a maintenance treatment for pavement deficiencies. Currently, there are no standard methods available to complete quality assurance checks during the treatment application. Field personnel must rely on previous experience or contractor expertise. The standard specifications are vague concerning the type of checks which would be useful.

Objectives: Develop standard quality assurance procedures for micro-surfacing treatment application to insure that the treatments are applied correctly. A set of quality assurance guidelines including check lists for materials, equipment, material tests, treatment

application process checks and post application checks should be developed. A training program should be prepared to allow agencies to train their inspectors on the quality assurance process. This process should improve the service life of micro-surfacing treatments. The audience for this work includes members of AASHTO, the FHWA, and local agency organizations such as APWA, and RTAP. The estimated cost of this research effort is $150,000.

Current Activities: No major work is known to be underway.

Urgency: Hundreds of millions of dollars are spent on surface seals each year in the U.S. More of that market is going to micro-surfacing each year. It is imperative that those purchasing this material have the proper quality assurance techniques to insure the treatment is placed properly.

Committee A3C08 - Maintenance Equipment

Computerized Repair Manuals

Problem: Equipment repair shop manuals are expensive to purchase in quantities to adequately support statewide applications, are cumbersome to use, and susceptible to becoming outdated and soiled with use.

Objectives: Develop a computerized repair manual system that can be specified in equipment purchase specifications and updated as changes occur. The system should be standardized in a mainframe or PC format.

Standardized Equipment Classifications

Problem: Manufacturers produce construction equipment in a variety of configurations and class sizes. Since there is no standardized equipment classification system, it is very difficult to develop competitive comparison of the equipment produced by several manufacturers.

Objectives: Develop a standard classification system with recommended weights, hp, capacity and other specifications, i.e., tractor-loader-backhoe in classes with recommended weight, hp, loader capacity, backhoe size. This would encourage manufacturers to build similar size units with comparable specifications.

Current Activities: None

Reducing Accidents During Vehicle/Equipment Backing

Problem: Several states are using motion sensing devices that display distance from obstacles for preventing side blind-spot backing accidents. Their cost effectiveness is unknown.

Objectives: Evaluate the cost effectiveness of motion display mirrors in preventing economic losses due to backing-up accidents.

Fuel Consumption and Alternative Fuels

Problem: There are several fuel related problems that public agencies and others are likely to face within this decade. They include emission constraints in diesel equipment, rising fuel costs, use of alternative fuels and fuel shortages. Although fuel is currently in adequate supply, history has taught us that this is not likely to be the case in the future.

Objectives: Conduct a policy study to assess the implications of fuel shortages, acceptability and availability of useable alternative fuels, and programs for managing use of fuels in the face of changing and diminishing fuel supplies.

Current Activities: None

Funding Methods for Maintenance Equipment

Problem: Acquiring consistent annual funding for maintenance equipment that facilitates improved fleet utilization, improved highway maintenance and reduced system costs is often an exercise in frustration for many states.

Objectives: Conduct a study of the revolving fund and annual baseline budget to identify the best method for fleet management operations.

Current Activities: None

Equipment Replacement Decisions

Problem: When is the right time to replace a piece of maintenance equipment? This is an often asked question that goes unanswered for many highway departments. Various guidelines are available in both the public and private sectors for replacing equipment. These guidelines, however, are often contradictory.

Objectives: Develop standardized guidelines for assessing when to replace a piece of maintenance equipment.

Current Activities: None

Computerized Equipment Specifications Comparison Program

Problem: Millions of dollars are spent each year for trucks and equipment to maintain the roadway system. Some construction and heavy equipment manufactures have developed computer programs that compare their equipment to other manufacturers' equipment. Expansion of this process should be made to include a broad spectrum of equipment types used in maintenance and construction activities in the public and private sectors.

Objectives: Develop a computerized equipment specifications comparison program applicable to a broad spectrum of construction and maintenance equipment. This program would be effective in assisting DOTs in the procurement of the best equipment with the limited resources.

Current Activities: None

Life-Cycle Cost Analysis for Alternative Fuel Vehicles and Equipment

Problem: There is a need for a standard procedure for calculating the life-cycle cost of alternative fueled vehicles and equipment. It is crucial to include all elements of costs and savings in the calculation to project accurately the total net costs or benefits.

Objectives: Develop a procedure to accurately determine life-cycle cost of various alternative fuel vehicles and equipment.

Committee A3C09 - Winter Maintenance

Economics of Highway Snow and Ice Control

Problem: The economic impacts of winter highway maintenance decisions are not well known. Agency costs are available, but little information exists on user costs and general economic impacts of snow and ice removal. The removal of snow and ice from the Nation's highways is a costly and time consuming operation for highway agencies. However, the failure to provide a reliable unimpeded high level of access for the industrial sector, the commuter, and the service elements of our economy can have a severe economic impact. The inadequate removal of snow and ice also has severe impact on safety and traffic congestion.

Snow and ice control operations represent a significant portion of many highway agency maintenance budgets. Aside from the direct costs, there are many other costs that need to be weighed in making decisions about snow and ice removal activities. Among these are traffic congestion, safety, lost productivity, freight charges, as well as environmental impacts and infrastructure deterioration.

Objectives: Develop a framework for highway agencies to use to perform an economic analysis of their snow removal and ice control operations. This framework would consider not only the operational costs but also the other economic impacts. Consideration should be given to new technology in weather prediction, pavement monitoring, alternative deicing chemicals, anti-icing techniques, equipment and information processing and management practices.

Current Activities: There are studies on the overall economic impacts of transportation, but little exists on winter maintenance details. The recently published Transportation Research Board study on salt/CMA points up the lack of this information.

Urgency: High priority. This research would be of immediate value to all state and local agencies involved with winter maintenance. Improved decisions will benefit agencies and the traveling public.

Effectiveness of Chemical/Abrasive Mixes for Snow and Ice Control

Problem: Maintenance agencies use chemical and abrasive mixtures under a wide variety of conditions. The traction capabilities of abrasive and deicing capabilities of chemicals have been evaluated. Abrasives provide traction and deicing chemicals melt snow and ice. Combining the materials produces a wide range of results. Current abrasive material specifications are developed and based primarily on the engineering physical properties of the material such as gradation (sieve analysis) and abrasion (materials hardness) testing. Since many abrasive materials are derived from recycled waste materials and other similar bi-products, it is necessary to develop specifications to include an analysis for complete chemical and mineral properties based on their potential hazard to the environment.

Objectives: Evaluate the effectiveness of abrasive and deicing chemical mixtures, and identify procedures to assess the chemical and mineral properties of the mixtures with specification parameters that are based on their potential hazard to the environment. Since many agencies combine abrasive and deicing chemicals in a wide range of proportions, look at a range of mixtures commonly used. Evaluate the friction and deicing abilities of the various mixtures. Analyze potential maximum contaminant levels (MCL) for component elements of selected abrasive materials. Investigate toxicity levels and analyze for heavy metals leachates based on their potential hazard to the environment. Savings of chemicals and abrasive would likely result from this research. The benefits of field performance and laboratory testing would be of value to agencies that have responsibility for snow and ice control.

Current Activities: Many studies have been conducted to evaluate individual deicing chemicals or abrasives. No studies have taken a comprehensive look at abrasive and deicing chemicals together. Some studies and analysis of some abrasive materials such as bottom ash have been performed, however, no specification parameters have been established that are tied to environmental impacts/concerns.

Urgency: High priority. This research is of major importance to the agencies that use both abrasive and deicing chemicals. The environmental impact of these materials combines with the safety implications of dealing with roadway pavements under winter conditions to make the results of this research very important.

Committee A3C12, Coatings, Signing and Marking Materials, and Committee A3A04, Visibility

The Aging Eye and Implications on the Visual Task in Traffic

Problem: Recommendations and standards for lighting have been based on data that do not incorporate the natural degeneration of the visual capability with age. This is true for lighting at the work place indoors as well as for standards set up for roadway lighting and regulatory traffic installations such as traffic lights and signs. The recommended luminance levels at the work place and on the road, the restrictions of disability and discomfort glare, the intensities of traffic lights and the studies on the legibility of traffic signs have all been based on the eye of an age group of 20-30 years. Only a few publications, such as *CIE-Report 19.2* mention some aspects of age on vision. According to many investigations the transparency of a 60-year old observer's eye media are an average 43% of those of a 25 year old. Also important changes in the retina decrease the capability of visual resolution of details resulting in a reduction of visual acuity. Calculations reveal that a 70-year old person needs about four times more light - measured as increase of the task luminance to achieve the same visual acuity as a 25 year old. This has essential consequences for the design and the recommendations for lighting to ascertain that the visual task can be performed by older persons.

Objectives: Quantify the various effects of age and their implications on vision and evaluate the lighting conditions that are necessary for the older eye to ensure appropriate visual performance. Within this study, data on effects of age on the eye and visual functions should be collected. Some effects, such as the course of the ocular media transmittance and the stray light occurring in them, and range of accommodation are very well researched and reconfirmed by many investigations. For those results numerical functions should be developed to incorporate the age function into the calculation of contrast sensitivity, visual acuity, disability glare, etc. These functions determine essentially the conditions that have to be provided to allow appropriate performance of the visual task for all ages. The results could be implemented into lighting standards to provide adequate conditions for older drivers, a substantial portion of the driving population.

Fields of Visibility

Problem: A quality assessment of a roadway lighting installation is based on the visibility of an object 17.8 cm (7 in) on each side. This is the smallest object which must be seen for safe travel. A model has been developed to calculate the required luminance difference threshold for detection of that target. A threshold multiplier or visibility level (VL) is used to quantify how visible a target is above its threshold of detection. These calculations have been included in the proposed IES RP-8. However, this model only calculates the detection threshold for a target which is along the line of sight. The driver's visual task is seldom restricted to the horizontal peripheral axis. For safe travel, the driver must detect and recognize objects in almost every portion of the visual field. Objects in the drivers path are in the lower half of the visual field. Road signs are to the side and upper half of the visual field. When considering the safety of a lighting installation, the quality criterion must include an assessment of the visibility of objects in the periphery of the visual field.

When a target is located peripherally, then detection threshold increases. Poppel & Harvey and Johnson, et. al., performed experiments which quantified this increase in off axis viewing angle, target size, and background luminance. Unfortunately, their data sets are contradictory and applicable to the horizonal axis only.

Objective: Data which considers the off axis viewing angle as well as the off horizontal viewing angle is required for varying background luminance and target sizes. Using this data, a model which describes the increase in the peripheral detection threshold would be developed to describe the visibility of targets off the visual axis. This model would then be used to describe fields of visibility. These fields would describe areas in which a target could be seen with equal visibility with visibility level as parameter. These fields as well as quantification of eye movements would be able to describe the probability of detecting a target in an area of a road surface. The result of this research would be a better assessment of the quality of a road lighting installation and a safe travel for the nighttime driver.

Committee A3C13 - Sealants and Fillers for Joints and Cracks

Bond Adhesion of Formed-in-Place Seals

Problem: The majority of states responding to a recent survey on formed-in-place joint sealant performance identified bond adhesion failure at the sealant-concrete interface as a major problem. Confronted with similar problems, several European jurisdictions have recommended use of primers for all formed-in-place sealants except for coal tar systems.

Objectives: The objectives of the proposed study are to:

- Develop diagnostic methods necessary to characterize the surface chemistry of pavements made with different aggregates with respect to interaction with formed-in-place sealants.
- Develop a protocol to select a primer or sealant system for various pavements under various climatic conditions.
- Design and evaluate field techniques for assessing the effect of geographical location and type of coarse aggregate on the performance of joint sealant-concrete interface bond adhesion.

To meet these objectives the following tasks are proposed.

- Identify major cement-aggregate systems that are or have been used in constructing concrete roads.
- Identify the details of adhesion failure of joint sealants occurring with various concrete types under various climatic conditions.
- Identify, through microscopic and chemical diagnosis, the modes of adhesion failure that occur with various concrete sealant systems. Emphasis should be placed on the role of aggregates in concrete and on the chemistry of formed-in-place sealant types used in the United States.
- Evaluate surface chemistry of cement phases and their adhesion characteristics to the sealant types. The evaluation should include surface chemical and adhesion measurements under simulated climatic conditions. The need for primers to enhance adhesion of cement phases should be recognized in the results of this task.
- Evaluate surface chemistry of typical aggregates used in concrete as pertinent to sealant adhesion in pavement joints.
- Evaluate adhesion of various sealants to major types of aggregates under both dry and wet conditions, and in

the presence of ions normally leaching out of concrete. Adhesion should be measured under various climatic conditions.

- Compile and summarize surface chemical and adhesion parameters prevailing with various concretes and sealants under various climatic conditions. The need for suitable primers or modification of sealants for various types of concretes and various climatic conditions should be determined.
- Construction pavement joints and use different primers and sealants on the laboratory scale. Test adhesion characteristics under various climatic conditions.
- Define and develop protocols to select primer or sealant systems for various concretes and climatic conditions.
- Develop diagnostic testing procedures necessary for successful implementation of technology.
- Prepare a final research report documenting all activities and results of research.

It is estimated that this study will cost $500,000 over 3 years.

Current Activities: A search of the TRIS database failed to identify any research in this area.

Urgency: The dollar payoff of this technology across the United States is in the hundreds of millions of dollars. The urgency of this research is high.

Sandblaster Nozzle To Simultaneously Clean Both Sides of a Joint

Problem: Preparing PCC pavement joints for joint sealing by sandblasting is both hazardous and not completely effective. The sandblast operator is forced to use nozzles that are better suited for flat surfaces. The nozzle compels the operator to blow sand from an elevation several inches above the joint. This causes obfuscation of the joint reservoir due to the large cloud of silica dust that has been created. The operator is in effect shooting in the dark. This causes two serious problems. The operator is forced to work in a cloud of silica dust, putting his/her health at risk, and is also missing portions of the joint reservoir, thus adversely affecting bond adhesion at the joint seal-concrete interface. Intermittent bond adhesion failure is the major cause of formed-in-place joint seal failures.

Objectives: Develop a sand blast nozzle which will effectively and efficiently clean both sides of the joint reservoir.

Current Activities: None reported.

Urgency: The use of currently available sand blast nozzles contribute to the problem of intermittent bond adhesion failure with formed-in-place joint sealants.

Infrared Analysis to Detect Faulty Joint Sealant Materials

Problem: Improper installation of joint sealant material is one of the major causes of poor joint sealant performance. Some of the typical deficiencies noted are joints are not properly cleaned before being filled with joint sealant, overheating of the hot-applied sealants, and improper mixing of the two-component joint sealants. The results can be a brittle material or one that does not cure. These joint sealant problems can be overcome by employing current analytical technology to insure proper mixing ratios and installation procedures.

Objectives: Develop a user friendly database of Fourier-Transform Infrared Spectroscopy (FTIR) readings from different joint sealants. These readings can be used by engineers to perform sealant quality control checks. FTIR readings identify the chemical characteristics of the joint sealants. Joint sealants that are improperly mixed, overheated or contaminated can be detected.

Current Activities: The Pavement Systems Division of the U.S. Army Engineer Waterways Experiment Station (WES) is currently taking FTIR spectra on joint sealants submitted for Federal Specification conformance testing (SS-S-1401C, SS-S-1614A, and SS-S-200E) for use on military projects. WES has also performed several site investigations of failed rigid pavement joint sealants using this technique. The database currently (1992) contains over 150 FTIR spectra readings of different joint sealants.

Urgency: The detection of faulty joint sealants during installation will have a significant impact on preserving and extending the life of the nations roadway system.

Anchoring System for Mechanical Bridge Deck Joints

Problem: Bridge deck joints come in a wide variety of sizes, shapes and configurations. One thing that is consistent with all types of joints is the problem of permanently affixing them to the concrete. Designers have a myriad of anchorage systems to choose from such as expansion, epoxy resin, cast-in, and post-tensioned anchors, to name a few. However, very little data exists on how these systems perform under constant impact loading.

Objectives: Develop test data on the performance of various anchorage systems on in-service bridge decks.

Current Activities: No research at present.

Urgency: Bridge deck joint failure results in sub-structural deterioration. In addition, loose joint components result in serious hazard to vehicular traffic. Anchorage breakdown is one of the major causes of bridge deck joint failure.

Evaluation of Pavement Joint Seal Failures

Problem: There is very little information on the condition of new joint seal installations, and the type and rate of joint seal failures.

Objectives: Evaluate the pavement joint seal condition starting immediately after installation. Determine the type and source of initial failures and their rate of progression through nondestructive testing over a 3 year period.

Current Activities: No national research activities are known to be underway in this area.

Urgency: A database with information on failure mode and rate for pavement joint seals is needed to help understand the joint seal failure problems which exist today.

Evaluation of New Pavement Joint Sealants and Installation Procedures

Problem: Some very expensive joint sealants have been developed over the past 10 years. However, the rate of joint seal failures has not markedly improved. Although sealants may pass laboratory tests, eventual failures are often blamed on installation procedures.

Objectives: Establish a joint sealant product and installation evaluation program for comparison of product performance.

Current Activities: Some evaluations of joint sealants are being done on a project or state wide basis. None are known to include a combined evaluation of sealant and installation.

Urgency: Performance of new products could be determined more reliably through a combined product and installation evaluation.

Sealant Materials and Installation Procedures for "Fast Track" Concrete Pavement Joints

Problem: "Fast Track" concrete pavements have gained acceptance as a viable pavement option in recent years. The accelerated pavement strengths made possible by innovations in mix designs and placement techniques are very encouraging. Concrete pavements can accommodate vehicular traffic 24 hours after placement. However, often times the joints cannot be sealed for some time afterwards, thus limiting the benefits of the "Fast Track" technique.

Objectives: Evaluate or develop sealant materials and installation procedures which would enable contractors to seal joints in a manner befitting the "Fast Track" concept, thereby improving pavement construction speed and pavement quality.

Current Activities: Several types of sealants have been used to seal "Fast Track" concrete pavements, including compression sealants and silicones. There is no standard practice.

Urgency: Development of such procedures would increase the usage of "Fast Track" and reduce highway user costs.

Analytical Investigation of Adhesive Stresses in Highway Joint Seals

Problem: Highway joint seals fail at a rate which is quite unacceptable. Recent studies have shown that adhesion

failure is the most troubling obstacle to obtaining long-term effective seals. Interest in this problem has grown in the past 5 years and this has led to research which has followed three main routes: field studies, laboratory studies, and materials research. The research proposed here follows a fourth route, stress analysis of the seal system. Stress analysis has helped in the design of many other types of physical systems and its application to the problem of adhesion failure of highway joint seals is long overdue.

Stress analyses to determine the magnitudes and distributions of adhesive stresses associated with specific material properties, seal configurations and joint distortions would complement the other forms of research currently in progress. Many combinations of material properties and seal geometrics can be investigated rapidly and economically to determine which combinations are most likely to succeed in the field. This can save much of the expense of laboratory and field studies. Analytical parametric studies can also help in the development of new or modified materials.

Part of the reason that stress analyses for joint seal systems have not yet been accomplished is that elastomeric seals behave in a complex manner which is not adequately represented by traditional methods of stress analysis. Furthermore, there has been very little work on defining the mechanical properties of sealant materials. Typical elastomeric sealant materials (such as polymer modified asphalt and silicones) stress relax at a very fast rate. Analyses which fail to account for this behavior are subject to error. Seals also incur large strains, so geometric non-linearity must be considered in the analysis. The material properties of most sealant materials also very with temperature. While these features of the seal system make analysis difficult, preliminary studies indicate that appropriate analysis method is entirely feasible and practical.

Objectives: The objectives of the proposed research are to:

- Develop a material constitutive equation which accounts for the critical features of sealant behavior.
- Develop an analysis algorithm which permits modeling the pertinent material and geometric characteristics.
- Test material to quantify parameters used in the constitutive equations.
- Perform analyses to determine adhesive stress magnitudes and distributions.
- Correlate analysis results with laboratory testing.

The research should be arranged in two phases. Phase I would consist of preliminary material testing, development of the algorithm and analyses to verify the approach. Phase II would consist of testing additional materials to determine their visco-mechanical properties and perform parametric studies using the analysis method developed in Phase I. The estimated cost for this effort is $450,000 over 3 to 4 years.

Committee A3C14 - Adhesives, Bonding Agents and Their Uses

Properties of Polymer Concretes Used in Bridge Deck Overlays

Problem: Polymer concretes used in bridge overlays need to have the appropriate flexibility, tensile strength, adhesion strength and durability in the presence of moisture to provide a long-service life. The ASTM D 638 procedure is currently used to measure the elongation and tensile strength of heat specimens. Overlays have performed reasonably well when the binders tested in the laboratory at 23°C (73°F) and at an age of 7 days exhibit a tensile strength of 10 to 27 MPa (1,500 to 4,000 psi) and an elongation at break of 20 to 90 percent. It is accepted that the flexibility of binders is temperature dependent but studies need to be done to show how currently used binders perform at temperatures other than 23°C (73°F), including the extreme temperatures of -18° and 60°C (0° and 140°F) typically encountered in service. Also, overlays exhibit a minimum tensile adhesion strength of 1.72 MPa (250 psi) when tested in accordance with ACI 503R. The overlays are typically applied to dry surfaces at temperatures of 18° to 38°C (65° to 100°F) and tested under similar conditions. Studies need to be done to measure the adhesion strength at other temperatures including -18° and 60°C (0° and 140°F) and when moisture is present in the substrate. Finally, studies should be done to show the effect of the age of the polymer concrete on these properties.

Objectives: Measure the tensile strength and elongation at break (ASTM D638) of selected epoxy, polyester, methacrylate and urethane binders and the tensile adhesion strength (ACI 503R) of selected polymer concretes, when tested in the ranges of temperatures, moisture conditions and overlay ages typically encountered on bridge decks. The research will help identify and refine the specifications for the most

durable polymer overlay systems. The published results of this research will allow engineers to specify materials and procedures which will produce longer lasting overlays. The estimated cost of this effort is $400,000, including $150,000 to study age effects.

Current Activities: None at temperatures other than 23°C (73°F).

Urgency: Results are urgently needed because millions of dollars are spent annually on polymer bridge overlays. Optimum properties of polymer overlays must be identified to obtain a long-service life.

Concrete Bridge Deck Crack Repair

Problem: A recommended practice is required for the repair of cracks in concrete bridge decks to seal effectively or structurally repair them to prevent further damage by chloride intrusion.

Objectives: Identify materials and procedures that should be used for the repair of various types of cracks normally found in concrete bridge decks. Develop a guide to assist engineers in writing specifications for better and longer lasting repairs. The estimated cost of this study is $100,000.

Current Activities: None

Urgency: Effective sealing of cracks in bridge decks will reduce chloride intrusion to the reinforcing steel, and thus reducing the possibility of corrosion and increasing bridge deck service life.

Non-Destructive Field Test to Measure Polymer Concrete Overlay Strength

Problem: Simple, non-destructive, rapid, field tests are needed to measure the strength of polymer concrete overlays, so engineers can determine when to allow bridges to be opened to traffic without affecting the service life of the overlay.

Objectives: The objectives of this study are as follows:

- Identify the relationships between strength development and curing temperatures for generic polymeric materials used to construct polymer concrete overlays.
- Develop a simple, non-destructive test that can be used in the field to measure overlay strengths.

This research will allow engineers to know when overlays have attained the proper strength and are ready to be opened to traffic. A user's guide with nomographs showing the relationship between strength and age at various temperatures for generic groups of polymer materials and a test method for measuring strength would be helpful extending the service life of polymer concrete overlays to their full potential. The estimated cost of this effort is $200,000.

Current Activities: None

Urgency: The use of polymers is increasing and therefore, this study is needed to reduce failures and increase service life of overlays.