TRANSPORTATION RESEARCH CIRCULAR

Number 179, September 1976

Transportation Research Board, National Academy of Sciences, 2101 Constitution Avenue, Washington, D.C. 20418

# Research Problem Statements

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63 mechanics (earth mass)
64 soil science
03 rail transport



GENERAL NOTE

This circular supplements Circular 160 dated November 1974 in which 81 priority research needs were identified by seventeen of the Group's committees. Although a few statements are repeated in this circular to emphasize their importance as top committee contributions, those remaining in Circular 160 are considered by the Group Council to be of current value and worthy of serious consideration for research effort.

# CONTRIBUTING COMMITTEES

| COMMITTEES | TITLES | CHAIRMAN |
|---|---|---|
| A2A02 | Geometric Design | B. H. Rottinghaus |
| A2A03 | Hydrology, Hydraulics and Water Quality | Samuel V. Fox |
| A2A04 | Safety Appurtenances | Jarvis D. Michie |
| A2A07 | Shoulder Design | John F. Nixon |
| A2B01 | Rigid Pavement Design | Ronald L. Hutchinson |
| A2B04 | Surface Properties Vehicle Interaction | Don L. Ivey |
| A2B05 | Pavement Condition Evaluation | Kenneth H. McGhee |
| A2B06 | Theory of Pavement Design | Ralph C. G. Haas |
| A2C01 | General Structures | Heinz P. Koretzky |
| A2C02 | Steel Bridges | John W. Fisher |
| A2C03 | Concrete Bridges | C. L. Hulsbos |
| A2C05 | Dynamics and Field Testing of Bridges | Conrad P. Heins, Jr. |
| A2D01 | Characteristics of Bituminous Materials | J. Claine Petersen |
| A2D05 | General Asphalt Problems | J. York Welborn |
| A2E01 | Performance of Concrete - Physical Aspects | David Stark |
| A2E02 | Performance of Concrete - Chemical Aspects | Bernard Erlin |
| A2E03 | Mechanical Properties of Concrete | V. M. Malhotra |
| A2E04 | Curing of Concrete | Chester J. Andres |
| A2E05 | Chemical Additions and Admixtures for Concrete | Richard L. Berger |
| A2E06 | Basic Research Pertaining to PCC | Katherine Mather |
| A2F01 | Rigid Pavement Construction | Sanford P. Lahue |
| A2F03 | Earthwork Construction | Richard P. Turner |
| A2F04 | Construction of Bridges and Structures | Marvin H. Hilton |
| A2F05 | Construction Management | James Douglas |
| A2G01 | Mineral Aggregates | T. C. Paul Teng |
| A2G03 | Sealants and Fillers for Joints and Cracks | Dale E. Peterson |
| A2G04 | Adhesives, Bonding Agents and Their Uses | F. Stanley Kinney |
| A2H01 | Instrumentation Principles and Applications | C. S. Hughes, III |
| A2J03 | Lime and Lime-Fly Ash Stabilization | Marshall R. Thompson |
| A2J05 | Soil-Bituminous Stabilization | Jon A. Epps |
| A2K02 | Embankments and Earth Slopes | Raymond A. Forsyth |
| A2K03 | Foundations of Bridges and Other Structures | Clyde N. Laughter |
| A2K05 | Mechanics of Earth Masses and Layered Systems | Harvey E. Wahls |
| A2K06 | Subsurface Drainage | George W. Ring, III |
| A2L01 | Exploration and Classification of Earth Materials | Robert B. Johnson |
| A2L04 | Frost Action | Appointment Pending |
| A2L06 | Environmental Factors Except Frost | Barry J. Dempsey |
| A2T57 | Task Force on Low Volume Roads | Melvin B. Larsen |

## INTRODUCTION

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 Group 2 Council endorses this activity and has established a Standing Committee on Research Needs to provide guidance and direction to its committees and to coordinate their efforts.

The problem statements in this circular represent a composite of efforts by thirty-eight of the Group's committees. They should not be considered an all inclusive recognition of research needs with the scope of Group's 2 activities. 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.

## PRIORITY RATINGS

In assembling these problem statements the Standing Committee on Research Needs has attempted to develop a best consensus of the top priority research needs. Each contributing committee was asked to identify, by its own method, not more than two problem statements falling in this category. All statements were then screened at the Group Section level for overlap and duplication. Two top priority statements were then chosen from the collective efforts of the section. All problem statements were then submitted to the Standing Committee for final review and processing. As a result of this review and based on the committee and section recommendations the problem statements have been rated in two priority categories:

A. The top priority statements from each section
B. The top priority statements from each committee including Category A
C. Miscellaneous other statements

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

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

# RESEARCH PROBLEM STATEMENTS

### PRIORITY STATEMENTS BY SECTIONS

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| A | Optimum Design and Use of Highway Shoulders | 8 |
| | Dropping Freeway Lanes | 1 |
| B | Relationship Between Pavement Distress and Pavement Performance | 16 |
| | The Effects of Abrupt Changes in Skid Resistance Levels on Accident Occurrence | 13 |
| C | Distribution of Wheel Loads on Highway Bridges | 17 |
| | Deflection Limitations for Bridge Structures | 18 |
| D | Reducing Dependence on Moisture Control in Hot Mix Plant Operations | 29 |
| | Tender Mixes | 30 |
| E | Abrasive Resistance, Surface Durability, and Skid Resistance of Concrete Pavements | 31 |
| | Criteria for Exact Determination of Alkali-Reactive Siliceous and Silicate Rocks | 33 |
| F | Utilization of an Open-Graded Stabilized and Free-Draining Subbase | 40 |
| | Financial Factors as a Contingency Cost in Construction | 47 |
| G | Asphalt Concrete Bridge Deck Overlays and Bridge Expansion Joints | 50 |
| | Sealing Cracks in Flexible Pavement | 51 |
| H | Nuclear Density Determination of Layered Bituminous Pavement System | 53 |
| J | Lime and Lime-Fly Ash Stabilization; Mixture Design-Quality Control | 54 |
| | Soil Lime Layers: Structural Behavior and Thickness Design | 55 |
| K | Full Scale Field Load Tests in Pile Groups | 60 |
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| | Surface and Pavement Drainage in Frost Areas | 72 |
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| | Safety Criteria for Low Volume, Low Speed Roads | 75 |

# RESEARCH PROBLEM STATEMENTS

## PRIORITY STATEMENTS BY COMMITTEE

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| A2A02 | Dropping Freeway Lanes | 1 |
| | Design and Operation of Passing Zones - Two-Lane Highways | 2 |
| A2A03 | A Rational Approach to Hydraulic Designs for Highway Encroachments on Flood Plains | 4 |
| | Flood Flow Hydrographs for Use in Culvert and Storm Sewer Design | 5 |
| A2A04 | Evaluate Field Performance of Guardrail Installations | 6 |
| | Traffic Barrier Evaluation Criteria | 7 |
| A2A07 | Optimum Design and Use of Highway Shoulders | 8 |
| | Design of Paved Shoulders for Non-Emergency Use | 9 |
| A2B01 | Optimizing the Structural Section of Portland Cement Concrete Pavement Systems | 10 |
| | Lateral Lane Placement of Trucks and Its Relationship to Rigid Pavement Distress | 11 |
| A2B04 | The Development of Skid Resistance Requirements from Traffic Observations | 12 |
| | The Effects of Abrupt Changes in Skid Resistance Levels of Pavements on Accident Occurrence | 13 |
| A2B05 | Development of Calibration Methods for Road Roughness Meters | 14 |
| | Guidelines for Establishing a Pavement Performance Information and Intelligence System | 15 |
| A2B06 | Relationship Between Pavement Distress and Pavement Performance | 16 |
| A2C01 | Distribution of Wheel Loads on Highway Bridges | 17 |
| | Deflection Limitations for Bridge Structures | 18 |
| A2C02 | Probabilistic Design of Steel Structures | 19 |
| | Tolerances in Steel Bridges | 20 |
| A2C03 | Long-Time Fatigue of Steel Reinforcement in Concrete Beams | 21 |
| | Fatigue Strength of Reinforcing Bars at Bar Cut Off Locations | 22 |
| A2C05 | Measurement of the Life Expectancy of Older Bridges | 27 |
| | Vibration Suppression in Rapid Transit Structures | 28 |
| A2D01 | Reducing Dependence on Moisture Control in Hot Mix Plant Operations | 29 |
| A2D05 | Tender Mixes | 30 |
| A2E01 & A2E04 | Abrasion Resistance, Surface Durability, and Skid Resistance of Concrete Pavements | 31 |
| A2E01 | Performance of Bridge Decks with Deep Reinforcement (>2") | 32 |
| A2E02 & A2E06 | Criteria for Exact Determination of Alkali-Reactive Siliceous and Silicate Rocks | 33 |
| A2E03 | In-Place Determination of Mechanical Properties of Concrete | 34 |
| | Improvement of Portland Cement Concrete by Modification with Chemicals | 35 |

| COMMITTEE | STATEMENT | PROBLEM STATEMENT NUMBER |
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| A2E04 & A2E01 | Abrasion Resistance, Surface Durability, and Skid Resistance of Concrete Pavements | 31 |
| A2E05 | Development of Non-Corrosive Accelerators and Corrosion-Inhibiting Admixtures | 35 |
| A2E06 & A2E02 | Criteria for Exact Determination of Alkali-Reactive Siliceous and Silicate Rocks | 33 |
| A2E06 | Performance and Characterization of Blended Cements and Optimization of Portland Cement-Pozzolan Mixtures | 37 |
| A2F01 | Utilization of an Open-Graded Stabilized and Free-Draining Subbase | 40 |
| | Optimization of Macrotexture (Roadway Surface Texture) and Rideability for Concrete Pavements | 41 |
| A2F03 | Construction Practices for Incorporation of Sanitary Waste in Highway Embankments | 43 |
| | Develop Rapid Non-destructive Control Test for Determining Engineering Sufficiency of Constructed Embankments | 44 |
| A2F04 | Paint Systems for Re-Painting Old Structural Steel and Coating New Steel | 45 |
| | Composite Behavior of Glulam Bridge Systems | 46 |
| A2F05 | Financial Factors as a Contingency Cost in Construction | 47 |
| A2G01 | Characterization of Acceptable Aggregates | 48 |
| | Review of Aggregate Beneficiation Processes | 49 |
| A2G03 | Asphaltic Concrete Bridge Deck Overlays and Bridge Expansion Joints | 50 |
| | Sealing Cracks in Flexible Pavements | 51 |
| A2G04 | Development of a System for Classifying Adhesive Compounds by Use | 52 |
| A2H01 | Nuclear Density Determination of Layered Bituminous Pavement Systems | 53 |
| A2J03 | Lime and Lime-Fly Ash Stabilization: Mixture Design-Quality Control | 54 |
| | Soil Lime Layers: Structural Behavior and Thickness Design | 55 |
| A2J05 | Compilation of Field Performance Data for Soil-Bituminous Stabilized Pavement Layers | 56 |
| A2K02 | The Effect of Construction Techniques on the Performance of Vertical Sand Drains | 57 |
| | Secondary Compression Characteristics of Organic Deposits | 58 |
| A2K03 | Full Scale Field Load Tests on Pile Groups | 60 |
| | Effects of Differential Settlement on Structures | 61 |
| A2K05 | Fracture Analysis of Pavement Systems | 63 |
| | Stochastic Analyses of Pavement Systems | 64 |
| A2K06 | Effectiveness of Daylighted Subbases | 65 |
| | Performance of Pavement Subdrains in a Freeze-Thaw Environment | 66 |
| A2L01 | Evaluation of Equipment and Procedures for Sampling Sand and Gravel Deposits | 69 |
| | Evaluation of Geophysical Methods and Instruments as Applied to Subsurface Exploration for Transportation Corridors | 70 |
| A2L04 | Frost Related Pavement Distress Manifestations | 71 |
| | Surface and Pavement Drainage in Frost Areas | 72 |
| A2L06 | Moisture Induced Strength Variations in Pavement Systems After Construction | 73 |
| A2T57 | Design Standards for Low Volume Roads | 74 |
| | Safety Criteria for Low Volume, Low Speed Roads | 75 |

# RESEARCH PROBLEM STATEMENTS

## MISCELLANEOUS OTHER STATEMENTS

| COMMITTEE | STATEMENT | PROBLEM STATEMENT NUMBER |
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| A2A02 | Additional Through Lanes at Intersections | 3 |
| A2C03 | Bond Fatigue of Prestressed Concrete Bridge Members | 23 |
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| | Fatigue Strength of Low-Allow Steel Reinforcing Bars | 25 |
| | Fatigue Strength of Prestressing Strand | 26 |
| A2E06 | Monitoring Environmental Responses of Concrete Constructions | 38 |
| | Accelerated Reactions/Curing of Portland Cement Paste | 39 |
| A2F01 | Investigation of the Wear Performance of P.C. Concrete Pavement Surfaces Constructed Using Type 1P Cement | 42 |
| A2K02 | Long Term Stability of Cut Slopes | 59 |
| A2K03 | Soil: Pile Load Transfer in Pile Groups | 62 |
| A2K06 | Predicting Permeability of Highway Materials from Physical and Chemical Characteristics | 67 |
| | Filter Cloths and Fabrics | 68 |

PROBLEM NO. 1 - COMMITTEE A2A02

I. NAME OF PROBLEM - DROPPING FREEWAY LANES

II. THE PROBLEM - Generally speaking, any lane reduction produces hazardous operation on the facility. There is indecision and confusion from the driver's standpoint relative to "What should I do now." The problem is generated as a result of a decrease in through traffic volume at an exit ramp. Studies are needed to establish criteria for standardized design. The studies should include all factors such as types of interchanges, vehicle paths, accident rates, safety, and traffic operations.

III. OBJECTIVES - To determine, from the standpoint of traffic operation and safety the best type or types of geometric design for reducing the number of through lanes on freeways to include: (1) the most desirable location with respect to interchange ramp terminals for reducing the number of lanes, (2) the geometric design of transition areas, (3) signing and delineation in conjunction with the transition. Such studies should cover all usual design and operating conditions so as to permit development of recommended practices or standards for reducing the number of through lanes.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 51, 53, and 55 have been scanned in preparing this statement.

B. Suggested key words are: geometric design, freeway lane drops, and freeway interchange.

C. NCHRP Project 3-16/1 is currently underway.

V. URGENCY - This project warrants an immediate and high priority, particularly since the Interstate system is nearing completion and secondly due to the increased emphasis on multilane high-speed urban facilities.

PROBLEM No. 2 - COMMITTEE A2A02

I. NAME OF PROBLEM - DESIGN AND OPERATION OF PASSING ZONES - TWO-LANE HIGHWAYS

II. THE PROBLEM - The level of service and safety of two-lane highways is highly dependent on the availability of passing opportunities. In turn, for a given traffic volume level, passing opportunities are related to the frequency and length of passing zones. The frequency and length of passing zones in turn depend on the highway alignment design standards (AASHO) and the no-passing zone striping standards (MUTCD). Unfortunately the design standards for passing sight distance and the striping standard for no-passing zones are based on different criteria.

Operational data are needed so that design and striping standards can be made compatible and at the same time optimize the safety and efficiency of traffic operations. Then design procedures can be developed to optimize the frequency and length of passing zones for any two-lane highway.

III. OBJECTIVES -

A. To determine how the length of a passing zone relates to the passing utilization of that zone for different traffic volume levels.

B. To determine how the length and sight distance profile of a passing zone relate to safe passing operations.

C. To determine how the frequency and length of passing zones affect the level of services.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 51, 53, and 55 have been scanned in preparing

this statement.

B. Suggested key words are: passing sight distance, vertical curvature, no-passing zones, and geometric design.

C. A small amount of data gathered (James Robert Jones, "An Evaluation of the Safety and Utilization of Short Passing Sections," Thesis, Texas A&M University, December 1970) indicates that short passing zones have a low utilization with a relatively high hazard.

V. URGENCY - The relatively high number of annual fatalities from collisions by passing vehicles warrants a much closer look at the operation of passing zones.

PROBLEM NO. 3 - COMMITTEE A2A02

I. NAME OF PROBLEM - ADDITIONAL THROUGH LANES AT INTERSECTIONS

II. THE PROBLEM - A highway usually has much higher traffic capacity between intersections than it does at signalized at-grade intersections. To utilize the highway capacity between intersections, additional lanes can be provided at intersections. These additional lanes are usually designed for turning movements. However, there are certain situations that may require additional through lanes. There is need for a determination of length of the additional lane, both in advance of and beyond the intersections, to permit safe and efficient flow of through traffic. This determination must be recognized as a separate problem, and not associated with an auxiliary lane as derived in the highway capacity manual. The most uncertain part of the design is what length of lane is required beyond the intersection to provide a satisfactory traffic merge when the added lane is ended.

III. OBJECTIVES - to make field studies and collect and analyze operational data over a sufficient range of lane lengths and traffic volumes to determine:

A. The required length of extra through lane (including taper requirements) beyond the intersection.

B. The required length of extra through lane (including taper) needed in advance of the intersection.

C. The refinements of the above lane length as they are affected by design speed, profile grade and percent of trucks.

D. The differences, if any, between high volume (peak hour) and low volume (off peak) design requirements.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 51, 52, and 53 have been scanned in preparing this statemnt.

B. Suggested key words are: geometric design, intersection design, capacity, safety, traffic merge, truck factor.

C. Many studies have been made of traffic capacity at intersections but none to directly apply to this problem.

D. A reprint of "Public Roads" for the August, 1967 and October, 1967 issues provides a theoretical method of determining length requirements of widened intersection approaches in Part 3 - Special Conditions, but research is needed to verify the suggested design is satisfactory.

V. URGENCY - This project warrants an immediate and high priority because existing highways can be provided with increased capacity at relatively minor cost if the designer is sure this design is safe and efficient.

PROBLEM NO. 4 - COMMITTEE A2A03

I. NAME OF PROBLEM - A RATIONAL APPROACH TO HYDRAULIC DESIGNS FOR HIGHWAY ENCROACHMENTS ON FLOOD PLAINS

II. THE PROBLEM - Conventional practice in the hydraulic design of highway encroachments on flood plains is to provide for conveyance, with little damage, of the peak discharge of a flood of a selected recurrence interval. Consideration is not usually given to uncertainties in the estimate of the flood peak or to the probability or chance that the design flood will be exceeded. A rational approach is needed for selection of the design flood frequency based on risk and economics.

III. OBJECTIVES - To develop criteria and procedures for incremental cost analysis and decision-making in the selection of design flood frequency for highway flood plain encroachments. The procedure would recognize the probability that the base design flood will be exceeded during the life of the highway, include techniques for arriving at an optimum design insofar as capital costs and deferred costs are concerned, and provide guidance for decision-making in view of budgetary constraints, both for capital investments and deferred costs.

The criteria for the selection of a base flood frequency for the design of a route or route segment would be based on traffic service considerations. The base flood frequency would be dependent upon the availability of alternate routes, the importance of the route or route segment to commerce or national defense, traffic volumes, the need for the route for emergency supply or evacuation in case of a natural disaster and other factors.

The procedure for the design of each encroachment would include an analysis of the risk to life and property, including both the risk of damage to the highway and damage to other property as it would be affected by the presence of the highway, total cost of the highway encroachment including capital costs for construction and deferred costs for maintenance, repair and reconstruction, and for liability to others for damages caused by the highway, costs of traffic interruption, and other factors. It should also provide guidance for decision-making in recognition of budgetary constraints both for capital investment and deferred costs. Inherent in this are methods for evaluating the

present worth of probable future costs from floods larger than the design flood and techniques to minimize or mitigate damages caused by the highway from such floods, as by flow over the highway.

The procedure would include consideration of flow duration as well as flood peak in assessing the risk of flood losses.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress area 15 has been scanned in preparing this statement.

B. Suggested key words for this problem: design flood, flood plain encroachments, risk, capital cost, deferred costs, hydraulic designs.

C. Related research activities: FHWA Contract research with Water Resources Engineers, Flood Risk Factor in the Design of Box Culverts and Bridges.

V. URGENCY - The Federal Highway Administration annual budget for emergency repair and reconstruction damages to highways on the Federal-Aid system from natural disasters is $100 million. The states and local jurisdictions undoubtedly spend a like amount for the repair and reconstruction of roads damaged by events which are not widespread enough to be declared an emergency. An additional $40 million from OEP is for flood damage repair.

In view of annual expenditures nationally on the order of $200 million+ for flood damage repairs, it is appropriate to take a hard look at design criteria and procedures and to develop procedures for optimizing designs based on the total cost of construction and maintenance.

PROBLEM NO. 5 - COMMITTEE A2A03

I. NAME OF PROBLEM - FLOOD FLOW HYDROGRAPHS FOR USE IN CULVERT AND STORM SEWER DESIGN

II. THE PROBLEM - Highway culverts and storm drain systems are usually designed on the basis of a steady-state peak flow. If the design hydrograph, including shape, peak, and volume could be approximated for a certain frequency of occurrence, many drainage structures could be designed to utilize storage effects. The use of storage to reduce peak outflows is being discussed widely and is required by some local governments, especially in the design of storm drain systems for urban areas.

III. OBJECTIVES - To review techniques of synthesizing runoff hydrographs and determine the best method or methods for use in rural and urban highway drainage design. This may require development of a new method if existing techniques are found inadequate. Investigate the relationship between peak flow frequency and volume frequency.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress area 15 has been scanned in preparing this statement.

B. Suggested key words for this problem: runoff hydrograph, synthetic hydrograph, runoff volume, hydrograph shape.

C. Related research activities: FHWA Contract Research Studies at Utah State University on urban runoff hydrograph and peak flow determination. Various synthetic hydrograph methods, such as Agricultural Research Service. Wyoming State Highway Department work on flood hydrographs.

V. URGENCY - To adequately design and perform risk analysis on highway drainage systems, some approximation of the inflow hydrograph must be made. Existing, simple methods for hydrograph simulation may or may not be adequate. Also, it may not be correct to assume that the peak frequency and the derived runoff volume frequency are the same. If an adequate synthetic hydrograph method could be derived for highway work, the benefits would be enormous.

PROBLEM NO. 6 - COMMITTEE A2A04

I. NAME OF PROBLEM - EVALUATE FIELD PERFORMANCE OF GUARDRAIL INSTALLATIONS

II. THE PROBLEM - The relative in-service performance of most guardrail systems is unknown. Although overall performance of guardrail installations, in general, can be determined from state and national accident statistics and expenditures, the limited degree of data collection precludes the analysis of specific guardrail systems in terms of safety and cost. Accordingly, the relative merits of two or more systems must be evaluated on the basis of idealized laboratory experiments (including full-scale crash tests) and gross accounting procedures.

III. OBJECTIVES -

A. Establish guardrail performance data collection center.

B. Establish accident reporting and installation and maintenance cost format.

C. Assemble data from national, state and local highway and enforcement agencies.

D. Provide continuing analysis of data, appraisals of guardrail systems and reports.

IV. CURRENT ACTIVITIES -

A. Highway Research in progress areas concerning traffic barriers (FHWA computer listing dated April 18, 1973) has been scanned in preparing this statement.

B. Suggested key words: guardrail, performance, experience, data center.

C. Various state highway departments and FHWA have conducted short-term, spot checks on specific barrier systems such as crash cushions. However, these efforts have lacked a uniform format and purpose.

V. URGENCY - The proposed research is a long-term effort to improve the overall performance of guardrail systems, thereby decreasing the number of fatal accidents.

Yearly cost of the program would be:

| | |
|---|---|
| First year | $100,000 - $200,000 |
| Subsequent years | 50,000 - 75,000 |

PROBLEM NO. 7 - COMMITTEE A2A04

I. NAME OF PROBLEM - TRAFFIC BARRIER EVALUATION CRITERIA

II. THE PROBLEM - Traffic barrier evaluation methods need to be revised. Standard impact conditions need to be extended to include broader coverage of the range of conditions to which a barrier may be expected to be exposed. Barrier performance evaluation measures need to be clearly defined so that the interpretation of results is uniform. Barrier performance criteria need to be revised to reflect the increased information available on human impact tolerance.

Unlike other engineering structures, traffic barriers are not designed to function under worst case conditions. For example, current standard test conditions for bridge railings call for a 4,000 lb. test vehicle and those for guardrails and median barriers call for a vehicle which is "representative of the majority of the highway passenger vehicle population." The reason for this state of affairs is not clear. Surely no bridge designer would design a bridge for a vehicle of median weight.

As a second example, standard test impact speeds for bridge rails, guardrails, median barriers, etc., are specified at no greater than 60 mph. Freeway speed survey data shows that more than 70% of the traffic travels at speeds in excess of 60 mph and that 60% of the recorded ran-off-the-road accident speeds are greater than 60 mph. Clearly, traffic barriers must be made to withstand more realistic test conditions if the traveling public is to be fully protected on the highway.

Criteria for performance evaluation of traffic barriers are in large measure based on recorded impact accelerations. No standards have been put forth for specifying how the accelerations are to be measured; however, nor are the terms "peak" and "average" acceleration clearly defined. Further, the bandwidth or frequency content of the acceleration signal is not specified. An impact acceleration signal that has been passed through a 25 Hz filter will very obviously yield different values for peak and average accelerations than will a signal with 500 Hz bandwidth. Unless the terms peak and average acceleration are clearly defined, then, and unless standard signal form requirements are specified, acceleration as a performance measure has no meaning from one investigator to another.

Human impact tolerance criteria for acceptable barrier performance are based on levels which were established over twelve years ago. Since that time, the amount of available impact tolerance data has increased substantially. The existing tolerance criteria should therefore be critically reviewed so that more realistic levels can be established.

III. OBJECTIVES -

1. Define the range of operational impact conditions to which a traffic barrier can be expected to be exposed, and from these define standard impact test conditions.

2. Review the measures which are used to define barrier impact performance and standardize the measurement techniques so as to eliminate ambiguity.

3. Review the criteria for acceptable traffic barrier performance -- particularly with regard to human impact tolerance -- and revise the criteria to reflect the most recent information.

IV. CURRENT ACTIVITIES -

A. HRIP Areas reviewed 27, 51.

B. Suggested key words: barriers, bridge rails, guardrails, impact tests, median barriers, simulations, standardization, standards.

C. There is no known research activity in this area.

V. URGENCY - This research should be implemented immediately in view of the long lead time between the development and the operational deployment of traffic barrier systems. The research findings would be used to upgrade the safety level of highways.

PROBLEM NO. 8 - COMMITTEE A2A07

I. NAME OF PROBLEM - OPTIMUM DESIGN AND USE OF HIGHWAY SHOULDERS

II. THE PROBLEM

The shoulder of a highway is defined by AASHTO as that portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses. This implies that the shoulder is used relatively infrequently by moving vehicles for very short travel distances. It supports the pavement structure implying that a lesser pavement structure is used for the shoulder. Also, this implies existence of an ideal main lane situation capable of accommodating demand volumes and that shoulders are clearly delineated as an area where occasional vehicles may safety stop. This idealized condition does not often exist in the real world, however. When the traveled way becomes overloaded, motorists, and in some cases highway operating agencies and officials, in the interest of expediency, used and permitted the use of the highway shoulder for other than emergency purposes. Some of these uses have been: (1) as a travel lane for slow moving vehicles to permit faster vehicles to pass, (a) as a temporary traffic lane during maintenance operations and (3) as a temporary or full-time traveled lane during peak traffic periods to provide capacity for an excess of traffic demand. Under these conditions the shoulder is called upon to carry heavier and more frequent loads when intended and requires varied delineation and demarcation.

III. OBJECTIVES -

The objectives of this project would be to: (1) determine what are the valid and appropriate uses of highway shoulders and to determine the conditions under which each of these uses should prevail, (2) to determine what the geometric requirements should be for each of the uses, (3) to determine what the structural requirements should be for each of the uses, (4) to determine what delineation and demarcation should be used for each of the valid uses, and (5) to determine what geometric and structural practices result in minimized pavement and shoulder maintenance.

IV. CURRENT ACTIVITIES -

Considerable work has been done on various parts of this problem. A state-of-the-art study on shoulder usage has been completed by the Michigan Department of Transportation and the report will be available shortly. The California Department of Transportation has published several brief reports on non-emergency use of shoulders and the North Carolina State Highway Commission has conducted the study concerning the relationship of accidents to paved shoulders. Also, the Georgia Department of Transportation has completed studies concerning shoulder encroachment by trucks.

V. URGENCY - The need for answers in this area is current. The problem is probably not of an emergency nature, but the wide variation in practices indicates that research is urgently needed. Immediate implementation of results here would be possible.

PROBLEM NO. 9 - COMMITTEE A2A07

I. NAME OF PROBLEM - DESIGN OF PAVED SHOULDERS FOR NON-EMERGENCY USE

II. THE PROBLEM - The shoulder of a highway is defined by AASHTO as "the portion of a roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses." This connotes relatively infrequent use by vehicles that are: decelerating to a stop, accelerating after a stop, in a stopped position, or in emergency maneuvers on the shoulder area. Also the shoulder mass serves to structurally support the traffic lane pavement. These general conditions prevail on many thousands of miles of highways where the highway cross section and the traffic types, volumes and speeds result in only infrequent shoulder usage.

In keeping with these concepts, shoulders on highways constructed or rebuilt during the 1950's and earlier generally were designed with a lesser paved or surfaced structure and lesser width than that of the adjacent traffic lane pavement. Maintenance has been found to be difficult and expensive to retain the essential smooth surface at the same level as the traffic lane and also to prevent surface water infiltration damages. This has called for higher type structural designs to provide shoulders that would satisfy the infrequent usage needs without excessive maintenance. Design techniques to this end remain in the development stage.

Additionally, on some sections of highway other forms or extent of shoulder non-emergency usage appear to be desirable and probably necessary for the optimum use of the overall highway cross section. These include use of the paved shoulder as a temporary traffic lane (1) during accident tie-ups on the traffic lanes, (2) to provide space for maintenance operations, (3) to accommodate overflow peak-hour volumes on short highway sections as between adjacent interchanges, (4) to permit passing of slow-moving campers or trucks on long upgrades, and (5) for general passing of slow-moving vehicles on two-lane highways. Shoulder design for such uses calls for a width of 8 feet or more and a pavement structure adequate to carry the anticipated volumes of heavy axle loads. Ideally, shoulders with such characteristics should be available on all sections of main highways. Within the highway program limitations this is not attainable on all highways but in the efforts for solution of the shoulder maintenance problems, recent shoulder designs tend to be of this type. Increasing use of the shoulder as a lane is being noted. There is need for determination of those types of highways, traffic volumes or operating conditions for which lane operations on shoulders should be considered and adequate provision made for such usage.

III. OBJECTIVES - The objectives of needed research studies are:

1. To identify the highway types and conditions for which some lane usage, either temporary or part-time, of a paved shoulder will be valid and appropriate

2. To establish criteria that can be used to determine specific highway sections for which shoulder lane usage is expected

3. To determine any unique geometric or delineation features applicable on shoulders designed for temporary lane usage

4. To develop a basis for estimate of the heavy axle load frequencies in a temporary or part-time lane usage of a paved shoulder which can be used for the shoulder structural design

5. To develop pavement design procedures which reflect the shoulder-lane usage conditions of (a) slow moving loads, (b) loads close to the outer edge of shoulder, and (c) lack of lateral support outside of the shoulder.

IV. CURRENT ACTIVITIES - There are only limited reports and data that pertain to shoulder-lane usage. The recent Michigan Department of State Highways and Transportation report on the State-of-the-Art Review of Paved Shoulders includes discussion of such use. Also, it has an extensive bibliography on studies on paved shoulders. The pending NCHRP 14-3 study report on Improved Pavement Shoulder Joint Design may contribute. The California Department of Transportation has prepared several reports on non-emergency use of shoulders. Also other state reports dealing with accidents in relation to paved shoulders contain pertinent data.

V. URGENCY - This problem is not of a general emergency nature, but solution is urgently

needed for certain sections of highways. There would be immediate application of research findings on the objectives.

PROBLEM NO. 10 - COMMITTEE A2B01

I. NAME OF PROBLEM - OPTIMIZING THE STRUCTURAL SECTION OF PORTLAND CEMENT CONCRETE PAVEMENT SYSTEMS

II. THE PROBLEM - In the past ten years, much effort has been devoted to improving rational techniques and software for analyzing/designing pavement structures. Physical testing has not kept pace and verification through accelerated testing under controlled conditions is almost nonexistent.

Many changes have occurred in rigid pavement systems. The use of chemically stabilized subbases is now widely practiced. Similar to this is "Econocrete" which is a combination of low strength concrete on the bottom and high grade concrete at the surface. Some states now are trying thicker slabs in an attempt to eliminate the treated subbase, hence, they are constructing the pavement in a single pass of the paver. Other agencies are trying to place stronger and more erosion resistant subbases in hopes that they can use ultra-thin high strength composites (fiber reinforced) or prestressed slabs as the wearing surface.

One of the basic reasons for this existing multi-directional research is that there is a lack of experimental information which could be used to optimize the pavement structure. A controlled experiment is needed to evaluate the interactions of the variables which determine pavement performance. Of primary concern are the strength and thickness of the slab versus the strength and thickness of the subbase over variable strength supporting media. Of equal importance is the optimum distribution of reinforcement in the cross section. Friction at the interface of the slab and the subbase is also important.

III. OBJECTIVE - The objective of this research is to conduct a controlled experimental study of the various components of the rigid pavement system in order to develop criteria for optimizing the structural capacity of the system, to develop and verify the structural concepts used in the rational design of portland cement concrete pavements.

IV. CURRENT ACTIVITIES -

A. There is a scattering of supportive information in the literature on this subject that should be studied before setting up the detailed work plan for this study.

B. Suggested key words: rigid pavement design, stabilized subgrades, reinforced pavements, erosive resistant subgrade, prestressed concrete slabs, post-stressed concrete slabs, continuously reinforced concrete pavements, load transfer at pavement joints, thermal stresses, transverse slope, surface texture.

V. URGENCY - This subject is deserving of a high priority as the expenditure annually for construction and maintenance of pavements is an enormous sum of public monies that are not always spent cost-effectively.

PROBLEM NO. 11 - COMMITTEE A2B01

I. NAME OF PROBLEM - LATERAL LANE PACEMENT OF TRUCKS AND ITS RELATIONSHIP TO RIGID PAVEMENT DISTRESS

II. THE PROBLEM - Present lateral lane placement of the design trucks is based on research data gathered before the prevalent use of paved shoulders. The construction of paved shoulders has resulted in changes in driver characteristics with many drivers running close to the pavement edge and/or encroaching on paved shoulders. Resultant edge and corner stresses are exceeding the design stress of the pavement structure with distress occurring in both the travel lane and the shoulder. The process compounds itself with travel lane distress causing additional shoulder distress and vice-versa.

III. OBJECTIVES - The objective of the problem is to measure the present lateral lane placement and relate it to performance. The lateral distribution has changed with changes in the use of paved shoulders, geometric alignment, travel speeds, and driver characteristics. The corrected distribution would then be used to modify design procedures such as that used by the Portland Cement Association. This basic approach has been used for years by airfield designers.

IV. CURRENT ACTIVITIES -

A. No highway research in progress scans were made in preparing this report.

B. Suggested key words: lateral truck placement, shoulder encroachment, edge stress, corner stress.

C. Related research: A preliminary paved shoulder encroachment study conducted in Georgia revealed numerous paved shoulder encroachments and a different lateral placement distribution from that now used for design.

V. URGENCY - The present travel lane and shoulder distress is costing vast amounts of maintenance and reconstruction funds to alleviate pavement distress which could have been prevented with the proper design techniques. These techniques should be developed now before the same problems are repeated in both new construction and reconstruction.

PROBLEM NO. 12 - COMMITTEE A2B04

I. NAME OF PROBLEM - THE DEVELOPMENT OF SKID RESISTANCE REQUIREMENTS FROM TRAFFIC OBSERVATIONS

II. THE PROBLEM - Three methods have been suggested for determining pavement skid resistance requirements. First, these requirements may be derived from accident data; second, from engineering data based on tire-pavement interaction and vehicle capabilities; and third, from direct observation of traffic and the accelerations that drivers impose on their vehicles. The third method is of primary interest in this

problem statement. In NCHRP Project 1-12, Pavement Friction Coefficients for Driving Tasks, this approach was taken. Detailed observations of traffic in a variety of roadway geometric situations were made to determine the friction levels demanded by a significant sample of vehicles.

In performing this research the assumption was made that pavement friction requirements for wet weather driving tasks could be derived from those accelerations imposed on a vehicle during dry weather. This assumption was considered necessary on the basis of practicality, because of the difficulty of timing field observations with rainfall. The assumption was rationalized by the argument that it was conservative, that pavement friction coefficients so derived would be somewhat larger than those coefficients demanded during wet weather driving. Although this hypothesis has not been rejected, there is concern that coefficients so derived may be overly conservative. This concern is based primarily on the relatively high vehicle accelerations that were observed during dry weather. Accident data has been used to show that when skid numbers are over 35, little hazard exists. However, in the report by Franklin Institute on Project 1-12, skid number requirements as high as 60 have been recommended in some critical geometric cases.

This report has not met with wide acceptance, because of the general feeling among highway engineers that the skid resistance requirements developed are too high for use on the highway system. There is little question among engineers that skid resistance levels this high would be desirable, but there is considerable opinion that they are not economically achievable. Since it appears that the Federal Highway Administration will put high priority in the future on improving skid resistance levels, there is natural concern that these levels be derived by the most appropriate means, and that overconservatism may lead to an economic problem that will result in the neglect of other areas just as critical to safety.

III. OBJECTIVES -

A. General

Determine the most appropriate methods of deriving the demand for skid resistance during wet weather based on traffic observations.

B. Specific

1. Determine the demand of traffic for friction under a variety of highway conditions during wet weather.

2. Determine the demand of traffic for friction under a variety of highway conditions during dry weather.

These observations should be made on identical section of roadway during traffic conditions which are as similar as possible. The basic difference between items 1 and 2 should be the wetness of the road surface.

3. Compare friction demand levels in wet and dry conditions and arrive at a method of interpreting dry weather friction demands so that more extensive field observations will not be limited to wet weather.

4. Compare the measurements made under items 1 and 2 to available accident data and to those engineering concepts and equations proposed for use in determining required friction. If good relationship can be established, the necessity of future traffic observations may be negated.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress in areas 22, 25, 26, 31, 32, 33, 34, 35, 51, 52, and 53 has been scanned in preparing this statement.

B. Suggested key words: skid resistance, friction demand, vehicle roadway interaction, traffic accelerations.

C. The objective of a project sponsored by FHWA is to recommend required skid resistance levels throughout the nation's highway system. This study will make use of previous research including NCHRP 1-12. Other tasks within the FCP Project 1-H relate to, but do not duplicate the objective of this proposed study.

V. URGENCY - Because the Federal Highway Administration will be making recommendations as to appropriate levels of skid resistance based on existing data including NCHRP Report 1-12, the correct interpretation in terms of necessary skid numbers is critical. This critical nature is illustrated by considering the cost of raising the skid resistance of our highway system by as little as 10 skid numbers.

VI. PROBLEM ESTIMATE

Amount Recommended - $150,000

Contract Term - 18 months

VII. REMARKS - Since this statement was prepared, FHWA Contract DOT-FH-11-8275 (Science Applications, Inc.) and NCHRP Contract 1-12 (2) (Ohio DOT) have been let. Both of these contracts call for determining the skid resistance demand, while this statement calls for the development of methods for determing the demand. This may sound like the statement attempts to discredit the ongoing projects. This is not the case, but A2B04 believes that the present projects can produce only a first, coarse measure of demand, while the need for refining the "demand equations" and for tools for application to special situations will continue, not only for the near future, but very probably permanently because not all sites and traffic situations lend themselves to precise classification. The urgency rating that A2B04 gave the statement therefore remains the same as when first prepared.

PROBLEM NO. 13 - COMMITTEE A2B04

I. NAME OF PROBLEM - THE EFFECTS OF ABRUPT CHANGES IN SKID RESISTANCE LEVELS OF PAVEMENTS ON ACCIDENT OCCURRENCE

II. THE PROBLEM - A recurring problem when the optimum skid resistance of pavement is considered is skid resistance variation between sections, between lanes, and across wheel paths. This problem was postulated by W. E. Mayer and R. A. Olsen at the 1969 Salt Lake City Summer Meeting as possibly being more important than the actual skid resistance level.

Probably the most predominant cause of nonuniformity is the polishing action of traffic which results in lower skid resistance in the wheel paths. Another cause is the lack of surface texture in patched areas and in newly placed surfaces due to the underlying pavement. Patched areas may contain excessive asphalt, while there may be a deficiency of asphalt under new surfaces. A third and possibly quite critical situation is the variation in skid resistance from area to area as different construction jobs and materials are encountered.

In an effort to reduce skid initiated accidents, engineers have in general advocated the placement of high friction surfaces in certain critical areas. However, drivers may assume incorrectly that the same high level of friction is available at other points on the roadway. This seems to indicate that placing higher friction surfaces at certain critical points on the roadway will only move accidents to other areas. This last concept, accident causation due to unexpectedly low levels of skid resistance, is our primary area of ignorance. We have here a conflict between "Balanced Friction Design," the engineering concept that friction should be proportional to the demand (high friction levels at critical demand sites), and the human factors concept that friction levels should be constant throughout the length of a given roadway. From this viewpoint, it is assumed that the driver will know what to expect and will not exceed the level of supply. There is little doubt that both concepts have merit and the most accident-free highway, as influenced by level of friction, will probably be a compromise between these two.

III. OBJECTIVES -

A. General

To determine the influence of skid resistance variations on accident causation, whether these variations be small scale, as in wheel paths or patches, or large scale, as in variations from one segment of highway to another.

B. Specific

1. To study the demand for friction, both in normal driving and in emergencies, of a representative group of drivers as a function of skid resistance levels and variations of these levels.

2. To analyze wet pavement accident records of adjacent sections of pavement having a wide range of skid resistance levels including changes in these accident records as skid resistance is increased at certain points on the highway.

The study of items 1 and 2 should be comprehensive enough to include the effects on different types of roadways, geometric conditions, traffic volumes and climatic regions.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 25, 26, 31, 32, 33, 34, 35, 51, 52, and 53 have been scanned in preparing this statement.

B. Suggested key words: skid resistance-driver expectation, friction demand, vehicle roadway interaction, traffic accelerations.

C. There is a potential overlap in this research with Task IV and V of the Federally Coordinated Program, Project 1-H. These tasks are (1) Friction Requirements for Highway Sites with High Skid Accident Potential and (2) Skid Accident Analysis and Identification of Highway Sites with High Skid Accident Potential. However, with proper management and statement of objective, this study and Task IV and V could be made highly complementary. There is also a likely interaction between this study and one of the priority goals of the Federal Highway Administration Field Test and Evaluation Centers, the development of recommendations for skid resistance survey procedures on highways.

V. URGENCY - Future required skid resistance surveys in all states will determine low friction sites and result in demands for changes. Therefore it is urgent that the states have the best procedures for reducing accidents as contrasted with the best procedures for increasing skid resistance.

VI. PROBLEM ESTIMATE -

Amount recommended - $300,000

Contract term - 3 years

PROBLEM NO. 14 - COMMITTEE A2B05

I. NAME OF PROBLEM - DEVELOPMENT OF CALIBRATION METHODS FOR ROAD ROUGHNESS METERS

II. THE PROBLEM - Road roughness measuring meters are used by many state highway departments to perform road roughness surveys. Although several different meters are used, all of the meters use the same method to obtain the road roughness measurement. This measuring method accumulates the absolute relative displacement between the rear axle housing and the body above the rear axle housing on a standard automobile.

The main advantage of the road meter for road roughness measurement is its relative low cost, simplicity of operation and its high measuring speed. The disadvantages are the road meter's susceptibility to changes that affect the

repeatability of its measurements. Without discussing the nature of these changes it is sufficient to say that most users recognize the effect of these changes and periodically perform a systems calibration to account for these changes. This calibration consists of driving the measuring vehicle over a road surface designated as a calibration road. The measurements obtained are then compared to the measured value for the calibration road. Based on this comparison a calibration factor is obtained to be applied to measurements made with that vehicle on other roads.

The problem with the calibration method is that the roughness value for the calibration road or roads is itself difficult to establish originally and then changes with season, age, and usage.

III. OBJECTIVES -

A. To provide a method for the calibration of road roughness meters using a calibrated road as the input to the road meter-vehicle measuring system.

B. To establish regional road roughness calibration test sites using measured profiles and computer programs to determine the road roughness values for these sites.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress Area One (Pavements), HRB Special Report 133 and other HRB publications have been scanned in preparing this statement.

B. Suggested key words: road meters, present Serviceability Index (PST), Serviceability Index (SI), calibration, GMR Profilometer, road roughness measurement, road profile measurement, computer program, data reduction.

C. A possible method for the calibration of road meters is based on the work of Walker and Hudson. In their approach the Serviceability Index (SI) was determined for road sections with a range of road roughness using the GMR Profilometer as a measuring tool and a computer program for data reduction of the measurements. The computed Serviceability Index is then used to calibrate a vehicle-road meter system driven on the same road sections. This method for calibrating the road meter overcomes most of the problems encountered in its use.

V. URGENCY - The extensive use of road meters by many state highway engineers makes the continual calibration of these devices a time-consuming task. This task is compounded by continuous changes in both the road meter-vehicle measuring system and the roughness of the calibration road itself.

The work load of the highway engineer involved in the use of the road meter will be greatly reduced by the development of this road meter calibration method.

These regional calibration sites will also provide a much needed absolute correlation between the many states now using road meter roughness measurement equipment.

PROBLEM NO. 15 - COMMITTEE A2B05

I. NAME OF PROBLEM - GUIDELINES FOR ESTABLISHING A PAVEMENT PERFORMANCE INFORMATION AND INTELLIGENCE SYSTEM

II. THE PROBLEM - Pavement performance data, information, and intelligence are of paramount importance in decision-making related to the programming of rehabilitation and major maintenance in the establishment of structural design methods, criteria, and policy, and in evaluating the levels-of-service provided by the highway network links. "Rational" management requires that all levels of management have available to them at the time it is needed not only the facts, but data which has been translated into usable information. Intelligence gained from the data through summary reports and various analyses can provide guidance for future actions.

Typically, in addition to performance data, a highway agency collects tremendous quantities of other data concerning contract execution, quality control, material and subgrade properties, traffic, and various other physical parameters, part of which can enhance the value of the performance data. Invariably, items of data are collected which are not relevant to the topic of performance, and often after a number of years data tends to be lost or is destroyed. An organized method is needed for the collection, storage, retrieval, analysis, and reporting of performance information. To be cost-effective, the information system must be restricted to only those items of data and only in such quantity as is needed to provide adequate coverage of performance and relevant other data. It seems clear, however, that if other collected data not now considered to be relevant, are referenced by means of a common location referencing system, such data can be captured at any future time with a minimum of effort. A common location reference system provides essential flexibility in data retrieval and information processing. It is realized that because of difference in organizational structure, it is difficult to formulate one single pavement performance information system which will satisfy the requirements of individual agencies. Thus guidelines are needed which identify those items of data which are believed to concern performance, which define the timing and extent of data collection, which provide recommendations for system of data storage up-dating and retrieval and which outlines those analysis procedures which yield useful and meaningful management information and intelligence.

This effort can perhaps be considered as a scaling-up of the ability of a single small township engineer to make decisions on the basis of his intimate knowledge of each piece of road, its performance over the years, together with all other factors, costs, manpower, etc.

III. OBJECTIVES - So that guidelines for establishing a pavement performance information and intelligence system can be formulated with confidence, the following tasks must be completed:

1. Review the literature and compile a list of material attributes or properties, construction, maintenance, traffic, environment, roadway geometrics, pavement structure, response to load, distress manifestations, riding comfort or serviceability, and other parameters which may influence pavement performance and/or management decisions on pavements. Describe for comparison, material on current agency practices in collecting, storing and retrieving data.

2. Identify and classify those items believed to be essential and relevant to a design/performance feedback system, and those which have bearing on management decision-making with respect to pavements.

3. Recommend where applicable, how, when, and at what frequency, to obtain the minimum amount of data which could fulfill the requirements of the objectives.

4. Recommend efficient and practical information system procedures based upon a coordinated location referencing system for collecting, recording, editing, up-dating, retrieving and reporting on data items. Where practical, make recommendations for automated data handling techniques. Suggest hardware and software packages.

5. Suggest methods of analysis and reporting which could provide feedback to "fine-tune" pavement design practices, and which could provide useful and meaningful information and intelligence for management decision-making. Develop a detailed concept of a Data/Inquiry Handling System to incorporate these suggestions (see Figure 1).

6. Illustrate quantitatively through practical examples the benefits which stem from possession of such a system. Information exchange between agencies would become practical by wide use of standardized terminology, data collection and retrieval techniques.

7. Suggest methods for system evaluation through feedback.

IV. CURRENT ACTIVITIES - Many states, notably Texas, Utah, Washington, California, and Ontario, either have a computerized information system, or have a system under development. There is a formidable amount of published information on how pavement performance and pavement distress is measured, on pavement materials parameters which are related to performance, on traffic load and on climatic effects as they relate to performance. There are numerous texts on information systems.

V. URGENCY - The potential of a pavement performance information system cannot be fully exploited until that system has been fed with a great deal of historical pavement data. As well, since such a system will in effect be replacing an existing method of recording data, there is a period when both systems must exist side by side. This situation will exist until data retrieval from the new system is as easy, quicker and more complete than formerly.

In spite of these drawbacks, the potential benefits in such an investment should be attractive enough so that immediate implementation becomes essential.

PROBLEM NO. 16 - COMMITTEE A2B06

I. NAME OF PROBLEM - RELATIONSHIP BETWEEN PAVEMENT DISTRESS AND PAVEMENT PERFORMANCE

II. THE PROBLEM - One of the major recommendations of the Highway Research Board Workshop on Structural Design of Asphalt Concrete Pavement Systems, held in Austin, December 7-10, 1970, and reported in Highway Research Board Special Report 126, was that the relationship between pavement distress and pavement performance (failure function) was a major research need. The report of the Advisory Committee for this workshop stated the problem as follows:

> "The mechanistic approach to pavement analysis and design can at best yield predictions of the nature and extent of pavement distress (e.g., the extent of rutting and the nature and extent of cracking). There is an urgent need for a technique whereby such structural distress and its objective measurements (including, for example, measurements of roughness) can be related to the functional performance and perhaps to ultimate failure of the pavement. It seems apparent at this time that the only feasible way to relate distress to performance is through a statistical analysis of serviceability-performance information (most probably subjective in nature) and objective distress predictions or evaluations. Such an analysis must (a) define important distress factors involved in pavement nonserviceability and failure, (b) establish suitable weighting functions to judge the relative importance of various levels of combined distress modes, (c) identify suitable limiting levels of distress occurring separately or in combination, and (d) develop or adopt suitable measures of performance or serviceability."

III. OBJECTIVES - It will be the purpose of this research to utilize available data from the AASHO Road Test, from other road test projects such as the San Diego Experimental Base Project, and the Brampton (Ontario) pavement research project, and results of AASHO satellite studies such as have been made by the states of Texas and Missouri to shed light on the relationship between observed distress, as indicated by measured roughness cracking, rut depth or other physical manifestations of distress, to pavement performance as indicated by the present serviceability index (PSI) or a similar subjective rating system.

Specific objectives are:

1. To summarize and analyze results, both published and unpublished, from road test projects and satellite studies indicated above

2. To collect additional data and perform other investigations of an objective or

subjective nature that might lead to a more clear understanding of the relationship between observed distress and either measured or subjective performance indicators

3. To indicate in a specific manner how these relationships may be used in a pavement design and management system, utilizing either empirical or theoretically based structural subsystem.

IV. CURRENT ACTIVITIES - No work is being done specifically in this area. However, there is considerable need for research as outlined below.

V. URGENCY - Considerable work is being done by the Federal Highway Administration and through NCHRP Area 1 projects to develop pavement design and management systems using both empirical and theoretical structural subsystems. In addition, work is being done on maintenance management systems. However, almost no work has been done since the AASHO Road Test to specifically relate performance to distress or to give guidance on what data should be collected to best relate these two important items. It is urgent that this work be accomplished as soon as possible, in order that the appropriate distress function may be incorporated in the pavement design and management systems now being developed.

PROBLEM NO. 17 - COMMITTEE A2C01

I. NAME OF PROBLEM - DISTRIBUTION OF WHEEL LOADS ON HIGHWAY BRIDGES

II. THE PROBLEM - The empirical load distribution factors for stringers and longitudinal beams have been in the AASHTO Specifications since 1931 and were updated in 1957. Except for more recent additions to accommodate new types of bridges, the distribution factors consist of the stringer spacing divided by a numerical value dependent on the type of structure support.

Analytical research is needed to provide a more realistic approach to load distribution which accounts for roadway width and multiple lane loading effects, span length, skew and continuity of structural supports. The load distribution research should be restricted to straight bridges without horizontal curvature.

III. OBJECTIVES - The objective of this work is to provide a unified formula or formulas for load distribution factors which are applicable to all types of straight bridges with varying types of roadway decks, and should include consideration of all variables which affect the distribution factors provided by these formulas. The results should provide design factors for all conditions of loading such as working stress, load factors, and for both inventory and operating rating of existing bridges.

New design criteria, new bridge types, and the possibility of increased loadings, as well as rating techniques on existing bridges can use these research results to immediate advantage.

REFERENCES: BRIDGE ANALYSIS PROCEDURES

1. Report No. 56-6. Discontinuous Orthotropic Plates and Pavement Slabs by W. Ronald Hudson and Hudson Matlock describes an alternating-direction iteration method for solving complex two-dimensional plate and slab problems with emphasis on pavement slabs. May 1966.

2. Report No. 56-13. A Discrete-Element Method of Multiple-Loading Analysis for Two-Way Bridge Floor Slabs by John J. Panak and Hudson Matlock includes a procedure for analysis of two-way bridge floor slabs continuous over many supports. January 1970.

3. Report No. 56-18. A Discrete-Element Analysis for Anisotropic Skew Plates and Grids by Mahendrakumar R. Vora and Hudson Matlock describes a tridirectional model and a computer program for the analysis of anisotropic skew plates or slabs with grid-beams. August 1970.

4. Report No. 56-25. A Discrete-Element Method of Analysis for Orthogonal Slab and Grid Bridge Floor Systems by John J. Panak and Hudson Matlock presents a computer program particularly suited to highway bridge structures composed of slabs with supporting beam-diaphragm systems. May 1972.

The above reports present part of the research developments resulting from Project 3-5-63-56 entitled "Development of Methods for Computer Simulation of Beam-Columns and Grid-Beam and Slab Systems" conducted for the Texas Department of Highways and Public Transportation in cooperation with the U.S. Department of Transportation, Federal Highway Administration by the Center for Highway Research, The University of Texas at Austin.

IV. CURRENT ACTIVITIES -

A. Research completed under NCHRP-83 should be included and extended under this project.

B. Research completed by Lehigh U. (Research Report 387.2B) on I-beam/slab prestressed concrete bridges should be included.

C. Lehigh U. Research Report 387.1 contains a summary of completed research and bibliography

V. URGENCY - This project warrants an immediate and high priority to provide the designer with a more realistic determination of probable load distribution.

Recent additions to the AASHTO design specifications for highway bridges have included more rational load distribution factors based on model tests and verified exact mathematical analysis. Techniques exist for extending previous work to cover the more general type structures and to combine miscellaneous design criteria into a single comprehensive load distribution section.

Estimate - $100,000

PROBLEM NO. 18 - COMMITTEE A2C01

I. NAME OF PROBLEM - DEFLECTION LIMITATIONS FOR BRIDGE STRUCTURES

II. THE PROBLEM - Current AASHTO deflection criteria for steel bridges state that the deflection due to live load shall be computed in accordance with the assumption made for loading when computing stress in the member. This is subrogated by a provision which permits all beams and stringers to be acting together with equal deflection, providing diaphragms are sufficient in depth or strength to insure lateral distribution of loads. This sufficiency is not defined nor is the effect of the roadway slab given consideration.

Moreover, the limitation in steel spans of 1/800 of the span or 1/1000 of the span if used by pedestrians, is questioned, together with cantilever requirements, as being a realistic or necessary design requirement. There are no such limitations for concrete structures, the control being only with regard to thickness or depth of structure.

III. OBJECTIVES - The objective of the proposed research is to investigate and provide a workable deflection limitation for all types of bridges consistent with stress limitations and limitations on the basic frequency and amplitude of the structure.

IV. CURRENT ACTIVITIES

A. Research by Goodpasture and Goodwin, University of Tennessee, September 30, 1971, evaluated the bridge vibration as related to Bridge Deck Performance.

B. Research by Goodpasture and Burdette, University of Tennessee, December 31, 1971, investigated dynamic behavior under varying live loadings.

C. AISI Bulletin No. 19, November 1971, prepared by Wright and Walker developed criteria for the deflection of steel bridges.

V. URGENCY - This project warrants an immediate and high priority to provide more rational and realistic criteria for design of bridges insofar as deflection requirements are concerned.

Estimated cost - $50,000

PROBLEM NO. 19 - COMMITTEE A2C02

I. NAME OF PROBLEM - PROBABILISTIC DESIGN OF STEEL STRUCTURES

II. THE PROBLEM - There is a need for more information on the relationship between actual truck traffic using bridge structures and the design loads for which the structures are designed. Much progress has been made in recent years defining the strength and performance of bridge components and the integrated structure. The definition of normal and abnormal traffic using the structure is not as well known particularly for spans greater than 150 ft.

To develop a reliability based design specification requires a better definition of the traffic that uses the structure under normal traffic flow and under abnormal overload conditions. Currently available studies of stress history indicate the probable stress distribution for spans up to 150 ft. for usual traffic conditions. However, the interrelationship of such factors as impact, vibration, deflection, actual induced stress vs. design stress (depending on analysis procedures, distribution factors, etc.) is not uniformly accounted for with bridges of varying span length.

Under normal traffic, the correlation of weight spectra with normal traffic counts and in turn with the stress spectra in actual bridges is not satisfactorily developed for many span lengths.

Further work is needed on the correlation of weight spectra with traffic counts and on the correlation of weight spectra with stress spectra on a wider cross-section of bridge structures.

III. OBJECTIVES - To determine the state-of-the-art of loadings and the resulting stresses in the various components of bridge structures. Particular attention should be given to normal and abnormal traffic and its effect on both strength and performance. To develop recommendations for field studies necessary to provide a satisfactory definition of the normal and abnormal stress conditions in various bridge structures.

IV. CURRENT ACTIVITIES -

A. Suggested key words for this problem are loading history, design loads, overloads, span length.

B. Several stress history studies are underway or have been undertaken on short and moderate length structures (40' - 150' spans). No significant studies available on spans of 150 - 1000 ft.

V. URGENCY - Our knowledge of the actual stresses in structures is limited. A better knowledge of the loads using bridge structures and the stresses they cause will provide improvements in design, better knowledge of performance under future traffic and overloads and more economic construction. As legal loads are changed or considered for change more rational basis will be available to assess their significance. It is urgent to pursue this research as safety, reliability and economic considerations are involved.

PROBLEM NO. 20 - COMMITTEE A2C02

I. NAME OF PROBLEM - TOLERANCES IN STEEL BRIDGES

II. THE PROBLEM - During the design and construction of steel bridges certain tolerances are assumed or exist. The effect of tolerances on the strength and performance of a bridge is not well defined. Since the level of tolerance has a substantial impact on the cost of the finished structure, it is desirable to evaluate the relationship between tolerance, performance, and strength.

Tolerances may decrease the strength of compressed elements (i.e., out-of-straightness), influence the geometry of the finished structure

or affect the performance of joints. Particular attention should be given to the influence of tolerance on fatigue strength. This can be critical if it results in large secondary stresses.

III. OBJECTIVES - To determine the state-of-the-art of the relationship(s) between tolerances and the strength and performance of various structural components. Currently information is available on isolated elements and joint conditions. However, no attempt has been made to organize and incorporate tolerances into design provisions in a comprehensive manner.

IV. CURRENT ACTIVITIES -

A. No work is being done specifically in this area. Indirectly some information has been used for the design criteria for compression members and for bolted joints.

B. Key words: tolerance, out-of-straightness, secondary stresses, connections, instability, fatigue, strength, performance.

V. URGENCY - Tolerances play a major role in the economics of construction. Furthermore, they may have a significant effect on design and the long term maintenance of the structure. It is urgent to pursue this research as considerable economies may result.

PROBLEM NO. 21 - COMMITTEE A2C03

I. NAME OF PROBLEM - LONG-TIME FATIGUE OF STEEL REINFORCEMENT IN CONCRETE BEAMS

II. THE PROBLEM - During NCHRP Projects 4-7 and 4-7/1 entitled "Fatigue Strength of High Yield Reinforcing Bars," it was found that considerable scatter in test results existed about the mean fatigue limit at 5 million cycles. Following completion of the NCHRP test program, two preliminary fatigue tests were carried out at stress ranges 2 and 4 ksi below the mean fatigue limit at 5 million cycles. Fatigue fracture of the test bars occurred after 31 and 352 million cycles, respectively. During the life expectancy of a bridge, this number of repeated loadings could occur and bar fracture would result.

III. OBJECTIVES - To determine the long-time fatigue properties of Grade 60 reinforcing bars at stress ranges near the fatigue limit.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress area 27 has been scanned in preparing this statement.

B. Suggested key words: fatigue (materials), loads (forces), reinforced concrete reinforcing steels, specifications, stresses, structural design.

C. NCHRP Projects HR4-7 and HR4-7/1 - "Fatigue Strength of High Yield Reinforcing Bars"

V. URGENCY - A procedure to establish a practical fatigue design limit would be established. This work is required since highway bridge designers have expressed concern about recent AASHTO specifications regarding fatigue stresses in reinforcing bars.

PROBLEM NO. 22 - COMMITTEE A2C03

I. NAME OF PROBLEM - FATIGUE STRENGTH OF REINFORCING BARS AT BAR CUT OFF LOCATIONS

II. THE PROBLEM - Current highway bridge specifications limit the service load stress range to which a reinforcing bar may be subjected. Often compliance with these requirements necessitates the extension of bar cut off locations beyond those selected to satisfy Load Factor moment capacity. This is due to the high stress range calculated in the remaining bars at the theoretical moment capacity bar cut-off location. However, each bar to be cut off would be continued a sufficient distance beyond the theoretical cut off point to allow for full development of the bar. Thus, at the theoretical bar cut off location, the actual stresses in the remaining bars are considerably lower than calculated.

III. OBJECTIVES - To determine the fatigue susceptibility of the remaining bars at a theoretical bar cut off location.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress area 27 has been scanned in preparing this statement.

B. Suggested key words: dynamic loads, fatigue (materials), loads (forces), reinforced concrete, reinforcing steels, specifications, structural design

C. NCHRP Projects HR4-7 and HR4-7/1, "Fatigue Strength of High Yield Reinforcing Bars"

V. URGENCY - The research findings would be implemented through recommended specifications to AASHTO. The results from this research could result in savings in steel reinforcement at bar cut off locations.

PROBLEM NO. 23 - COMMITTEE A2C03

I. NAME OF PROBLEM - BOND FATIGUE OR PRESTRESSED CONCRETE BRIDGE MEMBERS

II. THE PROBLEM - The bond between concrete and prestressing strand is adequate for uncracked prestressed concrete members, even for repeated loadings. However, recent tests of short prestressed members with high bending moments near the ends, have shown that the bond between the steel and the concrete can be destroyed by application of repeated loads. Precast pretensioned bridge deck slabs and short cantilevers are bridge members that fall into this class. Repeated loading of a member with a crack in or near the transfer length can cause early bond failure.

III. OBJECTIVES - To investigate the effect of repeated loading on the performance of prestressed members where bond fatigue is likely to occur.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 27 and 32 have been scanned in preparing this

statement.

B. Suggested key words: bond, cracking, cyclic loads, fatigue, pretensioned prestressed slabs, strand, and stress transfer.

C. Previous research at the Portland Cement Laboratories concerning Bond Fatigue Tests of Concrete Crossties and published in PCI Journal, September-October 1975.

V. URGENCY - The problem of bond fatigue has already shown itself in prestressed concrete railroad ties. It could also cause difficulty at the ends of prestressed beams if cracking occurs from some abnormal loading. It might also occur in precast concrete deck panels used as stay-in-place forms. The research would be implemented through design recommendations to prevent bond fatigue.

PROBLEM NO. 24 - COMMITTEE A2C03

I. NAME OF PROBLEM - FATIGUE STRENGTH OF BENT BARS IN CONCRETE BEAMS

II. THE PROBLEM - Bent bars, embedded within concrete beams having a spread V-shape in elevation, have been shown to have a considerably decreased fatigue strength from that of straight reinforcing bars. It is not clear whether this reduction in fatigue is primarily due to the bending of the test bars or due to the test method. However, the test method used did not realistically represent the stress conditions to which a bent up bar in a reinforced concrete beam might be subjected.

III. OBJECTIVES - To determine the effect of cyclic stressing on bent up reinforcing bars. Furthermore, such an investigation would determine the relative susceptibility to fatigue fracture of the bent up and continuing reinforcement, as the latter will ordinarily be subjected to higher stresses.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progess area 27 has been scanned in preparing this statement.

B. Suggested key words: beams, dynamic loads, fatigue (materials), loads (forces), reinforced concrete, reinforcing steels, stresses.

C. NCHRP Projects HR4-7 and HR4-7/1 entitled "Fatigue Strength of High Yield Reinforcing Bars"

V. URGENCY - The project would show if bent bars in beams are more susceptible to fatigue fracture than straight bars. The findings might be implemented through code specifications.

PROBLEM NO. 25 - COMMITTEE A2C04

I. NAME OF PROBLEM - FATIGUE STRENGTH OF LOW-ALLOW STEEL REINFORCING BARS

II. THE PROBLEM - The majority of data from fatigue tests of concrete reinforcement pertain to reinforcing steels conforming to ASTM Specifications A615, A616 and A617. Therefore, recommended fatigue design equations are only applicable to these steels.

The recently produced reinforcing steel A706, Grade 60, deserves special consideration. These low-allow steel deformed bars are intended for special applications where welding or bending or both are important. The question arises as to whether present design equations are also applicable to A706 reinforcing bars.

III. OBJECTIVES - To evaluate the fatigue properties of reinforcing bars meeting the requirements of ASTM Designation A706-74 and to determine if present design specifications can be used for these steels.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress area 27 has been scanned in preparing this statement.

B. Suggested key words: dynamic loads, fatigue (materials), loads (forces), reinforced concrete, reinforcing steels, structural design.

C. NCHRP Projects HR4-7 and HR4-7/1 - "Fatigue of High Yield Reinforcing Bars"

V. URGENCY - Research findings would be implemented by recommendations for including in AASHTO Bridge Specifications.

PROBLEM NO. 26 - COMMITTEE A2C04

I. NAME OF PROBLEM - FATIGUE STRENGTH OF PRESTRESSING STRAND

II. THE PROBLEM - The acceptance of prestressed concrete where cracking is permitted under service load conditions will lead to the need to consider fatigue in the design of the prestressing steel. Although some fatigue data is available for North American prestressing strand, further test data is required to support realistic design criteria for the economical use of prestressing strand.

III. OBJECTIVES - To gather fatigue test data for prestressing strand in an experiment designed and executive to permit a valid statistical appraisal of the factors influencing fatigue.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress Areas 27 and 32 have been scanned in preparing this statement.

B. Suggested key words: beams (supports), cracking, dynamic loads, fatigue (materials), loads (forces), prestressed concrete, prestressing steels, stresses, structural design.

C. Previous work at Lehigh and Iowa State Universities

V. URGENCY - As the trend towards strength design procedures continues, the importance of fatigue consideration in design is becoming increasingly important. This program would lead to the establishment of a fatigue limit for all types of prestressing strand available in North America.

PROBLEM NO. 27 - COMMITTEE A2C05

I. NAME OF PROBLEM - MEASUREMENT OF THE LIFE EXPECTANCY OF OLDER BRIDGES

II. THE PROBLEM - In establishing the priority for replacement of older structures on a rational continuing basis, an important consideration which is difficult to evaluate is the remaining life expectancy of each individual structure on the basis of safety and structural adequacy. Reliable information of this kind could assist engineers in determining the priority and rate of replacement of bridges where other factors such as obsolescence do not govern.

III. OBJECTIVE - To establish, through a selective program of field and laboratory testing on typical structures being removed from service, a technique for evaluating with accuracy the remaining life expectancy of other similar structures by utilizing the results of non-destructive material and/or dynamic response testing. The techniques established may be validated by fatigue and overload tests and purposely induce failures in selected typical older structures being dismantled. Various material and geometric types of structures would be categorized into a relatively small number of test specimens for minimizing the required scope of this research for extrapolating the findings on a national scale.

IV. CURRENT ACTIVITIES -

A. Scanned HRIP selections pertaining to measuring stresses and strains in bridges

B. Key words: structures, life expectancy, fatigue, overloads

C. Related Research:

1. Studies by Burdette and Goodpasture on bridges in Tennessee documented in Highway Research Record No. 507

2. A study under way by Sanders of Iowa State University on Ultimate Load Behavior of Full-Scale Highway Truss Bridges

3. A study under way by Baldwin of the University of Missouri on an Investigation of the Behavior of a Three-Span Composite Highway Bridge

V. URGENCY - There is need to establish priorities, on a continuing basis, for bridge replacement. A technique for relating remaining life expectancy to field tests of a structure would be an exceedingly useful tool for this purpose.

PROBLEM NO. 28 - COMMITTEE A2C05

I. NAME OF PROBLEM - VIBRATION SUPPRESSION IN RAPID TRANSIT STRUCTURES

II. THE PROBLEM - An important consideration in the life expectancy of rapid transit structures is the effect of rapid accumulations of large numbers of cyclic load applications to structural members. Efforts to minimize the fatiguing effects of cumulative loadings are generally limited to increased design stiffness of the primary structural members, a procedure which may not have a similar effect on connections and other structural details. In some cases isolation has been utilized to reduce vibration transmission but not to reduce vibration per se. A thorough investigation of the many available alternative procedures to minimize structural vibrations both in future and existing structures is warranted. The controlled loading path, magnitude and frequency of application common to rapid transit facilities make the adaptation of vibration suppression measures of other than stiffening a highly promising possibility.

III. OBJECTIVE - To provide a selection of alternative design and retrofit procedures for use in controlling structural vibrations which may be of an order of magnitude to result in reduced fatigue life expectancy of structural members.

IV. CURRENT ACTIVITIES -

A. Scanned HRIP selections pertaining to measuring stresses and strains in bridges

B. Key words: structures, vibration, fatigue

C. Related research on highway bridge vibration suppression:

1. Control of single-span highway bridge vibrations, Highway Research Record 354, 1971

2. Full-scale experimental verification of an analytical model for evaluating methods of suppressing excessive bridge vibrations, Report No. FHWA-RD-72-45

V. URGENCY - In view of the potentially rapid increase in the numbers of rapid transit structures in this country in response to the anticipated growth of this mode of transportation, any early contributions to more efficient design can provide very significant overall economics of construction.

PROBLEM NO. 29 - COMMITTEE A2D01

I. NAME OF PROBLEM - REDUCING DEPENDENCE ON MOISTURE CONTROL IN HOT MIX PLANT

II. THE PROBLEM - The control of moisture for good hot mix pavement construction and performance is universally accepted. While it is agreed moisture approaching zero is ordinarily desirable, it is also agreed some moisture is acceptable or required. But precisely what the moisture level should be differs widely, usually depending on local empirical practice. This conceivably is the best way for the present to integrate the several factors involved in addition to the percent moisture (operations, aggregate properties, aggregate gradations, percent asphalt, etc.). While this has served our overall interests to date it threatens to slow the proper consideration of needed development in hot mix equipment, operations, construction and materials. It could be said the problem is that the percent moisture is not a good measure of its effect.

Drum mixing is one such development as it offers emission reductions not readily obtained via conventional hot mix plants. But moisture

contents of mixes prepared in a drum mixer tend to run higher by 1/2 to 3/4 percent. The question is whether this additional moisture is a good trade-off for the lower emissions or merely creates a new problem.

A continuing development is the greater use of local aggregates that are different from those tried and proven. Thus volcanic cinders to be used require moistures at the 6 percent level where many state and engineering organizations specify maximums in the 3/4 or 1 percent range.

The effects of moisture movement from partially wet aggregates into the binder after mixing on the workability required for construction and on the retention of compacted mix strength and stiffness do not seem to be understood. This limits establishing universal specifications of drying.

A breakthrough of a sort to such developments would be obtained were it possible to develop an understanding of what in addition to the moisture contributes to the so-called moisture effects. Part of the problem could be that control of foaming, segregation, tearing, tenderness, stripping, etc., has centered on percent moisture when it might advantageously also systematically include other factors. Among these could be aggregate properties and gradations, percent asphalt, operations, additives, etc.

Another moisture problem could be a bias favoring lower moisture levels. One feature of this could be the loss of moisture during sampling and testing operations. Then, too, dryness may have been stressed when emissions due to overdrying were less of a concern.

It has been noted that good pavements reach higher equilibrium moistures than those permitted by customary controls.

From the above a systematic study is needed of past moisture requirements and of factors that could minimize moisture effects.

III. OBJECTIVES -

1. Establish the cost of adverse moisture effects experienced in specific representative pavements

2. Develop information about moisture problems and the factors in addition to moisture which contribute to or minimize moisture effects. This could include drying operations and conditions, type of aggregate, aggregate gradations, percent asphalt, mix characteristics, laydown and rolling and method of sampling and testing for moisture. A better understanding is needed of the level of moisture control required for workability (hauling, laydown, compaction) versus that required for qualities such as coating, adhesion, stripping, etc.

3. Develop functional tests capable of predicting moisture effects and develop information about factors other than moisture that contribute to the moisture problem. This should include a differentiation between free or active moisture and bound, static or inert moisture.

   Tests should be such that a judgment can be reached as to what factors in addition to moisture can be adjusted and controlled to give maximum freedom in the choice of materials and in mixing and construction consistent with good pavement performance. The goal is to obtain the effect of moisture not moisture level. It should be established if workability tests can be developed that would give more direct workability control than moisture control.

4. It is believed the studies should cover "moisture problems" as they influence:

   a. Hot mix plant operations and construction, i.e., problems with foaming and segregation in storage, under load and during laydown, with tearing and tenderness

   b. Pavement behavior, i.e., problems of flushing, pushing, and raveling due to stripping; problems with volume changes (swell-shrink) that could lead to transverse cracks and otherwise reduce the pavement's integrity.

5. The study of moisture problems should include a comparison of mixes prepared from aggregates with residual moisture levels comparable to those from drum mixers and to equilibrium moistures found in normal pavements in the field with mixes prepared from customary dry aggregates. It is believed that such studies should include moisture cycling or moisture-temperature cycling. Properties that might be examined are coating, strength, stiffness, resilient modulus, etc.

IV. CURRENT ACTIVITIES -

R. P. Lottman, R. J. Schmidt - Immersion-Compression

Minn. Cold-Water Abrasion - generally of a peripheral nature

Conference, "Second Look at Moisture Restrictions on Hot-Mix Plant Operations and Construction," January 23, 1974, Washington, D.C.

V. URGENCY - New procedures presently introduced plus need for new aggregate sources require reconsideration of past moisture control practices. New processes such as drum mixing appear to result in higher moistures but also offer lower emission. Conversely, conventional dryers could reduce emissions, were less drying permitted. Such developments could suffer if in the process we create new problems or reintroduce old problems. There is also a long term need for securing moisture control information.

VII. REMARKS - Being far reaching, the solution to the problem might be expedited were it broken down between well coordinated parts:

1. Construction

2. Properties of bituminous-aggregate systems

3. Pavement performance

The research could focus on overall effects

with interim research leading to a type of "end-result" mix performance specification dependent upon the particular mix type and its particular constituents.

NOTE: This research need in an earlier draft is found as problem statement no. 6 - Transportation Circular No. 160, November 1974.

PROBLEM NO. 30 - COMMITTEE A2D05

I. NAME OF PROBLEM - TENDER MIXES

II. THE PROBLEM - Some hot plant-mixed asphalt mixes are tender and remain softer than non-tender mixes several days after construction. Pavement surfaces constructed with tender mixes show tire prints under parked vehicles, mark easily when turning with power steering and the asphalt may strip from the aggregate more easily. Contractors contend the asphalt is the cause of tender mixes; the asphalt suppliers contend that the contractors have not used proper mixing temperatures, the aggregates contain excessive fines, or have not used the proper construction practices.

Tender mixes were a problem in the early 1960's but have not been much of a problem until 1974 when few occurrences were noted. During 1975, occurrences were more frequent. A survey made by the National Asphalt Pavement Association in 1975. Twelve states reported 1 or more cases of tender mixes. A few blamed the asphalt but no detailed analysis was made to determine the contributing factors.

Studies conducted in the 1960's indicated that low viscosity asphalts in the construction mixing and compaction range were a contributing factor. Changing from penetration at 77° F (25° C) to viscosity grading at 140° F (60° C) apparently minimized the problem because it tended to make asphalts more uniform at high temperatures.

III. OBJECTIVES -

A. Identify the various factors that may contribute to tender mixes. Among those that should be included are:

1. Asphalt source and grade
2. Aggregate properties
3. Asphalt-aggregate interactions
4. Environmental conditions -- pavement and air temperatures
5. Construction practices -- mixing temperature, moisture conditions, compaction, etc.

B. Determine method for correcting tender mixes on on-going projects

C. Develop new specifications and requirements to prevent tender mixes

IV. CURRENT ACTIVITIES -

A. Survey of occurrences, 1975

B. Literature survey, 1976

V. URGENCY - The solution of the tender mix problem is urgent because it has a direct bearing on the performance of asphalt pavements in many states. The solution may provide information to guide the development of better specifications for materials, mix design methods and construction practices.

PROBLEM NO. 31 - COMMITTEES A2E01 and A2E04

I. NAME OF PROBLEM - ABRASION RESISTANCE, SURFACE DURABILITY, AND SKID RESISTANCE OF CONCRETE PAVEMENTS

II. THE PROBLEM - Safe traffic operations require pavements to have adequate skid resistance. Our ability to attain and retain skid resistance will play an increasingly important role in specifications for p.c. concrete pavements and bridge decks.

Concrete pavement surfaces can be thought of as passing through three stages:

Stage 1 - Initial Texture. This stage begins when the pavement is opened to traffic and continues until initial texture is worn smooth. Skid resistance, particularly at higher speeds, depends largely on the macrotexture of the initial finish.

Stage 2 - Mortar. This stage begins when the initial texture is worn smooth and continues until coarse aggregate is exposed. Skid resistance is dependent primarily on the microtexture of the mortar which is a function of the properties of the fine aggregate and cement paste.

Stage 3 - Exposed Aggregate. This stage begins when the coarse aggregate becomes exposed. Tire contact with the mortar phase is reduced and macrotexture may increase depending upon the degree to which coarse aggregate and mortar wear differentially.

The problem is to influence the abrasion resistance of pavement concrete and its components so as to prolong the time required to reach Stage 2 and to maximize skid resistance in Stages 2 and 3.

III. OBJECTIVES -

A. Identify the role of the cement paste phase as regards the initial skid resistance of conventionally textured and grooved pcc pavements and the retention of skid resistance through all three stages of the pavement's surface.

B. Identify the effects of curing compounds on the skid resistance and serviceability of roadway and bridge deck pavements (conventionally textured and grooved pavements).

C. Establish meaningful evaluative criteria for skid resistance characteristics of both fine and coarse aggregates in conventionally textured pcc pavements.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 25, 26, 32 and 51 have been scanned in preparing this statement.

B. Suggested key words: concrete pavement durability, concrete properties, abrasion,

skid resistance, wear resistance

C. A partial list of related research activities which have been completed or are under way in this area follows.

1. Colley, B. E. et al., "Factors Affecting Skid Resistance and Safety of Concrete Pavements," HRB Spec. Rep. 101 (1969)

2. Chamberlin, W. P. and Amsler, D.E., "Pilot Field Study of Concrete Pavement Texturing Methods," Highway Research Board Record No. 389 (1972).

3. Weller, D. E. and Maynard, D. P., "The Influence of Materials and Mix Design on the Skid Resistance Value and Texture Depth of Concrete," RRL Report LR 334 (1970).

4. Iowa State Highway Commission, "Skid Resistance of Concrete Pavements," Project No. HR-168, (HRIS Accession No. 26 232140).

5. Virginia Highway and Transportation Research Council, "Durability of Certain Configurations for Providing Skid Resistance on Concrete Pavements," VHTRC Project No. 70 (HRIS Accession No. 104171).

6. California Department of Transportation, "Improve Portland Cement Concrete Wearing Surfaces," Project No. 19-635293, (HRIS Accession No. 26 232162).

7. North Carolina State University, "Surface Wear and Skid Resistance Properties of Portland Cement Concrete Pavements," Project No. HPR 74-3, (HRIS Accession No. 26 233036).

V. URGENCY - A high priority is warranted because of the accelerated wear and loss of skid resistance being experienced on many concrete pavements now being built. The problem has become acute with the recent emphasis on deeper textures, many of which wear at correspondingly higher rates.

PROBLEM NO. 32 - COMMITTEE A2E01

I. NAME OF PROBLEM - PERFORMANCE OF BRIDGE DECKS WITH DEEP REINFORCEMENT (>2")

II. THE PROBLEM - The accelerated deterioration of concrete bridge decks resulting from the corrosion of steel reinforcement has become the nation's most troublesome bridge maintenance problem. Damage results from tensile stress in the concrete produced by confined expansion of the products of corrosion. Corrosion results when chlorides from deicing chemicals permeate the deck surface to the level of steel reinforcement, and is most frequent when steel is relatively close to the surface and covered by porous, poorly consolidated concrete.

Upon conclusion of the extensive PCA-EPR studies of the mid-1950's, most agencies required a minimum of 2 inches of cover and took steps to decrease the permeability of bridge deck concrete. More recently, however, increasing emphasis has been placed on the use of waterproof deck membranes and low-void bonded concrete wearing courses which prevent or retard ingress of chlorides, and on coated reinforcing bars to isolate steel from chloride ions in the concrete.

While most agree that, given sufficient time, a critical chloride ion concentration can accumulate at any level within a reasonable distance of deck surface, studies in California suggest a logarithmic relationship between accumulation time and distance from the surface. This suggests, for instance, that 3 inches of cover may be 10 times more effective than 1 1/2 inches. Most reported bridge deck spalling has been associated with steel reinforcement with less than 1 1/2 inches of clear cover. The relative cost effectiveness of deeply covered reinforcement (i.e., greater than 2 inches) as an alternative middle or long-term solution to bridge deck deterioration has yet to be determined.

III. OBJECTIVES - The objectives of this research are to develop information on the time relationship among chloride concentration at the level of reinforcing steel, the onset and progression of corrosion and the development of spalling at the deck surface of delamination at the level of the reinforcement.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 27, 32, and 33 have been scanned in preparing this statement.

B. Suggested key words: bridge decks, corrosion, reinforcing steel, concrete durability

C. No HRIP entries directly considered the performance of decks with deeply buried reinforcement.

V. URGENCY - In view of the large sums now being spent and anticipated for bridge deck maintenance and the high cost of other alternatives being actively promoted, this research should receive a high priority.

PROBLEM NO. 33 - COMMITTEES A2E02 AND A2E06

I. NAME OF PROBLEM - CRITERIA FOR EXACT DETERMINATION OF ALKALI-REACTIVE SILICEOUS AND SILICATE ROCKS

II. THE PROBLEM - Several instances of alkali-silica reaction leading to distress in concrete structures have been recorded[1, 2, 3, 4, 5] in which the reactive aggregates have been rocks of types that would not be expected to be reactive with alkalies in cement using current criteria. New evidence has also been developed of alkali-silica reaction in concrete containing shales and hornfelses where the alkali is released from the aggregate by cation exchange with the clay-mica in the aggregate with the Ca++ in the mortar. The rock types involved have included phyllites, argillites, graywackes and metamorphosed subgraywackes, granite gneisses, shales and hornfelses, and vein quartz and quartzite. Differing opinions on the reactive vectors and on the mechanism of reaction have been expressed.[4, part IV; 1, 5, 6] Although detailed petrographic examinations have been published for some reactive varieties,[4, part II] the identification of

reactive species is not sufficiently exact. For example, we frequently hear the expression that "some" graywackes are reactive. It is apparently established that some, and perhaps most, varieties of graywackes are definitely not reactive.

III. OBJECTIVES - Define more precisely which rocks are alkali silica reactive and which are not. Determine if, in addition to defective structure, perhaps the presence of trace elements also triggers alkali reactions. Examine large number of particles which are known to be reactive in concrete and search for a common causal feature or features. Specific objectives include:

A. To develop criteria that will permit demonstration of reactivity in slowly reactive rocks within reasonable laboratory testing times.

B. To advance means other than the specification of low alkali cement that will effectively control slowly developing alkali-silica reaction.

C. To establish more perfectly the mechanisms of the reaction, including those mechanisms that cause low quartz to become reactive.

REFERENCES:

1. Brown, L. S. "Some Observations on the Mechanics of Alkali-Aggregate Reaction," ASTM Bulletin No. 205, p. 40, April 1955, Figure 5 and discussion of it.

2. Idorn, G., "Durability of Concrete Structures in Denmark," 1967, p. 111, Figures 47-53; Technical University of Denmark, Copenhagen, Denmark.

3. Dolar-Mantuani, L., "Alkali-Silica Reactive Rocks in the Canadian Shield," Highway Research Record No. 268, pp. 99-117, 1969.

4. Duncan, M. A. G., Swenson, E. G., Gillott, J. E., Foran, M. R., "Alkali-Aggregate Reaction in Nova Scotia. I. Summary of a Five-Year Study," Cement and Concrete Research, Vol. 3, No. 1, 1973, pp. 55-69. Duncan, M. A. G., Gillott, J. E., Swenson, E. G., "II. Field and Petrographic Studies," ibid., Vol. 3, No. 2, 1973, pp. 119-128. Duncan, M. A. G., Gillott, J. E., Swenson, E. G., "III. Laboratory Studies of Volume Change," ibid., Vol. 3, No. 3, 1973, pp. 233-245. Gillott, J. E., Duncan, M. A. G., Swenson, E. G., "IV. Character of the Reaction," ibid., Vol. 3, No. 5, 1973, pp. 521-535.

5. Buck, A. D., Mather, K., "Concrete Cores from Dry Dock No. 2, Charleston Naval Shipyard, S. C.," U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., Miscellaneous Paper C-69-6.

6. Mather, K., "Examination of Cores from Four Highway Bridges in Georgia," sponsored by the Georgia Department of Transportation, conducted by U. S. Army Engineer Waterways Experiment Station, Concrete Laboratory, November 1973, Miscellaneous Paper C-73-11.

IV. CURRENT ACTIVITIES -

A. No HRIS scans made.

B. Several programs of low to moderate size are underway in the U.S., Canada, Denmark, and other countries. Coordination and exchange of information proceeds informally and at a low rate.

C. A proposed "standard" alkali-silica reactive aggregate has been prepared by Purdue University.

D. Suggested key words: alkali-silica reaction, alkali-silicate reactions, graywacke, low quartz, argillite, baked shale, shale, hornfels, granite gneiss, arenite, quartzite.

V. URGENCY - Since recent studies have increased the number of rocks known to be alkali reactive and have even more increased the rocks suspected of being alkali reactive, it is essential to obtain more precise information to aid in distinguishing between reactive and nonreactive types of rocks.

Energy conservation in cement plants has already affected the ability of some plants to produce low-alkali cement; future cement plants will return even more of the alkali to the cement. It is urgent to learn now, while some lead time is available at least in parts of North America, how much alkali can be tolerated with highly reactive to slowly reactive rocks.

The problem is urgent with the increasing alkali content of cement already affecting choice of aggregates; it is highly relevant because it affects all of North America where concrete pavements and highway constructions are used; it can be implemented as a laboratory program of some but not insurmountable difficulty, and the laboratory findings can be confirmed in the field.

PROBLEM No. 34 - COMMITTEE A2E03

I. NAME OF PROBLEM - IN-PLACE DETERMINATION OF MECHANICAL PROPERTIES OF CONCRETE

II. THE PROBLEM - The current practice of acceptance of the crushing strength of the concrete cylinders, which are cast and cured independent of the parent concrete as "representative" of the concrete used oversimplifies the problem. Taking core samples from the actual structure is not always possible and in situations where core samples can be obtained, the integrity of the structure is damaged by varying degrees depending on the size, number and location of core samples. It is well known that concrete in a structure may have a considerably different strength from that in the comparison test cylinders. Acceptance of the tests on comparison specimens are representative of the concrete used inhibits the realistic design for in-place concrete. The lack of knowledge of the actual strength of concrete in a structure requires the use of a large factor of safety than would otherwise be necessary.

There are several methods to evaluate the quality and strength of in-place concrete. Some

of these are non-destructive like ultrasonic, resonance, radioactive, electrical, and hardness and some are partially or semi-destructive like the pullout and probe or penetration tests. These tests measure different parameters, many still not properly defined. Controversy still exists as to what in-place strength is and whether it is determinable. Considerable amount of future research is needed to adequately improve the accuracy of in-place testing of concrete.

III. OBJECTIVES -

A. To prepare a comprehensive state of the art on the various methods used for the evaluation of strength and quality of in-place concrete.

B. To critically compare the currently used methods and recommend appropriate methods and develop standard procedures for these methods recommended.

C. To encourage the use of in-place testing and realization of the economic significance of in-place testing by suitable publications.

IV. CURRENT ACTIVITIES - In-place test methods are under development by ASTM C09.02.05 (impact-rebound, indentation, and pullout) and C09.03.01 (pushout cylinders). The seven papers published in Highway Research Record No. 378 represent advancements in non-destructive testing and they contribute directly or indirectly to solutions of the problem of in-place testing of concrete. Research is in progress which is directly or indirectly connected with in-place testing of concrete in several states (North Carolina, Pennsylvania, Vermont and West Virginia).

V. URGENCY - There is a great potential and urgent need for in-place determination of the mechanical properties of concrete. Two fields where in-place testing could prove to be superior to traditional methods are quality control in construction of structural members, both precast and cast-in-place, and monitoring strength development to determine acceptance times for the removal of form work or transfer of prestressing forces to concrete.

Inspection authorities urgently require in-place safety and load-bearing capacity test methods. In-place testing also promises savings in time, money and resources, and improvement in quality control and realistic design.

VI. COST - The approximate cost of the above proposed research will be $100,000.

PROBLEM NO. 35 - COMMITTEE A2E03

I. NAME OF PROBLEM - IMPROVEMENT OF PORTLAND CEMENT CONCRETE BY MODIFICATION WITH CHEMICALS

II. THE PROBLEM - Along with the many good properties, portland cement concrete has a few weaknesses, such as the low tensile strength and the resulting tendency for cracking, and the limited resistance against chemical aggression. One possibility to improve these concrete properties is to modify the concrete by combining it with polymers, or prepolymers, or polymerizable monomer systems, or sulfur, or other suitable chemicals.

III. OBJECTIVES - The objective of this research is to find or to optimize technically and/or economically the various types of combinations of portland cement concrete with some of the chemicals mentioned above. There are two main types of such combinations: (a) the chemical is combined with a hardened portland cement concrete (such as in polymer-impregnated concrete) and (b) the chemical is combined with the fresh concrete during mixing.

Type (a) has been investigated thoroughly and developed successfully. However, the research on type (b) modification has been limited and the published results have been mostly negative. Since the technology of the type (a) modification at present is very complex and expensive, it is felt that research efforts concerning the simplification of this technology as well as research on the type (b) modification is justified.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progess areas 32, 33 and 34 have been scanned in preparing this statement

B. Suggested key words: chemical resistance, compressive strength, flexural strength, modified concrete, pavement, polymers, polymer-cement concrete, polymer-impregnated concrete, portland cement concrete, tensile strength.

C. Related research activities: Modification of portland cement concrete is a new development. Nevertheless a large amount of research has been done and published during the past 5 years, mostly on the type (a) modification. (See, for instance, "Cement Polymer Materials" by G. M. Idorn and Z. Fordos, Technical Note, Cembureau, Paris, 1974; or, "Polymer Cement Concretes for Field Construction" by S. Popovics, Journal of the Construction Division, ASCE, Vol. 100, No. C03, Sept., 1974, pp. 469-487; or, the preprints of the First International Congress on Polymer Concretes, London, May 5-7, 1975). The presently on-going research work is primarily also on this type of modification but limited work is taking place also on the type (b) modification both in this country (for instance, an HPR Project through the Arizona Department of Transportation) and abroad (for instance, at the Polytechnic University in Aachen, Germany).

V. URGENCY - The potential benefits for highway and airport pavements, bridges and harbor structures from a successful type (a) modification are so great that an immediate large-scale laboratory investigation of this research area seems justified.

PROBLEM NO. 36 - COMMITTEE A2E05

I. NAME OF PROBLEM - DEVELOPMENT OF NON-CORROSIVE ACCELERATORS AND CORROSION-INHIBITING ADMIXTURES

II. THE PROBLEM - The acceleration of strength

development in concrete is currently best effected by use of calcium chloride. In many applications, the presence of this admixture can result in serious reinforcing steel corrosion problems. Corrosion problems can also result from use of chlorides as deicing salts, as is evidenced by the current concern with regard to bridge decks. The corrosion is the result of electro-chemical action at the steel surface. This local action is enhanced by the presence of chloride ion in the contact solution. The chloride ion can enter by diffusion from the concrete surface.

III. OBJECTIVES - To develop an economical admixture which would replace calcium chloride as an accelerator and act with comparable effectiveness and to develop an admixture which would provide protection against steel corrosion. Such an admixture might either directly protect the steel, for example by formation of a surface film, or the admixture might prevent the diffusion of chloride ion through the concrete. Such accelerators would have the additional advantage of being energy-saving.

IV. URGENCY - This project warrants an immediate and high priority since concrete pavements and bridge decks must be repaired or replaced in as short a time as possible to maintain traffic flow. To accelerate set and strength gain accelerating admixtures are desirable. However, in order for the repairs or replacements to be desirable, these accelerators should be non-corrosive or corrosion inhibiting.

PROBLEM NO. 37 - COMMITTEE A2E06

I. NAME OF PROBLEM - PERFORMANCE AND CHARACTERIZATION OF BLENDED CEMENTS AND OPTIMIZATION OF PORTLAND CEMENT-POZZOLAN MIXTURES

II. THE PROBLEM - In view of the national need to conserve energy, blended cements will, at least partially, be substituted for portland cements in many forms of construction. While blended cements are used extensively in many countries, their use in the United States has been low. Knowledge of the factors affecting the performance of blended cements and methods of characterization of blended cements are needed to facilitate their acceptance for use in highway and other transportation construction without compromise on quality. The interaction between hydraulic cement or lime and pozzolanic solid waste materials such as fly ash has not been thoroughly characterized even though fly ash-portland cement mixtures are widely used for construction purposes. The interaction of the pozzolanic-hydraulic cement mixture depends on the chemistry of the total system. The mixtures currently in use are not the stoichiometric optima for the chemical reactions which take place. If the composition of the fly ash-hydraulic cement blend is balanced with additions of other reaction components such as lime and gypsum so that the potential stoichiometry of the reaction is satisfied, the engineering performance of the hardened mass may be improved.

With prospects for higher coal use in the future, the use of waste material such as fly ash from coal burning will be extremely important. Before the energy crisis, it was predicted that 30 million tons of fly ash will be produced by 1980 in the U.S.A. Use of this waste resource so as to reduce energy consumption in other segments of the economy would be beneficial. When fly ash is mixed with hydraulic cement, a high quality hydraulic binder with definite benefits is produced, which also extends the production of the portland cement industry which uses much energy. The current levels of fly ash addition result in a reduction of the energy required for producing 100 lbs. of a hydraulic cement (Type IP) by about 10-15 percent. Considering the energy-critical future we face, the development of systems of optimum fly ash cement which in effect will use less energy for production of a high quality hydraulic binder is of national importance.

III. OBJECTIVES -

A. To determine the factors affecting the performance of concretes made from blended cements of the portland-pozzolan and portland-blast furnace slag types, in relation to the needs of highway construction. Performance characteristics to be considered would include rate of strength development, workability, behavior with chemical admixtures, resistance to freezing and thawing, sulfate attack, soundness, creep, alkali-aggregate reactions, corrosion of reinforcing steel, and salt scaling.

B. To develop necessary methods for the characterization of blended cements in terms of phase composition, phase distribution (including particle size and shape), and reactivity.

C. To optimize the pozzolanic (fly ash)-hydraulic cement interaction.

IV. CURRENT ACTIVITIES -

A. No HRIS scans have been made.

B. Suggest key words: concrete, blended cements, fly ash, blast furnace slag, performance, characterization, test methods

C. Several projects on the use of fly ash and blast furnace slags in cement are under way, but there is no coordinated program.

V. URGENCY - Because relevant research activities are at a low level and are fragmented, the rate of progress is unlikely to be consistent with the national need. Since the use of blended cements in highway construction may be as readily accepted as use of portland cement-fly ash blends in construction, steps should be taken immediately to facilitate their use in response to the national need to conserve energy and resources and to prepare for possible future problems in the supply of portland cements.

PROBLEM NO. 38 - COMMITTEE A2E06

I. NAME OF PROBLEM - MONITORING ENVIRONMENTAL RESPONSES OF CONCRETE CONSTRUCTIONS

II. THE PROBLEM - Both fundamental investigations and applied studies of portland cement construction are ultimately affected by the response of each portland cement concrete and its cement paste and aggregate constituents to the

microclimates to which the construction is exposed. The microclimates are changed by the introduction of the construction and the construction is affected by and responds to the environments in which it finds itself. Dimensional or quasi-dimensional behavior and characteristics of concrete, paste, and aggregate are mutually affected by the interactions of concrete and microclimate. Fundamental investigations of properties of cement paste may represent misapplied effort unless the investigations relate in basic respects to the microclimates to which real constructions are exposed; applied investigations aimed at design considerations or at explanation of the behavior of a particular construction through time may fail because of lack of understanding of the particular interactions of construction and microclimate that have decisively influenced the coupling between reaction of cement paste, concrete aggregate, and microclimate, and the behavior produced by their interactions. There is a missing link in concepts in both fundamental and applied research on the behavior of cement paste, concrete aggregate, and the whole construction, because only rarely is a structure instrumented so that it may be interrogated during its life by those who plan and conduct basic and applied research. The connection between structure and investigator should be sought in improved instrumentation and telemetered from constructions so that continuous interrogation of the construction, and possibly responsive modification of its microclimate, may be brought about for investigations both fundamental and applied. Although gages and meters that can be placed in concrete exist, their installation is sometimes awkward and it is frequently necessary to read the instrumentation by leads brought out of the construction to which a potentiometer is attached. Thus readings are usually intermittent instead of continuous, and many important characteristics are not interrogated at all or even intermittently.

III. OBJECTIVES - It would be highly desirable to develop a series of instruments having the following characteristics, for use in many concrete constructions:

Size: About the size of a small hen's egg, an ellipsoid about 1 1/2 in. long and 1 in. in diameter.

Contents: Some would contain strain meters, others would contain moisture meters, some would measure compressive and others tensile forces and others chloride content; all would contain miniaturized transmitters, battery operated and capable of sending coded signals through not more than 100 ft. to an

Automatic multichannel recorder which would be able to pick up an identifying signal from each little gage and then record in code the information that gage is suited to transmit. With gages like those described above, the intimate history of temperature, moisture movement, and strain and stress within a bridge or a length of highway with its subbase and subgrade could be monitored and this ability would vastly increase understanding of interactions between construction and microenvironment. The output should be computer compatible and should be recorded continuously, or when trends are apparently developed, often enough to establish the reality and direction of the trends.

IV. CURRENT ACTIVITES - None known.

A. No HRIP scans were made.

B. Suggested key words: telemetry, strain, moisture movement, chloride content, history of forces in a construction, construction-environment interaction, microclimate of construction.

V. URGENCY - Much of the interior developments in concrete structures remains obscure because so few structures are instrumented and retrieving data is often onerous. The development outlined here could ultimately lead to cheap mass produced gages broadcasting information to recorders whose output could be retrieved once a week or continuously. This could produce a greatly increased understanding of the mechanisms that affect successful and unsuccessful structures, and would thus advance fundamental and applied investigations.

PROBLEM NO. 39 - COMMITTEE A2E06

I. NAME OF PROBLEM - ACCELERATED REACTIONS/CURING OF PORTLAND CEMENT PASTE

II. THE PROBLEM - A number of both favorable and unfavorable effects are associated with elevated temperature curing of portland cement paste. The unfavorable factors result in the observation that ultimate strength in cements initially cured at high temperatures, after prolonged curing is lower than in a similar paste cured at room temperature for the whole time. On the other hand, the advantages to generating early strength by curing at elevated temperatures (ca. 50-90° C) for a few hours, followed by normal curing, are considerable. While much research has been and is continuing to be conducted on elevated temperature curing, additional effort is justified for more clearly identifying the favorable and unfavorable factors, and optimizing with respect to the former. Useful research may involve comparison with phenomena involved in one or more other methods of accelerated reaction, to identify possible common factors and differences. The obvious "other methods" include modifying cement composition (e.g. regulated set, high $C_3A$ cements); surface area; or use of admixtures such as $CaCl_2$ or triethanolamine.

III. OBJECTIVE - The eventual results would be the development of better programs for optimum curing, extended by additional research, to implementation in concrete.

IV. CURRENT ACTIVITIES -

A. Two papers in ACI Special Publication SP-39 on elevated temperature concrete curing. ACI Committee 516 on steam curing activities. No comprehensive literature survey has been made.

B. Suggested key words: concrete, cement paste, high temperature, acceleration, strength.

C. Paper by Venuat in Moscow Congress summarizes current status on elevated temperature

studies of cement paste, while Vavrin has summarized the effect of admixtures.

V. URGENCY - Concrete is increasingly called upon to perform its best. While elevated temperature curing will reach probably its greatest usefulness with prestressed and precast units, accelerated curing is desirable in many situations (including repair, re-paving) for economic reasons.

PROBLEM NO. 40 - COMMITTEE A2F01

I. NAME OF PROBLEM - UTILIZATION OF AN OPEN-GRADED STABILIZED AND FREE-DRAINING SUBBASE

II. THE PROBLEM - Drainage layers are gaining nationwide interest. Even though there is a considerable amount of information on their performance as far as draining the water is concerned, there is very little published information on (a) stability of drainage layers using various types of aggregates under construction equipment, (b) drainage layers as part of a composite black base construction and (c) effects of stripping of the asphalt under heavy rainfall.

III. OBJECTIVES - There is a lack of uniformity in the procedures used by the various states and there exists the need to develop national guidelines for using open-graded stabilized subbases. A synthesis of nationwide uses of draining subbases including selected on-site surveys is warranted at this time. The synthesis should identify reasons for the varied utilization and definite problems, if any, which need further attention. This effort would be appropriate for NCHRP Project 20-5.

IV. URGENCY - Pavement maintenance now exceeds 50 percent of the maintenance dollar and the effects of water cause the major repair jobs. This trend will continue unless the water can be controlled. This is an immediate problem and work should begin as soon as possible on the synthesis.

V. ESTIMATE -

2 years -- $50,000 - $100,000

PROBLEM NO. 41 - COMMITTEE A2F01

I. NAME OF PROBLEM - OPTIMIZATION OF MACROTEXTURE (ROADWAY SURFACE TEXTURE) AND RIDEABILITY FOR CONCRETE PAVEMENTS

II. THE PROBLEM - The optimum road surface desired is one which will offer the best of skid resistance with the best riding quality possible. In order to accomplish this we need to establish relationships between specifications, macrotexture and rideability and develop ways of measurement for each.

III. OBJECTIVES -

A. Determine the relationship between specifications and (1) optimum macrotexture and (2) optimum rideability.

B. Refine ways of measurement for macrotexture and rideability.

IV. CURRENT ACTIVITIES -

A. As a result of the AASHO Road Test most highway engineers have adopted the psi-psr concept for measuring pavement rideability or serviceability. Some states use the BPR Roughometer as their measurement of pavement rideability. The only recent research into the relationship between Record 535 "Development of a Specification to Control Rigid Pavement Roughness," by James E. Bryden of New York DOT.

B. Suggested key words: rideability, roughness, surface tolerance, specifications, roadmeter

C. No related research activities reported.

D. Texturing methods and requirements have varied considerably from state to state and many times within states. Methods such as brooms, drags, tines, vibrating grooves, etc., have been used and experimented. Due to the development of new equipment in recent years and the present emphasis on attaining durable skid resistant surfaces, it is believed that efforts toward more uniform methods are feasible and desirable. Experimental construction of transverse and longitudinal texturing in fresh concrete has resulted in a trend towards heavier macrotexturing. A synthesis of nationwide uses and recommended optimum procedures is needed.

E. This effort would be appropriate for NCHRP 20-5.

V. URGENCY -

A. There is a wide variance in state highway department specifications regarding surface tolerances and methods of measurement. There is also a fairly wide range in the roughness or rideability of completed pavements. More uniform specifications and compliance with specifications would permit contractors and equipment manufacturers to respond in a more positive and more economical manner to the problem of building smooth riding pavements. Modern roadmeters are available to measure psi. Attempts should be made to determine whether current specifications on construction are really related to final riding qualities as measured by roadmeters.

B. There is an immediate need to reduce wet weather skidding accidents on concrete pavements, therefore, work should begin on this synthesis as soon as possible.

VI. ESTIMATE -

2 years - $30,000 - $50,000

PROBLEM NO. 43 -COMMITTEE A2F03

I. NAME OF PROBLEM - CONSTRUCTION PRACTICES FOR INCORPORATION OF SANITARY WASTE IN HIGHWAY EMBANKMENTS

II. THE PROBLEM - Millions of tons of trash proliferate in America's cities each day. Environmental considerations preclude normal disposal

procedures such as burning or dumping. Land-use constraints prohibit any large scale land fill construction sites. Thus, answers must be found to the trash surplus problem.

One interesting and highly potential use is to incorporate the trash in an orderly, designed process as part of a normally placed highway embankment. Unanswered questions as to lift thickness, degree of breakdown, bio-degrading protection, artificial vent systems to preclude internal gas buildup, rodent protection, method of placement, and long-term strength characteristics must be examined.

III. OBJECTIVE - The objective of this research is to develop the procedures necessary to properly incorporate sanitary waste products within roadway embankments.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas, including the FHWA, Federally Coordinated Projects, HRIS service bureau, and ASCE indices have been scanned in preparing this statement.

B. Suggested key words: sanitary waste, highway embankments, landfills, waste products

C. There is no known related research activities in this area.

V. URGENCY - Waste products created by man and their safe and sanitary disposal are everyone's problem. The transportation industry holds the potential to a key solution to some part of this problem. Additionally, it is becoming more difficult to buy expensive and scarce fill materials for large embankment construction. Conservation of natural materials is becoming a greater national issue. We must do our part.

Since a few states have experimented with utilizing some waste products in embankment fills, the research can augment the technology currently being developed piecemeal, and greatly advance the improved use of a surplus nuisance into a workable construction material.

PROBLEM NO. 44 - COMMITTEE A2F03

I. NAME OF PROBLEM - DEVELOP RAPID NON-DESTRUCTIVE CONTROL TEST FOR DETERMINING ENGINEERING SUFFICIENCY OF CONSTRUCTED EMBANKMENTS

II. THE PROBLEM - The one universal approach to evaluating engineering sufficiency of highway embankment fills is to mechanically compare a unit weight ratio of a known in-place volume with an artificially prepared maximum. Percent compaction of this prescribed maximum value may not be the degree of strength, stability or whatever, to assure satisfactory performance of the fill for its intended purpose.

Millions of dollars are expended each year by transportation agencies in the training of field personnel, implementation testing, and compilation of results to "control" embankment construction. It is assumed that such control will assure serviceability.

The test is not rapid, can be non-destructive if nuclear means are used, but the test may not be defining the proper parameter. In many instances, the engineer may be specifying far greater requirements than are needed.

III. OBJECTIVES - It is intended to study those parametric relationships necessary to judge the engineering sufficiency of embankment fill construction procedures. A rapid, non-destructive field test would be developed to evaluate the parametric relations in keeping with the prescribed use of the finished embankment.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas including TRB, HRIS, FHWA, FCP, and ASCE indices have been scanned in preparing this statement.

B. Suggested key words: rapid test, embankment construction, non-destructive test, engineering sufficiency

C. There is considerable research, both under way and completed on the subject of compaction of soil and rock materials. This is not the major thrust of this project. A parametric study of the variables effecting the supporting ability of the fill for its intended purpose is needed and is presently not yet available.

V. URGENCY - The present approach to embankment construction is the stronger, the better. This means heavier compactive effort, greater use of heavy equipment, thinner left thicknesses, etc., all of which may not be required in all instances. Hence, considerable money, time, and energy are being expended for a questionable end result. This problem must be solved and as soon as possible.

PROBLEM NO. 49 - COMMITTEE A2F04

I. NAME OF PROBLEM - PAINT SYSTEMS FOR RE-PAINTING OLD STRUCTURAL STEEL AND COATING NEW STEEL

II. THE PROBLEM - Inorganic and organic zinc paint systems are being promoted extensively as the ideal systems to replace red lead and lead based alkyd coating systems. Confusing and conflicting reports from using agencies indicate that zinc paint systems either have failed or have furnished proportionately less protection to structural steel in high or mild corrosive environments than have the proven alkyd systems. Some agencies are abandoning the use of inorganic zinc systems while still others are being convinced by manufacturers to adopt them.

Shop coating of new fabricated structural steel, as well as re-painting of old structures, with the self-curing zincs has produced both success and failures. Preparation and application requirements with zinc systems are so sophisticated that only the most experienced applicators seem to achieve acceptable results. Both shop and field application of zinc paints are plagued by: short pot life, complicated self-agitating spray equipment resulting in expensive losses of paint material due to frequent cleaning of equipment, and unsuccessful ability to touch up thin paint or damaged areas, and areas contamined with grease and

other foreign matter. The inability of formulators to successfully tint the zinc primers so as to provide a contrast with the prepared steel surface often results in undetected thin films and screening by dry overspray. Spray application of inorganic zinc primers, if too heavy, results in sags and "mud cracking." Thin films may result in "salting," producing porous coating and subsequent progressive rusting. Shipping abrasions and erection damage, along with rapid rusting through undetected paint overspray is a common field problem. The re-blasting in the field and field touch-up of unacceptable primed areas produce unavoidable overlaps of the original cured primer. Differences of opinion exist as to whether the overlap of zinc onto a previously cured film of paint will adhere.

Dry film paint thicknesses for these types of "low build" systems are difficult to measure with devices which are not available on the market. Sharp edges and areas most likely to have thin films are difficult, if not impossible, to detect with these devices.

III. OBJECTIVES - To develop a paint system that will eliminate the problems which are being experienced with self-curing zinc paint systems. A new paint system is needed which should have the following characteristics:

1. The system should be economical and as durable as the long proven red lead system.

2. The system should require less expensive and less critical surface preparation than white metal and near white blasting now required for either shop or field maintenance painting.

3. The paint system should have reasonable latitudes, be a non-proprietary system, be free of performance variables, and be simple to apply by spray or brush.

4. The average field painter should be able to apply the formulation under less than laboratory conditions.

5. The system should be practical to use permitting touch-up in the field so as to bond to previous cured coats. Paint should be formulated to enable second coats of primer to be applied in order to obtain specified film thicknesses.

6. The system should be compatible with small residues of alkyd system paints, so as to seal and cover open joints when field re-painting old trusses.

IV. URGENCY - This research should be started immediately. The states are being confronted with the crippling demands of ecology and inflation. Environmentally, the use of red lead paint has been of some concern to persons involved in ecology. Highway maintenance is just as concerned with the rapidly rising costs especially with re-paint maintenance. Structures painted with the zinc systems will also have to be re-painted along with those previously painted with red lead. Fresh paint overspray, as well as old paint removed by blasting and cleaning will fall onto underlying land and water areas. The effect of zinc and vinyl contamination on marine life and human biology may be just as undesirable as red lead.

PROBLEM NO. 46 - COMMITTEE A2F04

I. NAME OF PROBLEM - COMPOSITE BEHAVIOR OF GLULAM BRIDGE SYSTEMS

II. THE PROBLEM - Most timber bridges current in place are based on out-of-date standards (pre 1940) and are generally considered obsolete. A new timber bridge configuration, comprised of preservatively treated glued laminated (glulam) stringers and novel glulam deck panels has been recently developed and achieves a modern, practical, and easily constructed timber bridge system. Design methods must be developed to include the effect of composite action between the stringers and the deck as is commonly done for steel and concrete systems. Current design recommendations do not allow for this composite action and as such, the distribution of loads to the stringers is underestimated. A full evaluation of this component interaction and its recognition in new design procedures is critical to efficient utilization of materials. Experimental and analytical investigations of full-scale systems are needed to develop rational analysis and design methods.

III. OBJECTIVES -

A. Investigate the structural behavior of full-sized glulam bridges through on-site testing.

B. Establish the degree of composite action present and assess its reliability.

C. Develop and verify a mathematical model for the system.

D. Use the verified model to prepare practical design recommendations.

E. Study methods of connection of stringer and deck members to improve the composite behavior of the system and to insure the integrity of the system under repeated and long-term loading.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas related to bridge design and construction have been scanned in preparing this statement. No current activity related to timber bridges is currently referenced. Bridge evaluation studies in various states have also been referenced.

B. Suggested key words: bridges, glulam, timber, composite behavior, design, full-scale tests.

C. A preliminary study of glulam T-beams comprised of reduced-scale bridge components including stringers and deck panels is currently underway at Colorado State University.

V. URGENCY - Rural transportation avenues provide the major means for movement of consumer commodities, foodstuffs, and resources. A

significant percentage of bridges on these rural routes have outdated design and/or configuration or have seriously deteriorated so as to render them unsafe. In fact, newspaper accounts in some states have labeled them "death traps." These facts combined with continued abandonment of rail service to rural areas, make bridge replacement programs a vital and urgent need of this country. The glulam bridge system is an economical, durable, and easily-constructed system which is specifically suited to short to medium span highway bridges.

The use of maintenance workers or local county road employees for the construction of these bridges also affords a savings to the highway department in reduced construction costs and more effective use of available manpower.

In addition, deterioration of reinforced concrete bridge decks has become a major maintenance consideration in those states affected by freezing and thawing and the associated use of salts during winter weather. The laminated timber bridge deck system with an asphalt wearing surface offers a viable alternate for future bridge deck construction since this system is not affected by the deteriorating effect of deicing salts and chemicals.

PROBLEM NO. 47 - COMMITTEE A2F05

I. NAME OF PROBLEM - FINANCIAL FACTORS AS A CONTINGENCY COST IN CONSTRUCTION

II. THE PROBLEM - Once all direct costs are calculated, the contractor must decide what extra margin to add to his bid. Because of the high risks, intense competition, high working capital requirements and relatively low profit margins involved in the construction market today, an important set of questions that must be answered is related to the costs of financing the project. Examples of these questions are: what percentage of work completed will be paid, how promptly will it be paid, what are the chances of owner imposed delays to project completion, how stable will labor and material prices remain over the life of the contract and if the size of the contract is changed, will equitable compensation be made for the change. While it may be possible for a given owner to specify all the answers to these questions, doing so would negate many of the considerable advantages of the competitive bid construction system. By not putting any specific limitations on the answers to these questions, the owner virtually assures that, either construction costs will be exorbitant because all bidders considered the risks high, or the low bidder or bidders will lose money resulting in poor quality, unfinished work or bankruptcy. In any of these cases litigation is almost surely the final result. Establishing the proper balance for limitations on these contingency costs will use, to maximum advantage, the competitive construction industry and will assure the owner of greater cost efficiency for his project.

III. OBJECTIVES - The objective of this research is to identify the financial contingencies, to determine the effect of limitations as related to risk-taking by either the owner or contractor, and to recommend methods that may be used to determine the most efficient balance to the limitations on financial costs factors.

IV. CURRENT ACTIVITIES -

A. Studies have been made, primarily in the building construction field, that have identified specific problems and made worthwhile recommendations. A number of experiments have been carried out in various parts of the construction industry with varying degrees of success. Because of limited funding, and limiting conditions, many of these studies and experiments have been very limited in scope, and few have been evaluated as to their effectiveness after the fact.

B. Suggested key words: construction costs, construction financing, contract procedures, contingency costs

C. No such research activities are known to exist on a comprehensive national or industry-wide basis.

V. URGENCY - Available construction money has not kept pace with rising construction costs, resulting in less volume of physical construction each year. To provide the needs of society, owners are searching for high cost effectiveness. Contractors are striving to be more competitive in a shrinking market. The knowledge and recommendations resulting from this research could provide significant benefit to both parties and therefore, increase the cost effectiveness of construction dollars to society.

PROBLEM NO. 48 - COMMITTEE A2G01

I. NAME OF PROBLEM - CHARACTERIZATION OF ACCEPTABLE AGGREGATES

II. THE PROBLEM - Information on the correlation between aggregate properties and the performance of aggregates in highways and on appropriate test methods predictive of performance need to be developed. The lack of this information presents a major obstacle to better utilization of currently available aggregates and to the development of new supplies of aggregates for highway construction.

III. OBJECTIVES -

A. Determine the correlation between quantitatively different levels in aggregate properties and aggregate performance in highway construction.

B. Develop suitable test methods for predicting field performance through review and evaluation of existing tests, where appropriate, and develop new test procedures where existing methods are inadequate or nonexistent.

C. Develop aggregate specifications based on fundamental properties. These specifications would include relation to performance criteria in order that aggregate selection can be suited to the requirements of a particular job and location.

IV. CURRENT ACTIVITIES -

A. This project statement was one of several developed on NCHRP Project 4-10 FY 70

(Report No. 135). HRIS areas 25, 26, 31, 32 and 35 were scanned in the preparation of this statement.

B. Key words: mineral aggregates, aggregates, aggregate properties, aggregate characteristics, physical and chemical properties, engineering characteristics, construction materials

C. Current research includes studies of the wear resistance, abrasion resistance, polishing characteristics, load deformation characteristics as a function of geometric properties, toughness, and petrological characteristics of select aggregates. In a limited number of studies performance is being related to aggregate properties.

V. URGENCY - Information on the characteristics of aggregates that affect performance is needed to permit the design of pavements that will serve traffic throughout their design life. A high priority should be assigned to this effort to enable the development or revision of design criteria and, thereby, reduce the number of pavements that will be constructed to "improper" standards.

Estimated time: 5 years

Estimated cost: $500,000

VI. SUGGESTED PROGRAM -

A. Review of existing test methods by a steering committee composed of (a) engineers knowledgeable in highway construction, performance, and testing; (b) scientists knowledgeable in characterization of raw materials and products; and (c) geologists and plastics experts. This committee first should determine the aggregate properties and the existing test methods that correlate with performance, then recommend the aggregate properties that require further investigation and the test procedures that should be developed. The committee should meet bi-monthly, after formulation of the initial plan, to review the project performance and to determine the direction of the research.

B. Investigate in the laboratory the characterization of aggregates in accordance with the plan previously developed. It is anticipated that the characterization would evaluate the variety of aggregates that have known differences in field performance. The properties evaluated may include: strength, pore quantity, toughness, particle size distribution, pore size distribution, particle shape, abrasion resistance and hardness, wettability by different classes of cementitious agents, adhesion strength to different types of cementitious agents, drainage characteristics and water retentivity, thermal expansion, moisture expansion, surface characteristics, soundness of a composite under repeated temperature and moisture cycling (weatherability), composition, soluble salts.

C. Prepare proposed specifications for aggregate properties based on the knowledge gained from the research outlined previously. The specifications should recognize different levels of performance to assist in the characterization of aggregates for particular job localities and requirements.

PROBLEM NO. 49 - COMMITTEE A2G01

I. NAME OF PROBLEM - REVIEW OF AGGREGATE BENEFICIATION PROCESSES

II. THE PROBLEM - The availability of quality aggregate for highway construction is limited. The rapid depletion of proven aggregate sources and the cost of increasingly longer haul distances make it difficult to obtain or uneconomical to purchase the quality aggregate desired, thus creating ever greater pressures for use of marginal aggregate sources that were previously rejected. It is becoming increasingly more attractive, economically, to apply some means of beneficiation to marginal aggregates, thereby rendering them attractive for highway use.

Many beneficiation processes are presently in use or in the experimental stage; some are expensive, such as heavy media separation, and others have limited application, such as elastic fractionation, which is successful only for rounded aggregates. A review of beneficiation processes is needed to define the effectiveness and economy of removing various deleterious materials from some marginal aggregates.

Study is also needed on so-called beneficiation processes such as heat treatment and blending of "good" and "bad" aggregate. Additional research may be included on methods of beneficiating aggregates to reduce degradation. An investigation should be undertaken to determine the feasibility of developing new beneficiation techniques. Economical and efficient beneficiation processes may ultimately allow use of aggregates presently classified as marginal or poor quality and give greater flexibility in the choice of highway aggregate materials.

III. OBJECTIVES -

A. Review of aggregate beneficiation techniques with economic considerations

B. Identify areas that can benefit most by immediate research and development

C. Investigate the development of new aggregate beneficiation techniques.

IV. CURRENT ACTIVITIES -

A. This project statement was one of several developed on NCHRP Project 4-8 FY 68 (Report No. 100). HRIS areas 25 and 35 were scanned in developing this statement.

B. Key words: aggregate beneficiation, mineral aggregates, beneficiation, upgrading, construction materials

C. Current research is being directed to specific techniques for improving a marginal aggregate for use in construction. A

comprehensive review of existing methods and the establishment of the relative effectiveness of each method for specific aggregate types is needed.

V. URGENCY - Aggregates are used extensively in construction and affect the performance of these constructions. Quality aggregates are specified for use to provide good performance. A diminishing supply of quality aggregates in some sections of the country and an increasing demand for aggregates for construction, developing in part as a result of shortages of asphalt and cement and the current energy crisis, place a high priority on the proposed research activity. A compilation of existing knowledge on the subject will be the first step towards the development of specifications that will permit use of beneficiated aggregates in construction.

Estimated cost: $150,000

VI. SUGGESTED PROGRAM -

A. Literature search and review

B. Field study to evaluate the significance and economics of present beneficiation techniques

C. Develop criteria for using certain techniques for a given use of aggregate

D. Laboratory and field study investigating the development of new aggregate beneficiation techniques and establishing guidelines for future research.

E. Data analysis, synthesis, and report

Time:

| Program Item | Time | Man-Months |
|---|---|---|
| 1 | 3 | 3 |
| 2 | 12 | 18 |
| 3 | 3 | 3 |
| 4 | 12 | 12 |
| 5 | 6 | 3 |

Calendar months for completion: 24 months

PROBLEM NO. 50 - COMMITTEE A2G03

I. NAME OF PROBLEM - ASPHALTIC CONCRETE BRIDGE DECK OVERLAYS AND BRIDGE EXPANSION JOINTS

II. THE PROBLEM - Numerous bridge decks have been and are being overlaid with asphaltic concrete as a result of bridge deck deterioration. The overlay is generally provided to protect a waterproof membrane system. A solution is needed to the apparently unavoidable migration, wearing or time dependent lowering of these asphaltic concrete overlays in areas adjacent to the expansion joint system.

The effect of this phenomena is to expose to the rigors of traffic the expansion joint system in a "sitting duck" manner with the result that it is literally beaten out of service prematurely. The high cost of this phenomena is staggering to bridge maintenance personnel around the world today. In snow plow areas, expansion systems are often ripped completely out of the deck and the cost plus the urgency of immediate repair is very high.

III. OBJECTIVES -

A. Identify and evaluate methods currently in use for sealing bridge joints where asphaltic concrete overlays are used.

B. Identify and evaluate the properties of various types of asphaltic concrete used to overlay bridge decks and the methods used for placing and compacting it next to the expansion joint system.

C. Determine the most suitable materials and methods for minimizing distress and failure of the overlay at the overlay-joint interface and the subsequent failure of the expansion joint system.

D. Develop and experimentally evaluate improved systems and guidelines for use by maintenance in repairing distressed joints.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 27, 31, 33, 34, and 40 were scanned in preparing this statement. An HRIS selection pertaining to sealants and fillers for joints and cracks made June 11, 1973 was also reviewed.

B. Suggested key words: bridges, asphaltic concrete, flexible pavements, bituminous materials, expansion joints, joint sealers, and membranes.

V. URGENCY - The problem of bridge deck deterioration is universal and efforts are under way to find a solution. One method widely used is placing a waterproof membrane overlaid with asphaltic concrete. This also requires raising of the expansion joint system or the placement of a new system. This is the only practical method of restoring and protecting older bridge decks. It is therefore urgent that a solution be found to the problem of the expansion joint system-overlay interface. The results could be immediately implementable in design and construction.

It is estimated that $100,000 would be required to accomplish this research.

This problem is certainly an aggravating one. With the current interest and activity in bridge deck resurfacing, the solution takes on some urgency. A design to eliminate the problem would be worthwhile, welcome, and immediately implementable.

PROBLEM NO. 51 - COMMITTEE A2G03

I. NAME OF PROBLEM - SEALING CRACKS IN FLEXIBLE PAVEMENTS

II. THE PROBLEM - The problem of cracking of flexible pavements is widespread throughout the country. This cracking may result from a number of factors including temperature (thermal), expansive soils, and load. If surface cracks are left untended, they may result in more serious structural damage to the pavement system. They permit the entrance

of water which may saturate the subgrade and reduce the load carrying ability of the pavement or result in frost heaves. Pavement systems with free draining subgrade material may not have serious problems if water is allowed to enter. Many of the existing materials and methods used for crack sealing are not very effective or permanent. The problem is then determining which cracks are to be sealed (subgrade type, crack width), how they are to be sealed (equipment, materials, methods), and when. Efforts are underway to improve design and construction of pavements so as to minimize cracking; however, many pavements are in place where cracking is a serious problem.

III. OBJECTIVES -

A. To determine the extent of the cracking problem in flexible pavements and identify the existing materials and techniques used to seal the cracks. Evaluate the effectiveness of the various methods used.

B. Determine the consequences of not sealing cracks for flexible pavements composed of different types of materials in various layers such as subgrade materials variations.

C. Determine the types and magnitudes of movements occurring at cracks and determine the critical crack width or the point where it must be sealed.

D. Determine the required properties of a crack sealer such as movements, temperature, etc. and identify materials that will meet those requirements.

E. Develop criteria for crack sealing of flexible pavements to include evaluation of need for sealing, types of materials and equipment, and when the crack should be sealed.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 25, 26, 31, 33, 34 and 40 have been scanned in preparing this statement. HRIS selections made June 11, 1973 pertaining to sealants and fillers for joints and cracks were also reviewed.

B. Suggested key words: flexible pavements, asphaltic concrete, bituminous mixtures, cracking, crack sealing, and sealants

C. There has been a very limited amount of formal research on crack sealing of flexible pavements and most of that was accomplished several years ago. The only recent research identified is an experimental crack sealing field study in Minnesota.

V. URGENCY - The solution of this problem is urgent for the many states with the flexible pavement cracking problem. The solution of the problem would help reduce costs on other maintenance activities. For example, why place a seal coat over the entire surface to temporarily cover the cracks when all that was needed was crack sealing. The results could be implemented directly by an agency.

It is estimated that it would cost approximately $125,000 for this research.

PROBLEM NO. 52 - COMMITTEE A2G04

I. NAME OF PROBLEM - DEVELOPMENT OF A SYSTEM FOR CLASSIFYING ADHESIVE COMPOUNDS BY USE

II. THE PROBLEM - Considerable effort is being devoted to the writing of guides for the proper use of adhesive compounds in maintenance and construction operations. Among the manuscripts now in preparation are a major publication on the use of epoxies with concrete by ACI Committee 503 and portions of a recommended practice for the repair of concrete bridge superstructures by ACI Committee 546. While such guides provide excellent information on application techniques, they cannot tell the reader which of the myriad of available compounds are suitable for particular jobs. A system through which adhesive compounds can be grouped according to their uses is needed.

III. OBJECTIVES -

A. To determine the ranges of engineering properties, such as modulus of elasticity, strength, durability, etc. required of an adhesive compound in a variety of common maintenance and construction operations

B. To develop a system through which such compounds could be classified according to their uses. The system would enable an engineer faced with a particular operation to determine immediately the required properties of the adhesive and, conceivably, to order the compound by its use classification. The suggested research should be national in scope to obtain the full advantage of the experience of all highway agencies and to ensure final acceptance of its findings.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 25, 26, 27, 31, 32, 33, 34 and 40 have been scanned in preparing this statement.

B. Suggested key words: adhesives, adhesion, bond, bonding agents, concrete construction, concrete repair, epoxy resins, material specifications, organic compounds, patching materials

V. URGENCY - No studies meeting the objectives of this proposed problem statement were discovered. The most closely related current work appears to be a study, "Formulation and Evaluation of New Adhesives for Highway Construction," now active in California. HRIP also lists a study entitled "Identification Tests on Synthetic Resins," one of several concerned with synthetic resins underway in the Netherlands. Several studies not directly related to adhesives could provide useful data. Several agencies are studying repair techniques for concrete members, and one organization has investigated the strengthening of concrete beams through the use of bonded steel panels. Background information could also be gathered from the many completed studies of the use of

adhesives and bonding agents in highway construction and maintenance.

V. URGENCY - Adhesive compounds are being used to a greater extent in transportation facilities. This research would produce an output that would be useful to the engineer in selecting the proper adhesive compound. The results of the suggested study would be immediately useful to practicing engineers. This research is considered to be urgent, relevant and implementable.

PROBLEM NO. 53 - COMMITTEE A2H01

I. NAME OF PROBLEM - NUCLEAR DENSITY DETERMINATION OF LAYERED BITUMINOUS PAVEMENT SYSTEMS

II. THE PROBLEM - Various nuclear gauge types or models are commercially available to determine the density of bituminous concrete. The influence of depth, that is, the effective depth to which the nuclear gauge reads the density varies from one model to another. This makes density determinations in layered systems difficulty. It becomes more critical on overlays where 3/4" - 1 1/2" bituminous concrete wearing course is placed on existing bituminous pavements.

During the investigation of some prematurely distressed overlays, it was observed that the core densities obtained by the nuclear density gauges. It was determined that the existing bituminous pavement before resurfacing, had substantially higher density due to traffic compaction, and was affecting the nuclear gauge readings taken on the 3/4" - 1 1/2" overlay. During construction this resulted in to misleading nuclear density values, which met the specification requirements of more than 95% of the design density.

Whereas this problem is not generally encountered on new construction jobs, it will be faced more frequently on resurfacing projects undertaken by the various highway departments.

III. OBJECTIVES - Research should be conducted to achieve the following objectives:

A. To evaluate the depth of influence (the effective depth to which the nuclear gauge reads the density) for the various models of commercially available nuclear gauges

B. To determine the effect of thickness and density of the bituminous concrete on the depth of influence

C. To develop practical procedures to account for the influence of depth and the densities of the underlying layers in arriving at the most accurate density of the surface

D. To determine the effect of aggregate on the nuclear densities

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress. To our knowledge no such research is in progress at the present time.

B. Suggested key words: bituminous concrete, asphalt concrete, density, nuclear density, overlays, nuclear gauge, rapid test method, construction

C. Field testing of a nuclear density device was reported in the Proceedings of Assoc. of Asphalt Paving Techn logists, Vol. 32 in 1963 by Hughes and Ralston, who discussed the depth of influence, and the problems associated with it. Some operation manuals mention the depth of influence but do not suggest a practical procedure to account for the underlying layers. Limited study using two nuclear gauges (Troxler and Campbell) was conducted in 1975, by the Bureau of Materials, Testing & Research, Pennsylvania Department of Transportation, using various combinations of precast bituminous concrete slabs. Depending upon the density of the top layer, the two gauges had different depths of influence. The maximum depth was estimated at 2 inches.

V. URGENCY - It is expected that most highway agencies will be engaged in considerable resurfacing jobs in the immediate future. Overlays of 3/4" to 1 1/2" thickness will not be uncommon to stretch the tax dollars for resurfacing. If the nuclear gauges are to be used to determine the actual density of the top layer, it is of prime importance to develop procedures to account for the depth of influence and the densities of the underlying layers.

PROBLEM NO. 54 - COMMITTEE A2J03

I. NAME OF PROBLEM - LIME AND LIME-FLY ASH STABILIZATION: MIXTURE DESIGN-QUALITY CONTROL

II. THE PROBLEM - Lime and lime-fly ash stabilization procedures are widely utilized. Although there are several mixture design procedures being utilized to establish the required lime or lime plus fly ash contents required for stabilization, there are no procedures that have gained widescale acceptance. In most instances, the mixture design procedures are not sufficiently flexible for broad scale application to achieve various lime treatment objectives (modification, swell control, strengthening) or accommodate special situations encountered in lime-fly ash stabilization (fine aggregate sources, by-product aggregates, late season construction conditions, etc.). Quality criteria (strength, durability, volume stability, etc.) for lime and lime-fly ash treated materials have not been well defined. The criteria generally do not account for the wide diversity of applications and range of service conditions (traffic, environmental factors, etc.) encountered in practice.

Most lime-fly ash construction is of the "plant mix" type while "mixed in place" procedures are normally used in soil-lime construction. The major quality control items of interest are: 1) lime and fly ash quality, 2) soil or aggregate properties, 3) lime and fly ash quantities and distribution, 4) mixing, 5) pulverization, 6) compaction, and 7) curing. All aspects of the construction process must be carefully controlled. The degree of control varies depending on the stabilization objective. Satisfactory quality control tests, procedures, and appropriate quality criteria are essential to achieving adequate quality control. Although

many aspects of lime and lime-fly ash quality control are considered in current specifications, additional effort is needed to refine and expand the present practices and develop supplemental procedures where appropriate.

III. OBJECTIVES - The general objectives are to develop comprehensive mixture design procedures with associated quality criteria and construction quality control procedures for lime and lime-fly ash stabilization. Mix design procedures and quality criteria must be adaptable to the entire spectrum of stablization objectives and applications. The quality control procedures would: a) include appropriate field testing procedures, b) consider sampling and testing frequency, c) establish quality criteria, d) consider tolerances and allowable variability, e) provide rational methods for determining curing requirements and cut-off dates if applicable, f) provide a method of construction acceptance, and g) provide for post-construction surveillance.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 25, 26, 32, 33, 34, 35, 62, and 90 have been scanned in preparing this statement.

B. Suggested key words: lime, soil-lime, lime stabilization, soil stabilization, fly ash, lime-fly ash, mixture design, test procedures, quality control, construction, quality criteria

C. Identified research efforts relating to the research area are:

1) Studies at Pennsylvania DOT, University of Illinois, Villanova University, and University of North Dakota on lime-fly ash stabilization

2) Soil-stabilizer mixing studies at the California DOT and MIT (sponsored by Air Force Weapons Laboratory)

3) Soil-lime research studies at the University of Texas at Austin, Air Force Academy, University of Illinois and the South Dakota DOT

4) Soil stabilization Index studies at Texas A&M sponsored by the Air Force Weapons Laboratory

5) Freeze-thaw durability evaluation of stabilized materials studies at the University of Illinois

V. URGENCY - There is an increased utilization of lime and lime-fly ash stabilization in pavement construction. Based upon the current state of the art relating to mixture design and quality control and the judgment of currently active researchers this project area is classified as "urgently needed" and was ranked as the number one priority by Committee A2J03.

PROBLEM NO. 55 - COMMITTEE A2J03

I. NAME OF PROBLEM - SOIL LIME LAYERS: STRUCTURAL BEHAVIOR AND THICKNESS DESIGN

II. THE PROBLEM - Soil-lime layers are utilized in pavements as base and subbase layers and also as modified subgrades. Current procedures for predicting structural behavior and establishing design thicknesses for soil-lime layers are generally empirically based and thus their applications are somewhat limited. Soil-lime stabilization can be used in so many different ways in pavement construction that it is essential to have a comprehensive methodology for considering structural behavior and thickness design problems.

III. OBJECTIVES - The objectives of the research are to develop adequate procedures for predicting the structural behavior and establishing thickness requirements for soil-lime layers in pavements. The procedures should consider a) soil-lime mixture properties, b) subgrade support conditions, and c) traffic and load factors. The procedures should preferably be applicable for a broad range of applications varying from low traffic volume roads, to construction haul roads, to higher type pavements.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 25, 26, 32, 34, 35, 62 and 90 have been scanned in preparing this statement.

B. Suggested key words: soil-lime, thickness design, structural behavior, lime stabilization, pavement design

C. Recent studies relating to this proposed project have been conducted by the California Division of Highways (HRIP 40-082731, HRIP 22-234710), U.S. Army Construction Engineering Research Laboratory (HRIP 62-2135101), the U. S. Army Waterways Experiment Station (HRIP 62-234097, HRIP 26-234104), South Africa (HRIP 62-062 215, HRIP 62-600812) and Brazil (HRIP 62-066562).

Extensive field studies on pavements containing soil lime layers have been carried out by the South Dakota, Minnesota, and Virginia Highway Departments and other highway departments have also conducted field studies or otherwise considered the performance of soil-lime layers on pavements sytems. A recent National Lime Association Publication (Bulletin 327) considers the topic of flexible pavement design. Even though there has been substantial interest in related research areas, there have not been any extensive recent studies directed specifically to the problem outlined in this research needs statement.

V. URGENCY - Soil-lime mixtures are being used to a greater extent than ever in pavement construction. Considering the current problem of materials shortages and the energy crisis, increased emphasis will probably be placed on the use of local materials, including stabilized soils, in pavement construction. It is apparent that improved procedures for considering structural behavior and thickness design problems are needed. This research area was ranked the number two priority by Committee A2J03.

PROBLEM NO. 56 - COMMITTEE A2J05

I. NAME OF PROBLEM - COMPILATION OF FIELD PERFORMANCE DATA FOR SOIL-BITUMINOUS STABILIZED PAVEMENT LAYERS

II. THE PROBLEM - Several mixture design and layer thickness design procedures exist for soil-bituminous stabilized soil-aggregate mixtures (where the soil or soil-aggregate mixture is not required to meet gradation specifications). Bituminous treatments meeting this definition have been used as: 1) stablilized subgrades in high quality pavement systems, 2) stabilized subbases in high quality pavement systems, and 3) low cost stabilized bases and wearing surfaces in low-volume secondary, country, or farm-to-market roads.

However, no generally accepted design procedures have been recognized since the field performance of these stabilized pavement components has not been evaluated on the basis of a statistically valid sample of case studies collected from throughout the United States. A meaningful development of standardized mixture and thickness design procedures cannot be achieved without field performance information.

III. OBJECTIVES - The major objectives of the proposed research are directly related to the severe deficiencies in the existing mixture design and layer thickness design procedures for soil-bituminous stabilized materials. Both design technologies can be properly assessed and improved only if the field performance of the stabilized soil materials can be evaluated. The field performance evaluation must have as a basis three files of information to define a single performance case study:

1. mixture and layer thickness design procedures used for the soil-bituminous stabbilized layers
2. as constructed mixture constituency and layer thickness, and
3. traffic and maintenance theory.

This type of evaluation has not been conducted since sufficient data have not been compiled and analyzed. The missing "feed-back" loop needs to be developed in order that soil-bituminous stabilization mixture design and layer thickness design methods can be assessed, improved, and perhaps standardized.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 25, 26, 31, 34, and 62 have been scanned in the preparation of this statement.

B. Suggested key words: bituminous stabilization, pavement design, pavement performance, mixture design, thickness design

C. NCHRP Synthesis of Research Practice 30, Bituminous Emulsions for Highway Pavements, has been printed and distributed in 1975.

V. URGENCY - This project warrants a high priority since bituminous stabilization will become increasingly important for low-cost/low-volume roads in areas characterized by surficial coarse grained soils. Asphaltic emulsions will have major secondary benefits since no heat, and therefore no energy, is required for field mixing and the emulsion does not have a volatile solvent, but only water and an emulsifier. The utilization of emulsions and other bituminous products will be deterred by the absence of standardized design procedures.

PROBLEM NO. 57 - COMMITTEE A2K02

I. NAME OF PROBLEM - THE EFFECT OF CONSTRUCTION TECHNIQUES ON THE PERFORMANCE OF VERTICAL SAND DRAINS

II. THE PROBLEM - The different methods of installation of vertical sand drains have a direct effect on the engineering characteristics of the soil in which the drains are installed. The major characteristic which appears to be subject to alteration is the coefficient of permeability. The difficulties attendant to accurate predictions of the time required for settlement have created severe construction scheduling problems and costly delays.

A rational design procedure is needed to permit the engineer to accurately predict the rate of settlement which accompanies the various methods of sand drain installation.

III. OBJECTIVES - To develop a rational design procedure for the rate of settlement by investigation which includes laboratory tests, field tests and observations of vertical sand drains installed by current methods in a variety of oil types.

IV. CURRENT ACTIVITIES -

A. Suggested key words: permeability, natural drainage paths, remolding, smearing, sand drain diameters

B. Although several projects have been constructed where different sand drain installation techniques were evaluated via test sections, no formal research has been conducted and no design procedures are available for accurate predictions of rate of settlement.

V. URGENCY - Millions of linear feet of sand drains have been installed in the United States. Many projects are being designed which traverse soft ground acres where settlement is a major design consideration. A rational design procedure for sand drains is imperative to allow an economical evaluation of sand drain construction techniques and to avoid costly construction delays.

PROBLEM NO. 58 - COMMITTEE A2K02

I. NAME OF PROBLEM - SECONDARY COMPRESSION CHARACTERISTICS OF ORGANIC DEPOSITS

II. THE PROBLEM - Embankments constructed over organic foundation soils are subject to long term post construction settlements that are often detrimental to the subsequent performance. A large portion of this settlement is attributed to the secondary consolidation characteristics of the organic soil. Currently, there is no design method available which produces accurate predictions of the amount of or the rate of

secondary consolidation.

III. OBJECTIVES - Basic information on the consolidation properties of organic soils is required in order to develop economical and satisfactory methods of stabilizing such deposits. The objectives of the research are:

A. By means of laboratory investigations, determine the consolidation characteristics of various types of organic soils, including the limitations of applying the present "primary" and "secondary" consolidation concepts to these soils. New test procedures and equipment may be required.

B. Develop rational design procedures which include predictions of rate and magnitude of secondary consolidation with reasonable accuracy.

C. Compare the results of observations and measurements of long term settlement of embankments constructed over organic deposits with laboratory test data and design assumptions.

IV. CURRENT ACTIVITIES -

A. Suggested key words: primary consolidation, secondary consolidation, organic content, amount of settlement, rate of settlement, test methods

B. Many small research projects have been undertaken on this subject, but their scope has been too narrow to fulfill the necessary objectives which will lead to rational design procedures.

V. URGENCY - In some parts of the United States, especially in urban areas, the only land areas remaining for location of new transportation facilities are swamps and marshes. This is particularly true of coastal areas. Removal of the organic soil requires disposal areas and substantial quantities of suitable borrow material. Such areas are becoming less advisable due to associated ecology problems and economic considerations. Thus the utilization of the organic deposit as a foundation material has become imperative in many sections of the country. Successful completion of this research will result in substantial savings in the transportation field.

PROBLEM NO. 59 - COMMITTEE A2K02

I. NAME OF PROBLEM - LONG TERM STABILITY OF CUT SLOPES

II. THE PROBLEM - Many cut slopes that were built 8-10 years ago are now starting to fail without showing any previous signs of instability. This, in part, is due to the long term effects on the stability of the cut slopes that were not recognized when making the original design.

A rational procedure is needed to permit the engineer to determine which cut slopes will fail due to long term effects, and how to adequately design for them.

III. OBJECTIVES -

A. To develop an investigational procedure that will determine which cut areas may need to be designed for long term stability.

B. To develop a design procedure for the long term effects.

C. To develop stabilization methods to use in the correction of existing failures, in areas of potential failure and for new construction.

IV. CURRENT ACTIVITIES -

A. Suggested key words: creep, long term stability, drained and undrained conditions, stabilization

B. A few states have made some progress in this area, but most states are still designing without any special considerations. Corrections are then made after failures occur.

V. URGENCY - Many cut slopes that are now 8-10 years old are failing due to the inadequate design for long term effects. Unless new techniques are developed to spot these potential failure areas before they fail, we will continue to have a problem that will cost thousands of dollars a year.

PROBLEM NO. 60 - COMMITTEE A2K03

I. NAME OF PROBLEM - FULL SCALE FIELD LOAD TESTS ON PILE GROUPS

II. THE PROBLEM - Over the years a considerable number full scale field load tests have been conducted on single piles, but very few full scale field load tests have been conducted on pile groups. Of course, there are no foundations constructed on single piles and pile foundation design must include consideration of group action. Both bearing capacity and settlement of the group must be considered. Design for bearing capacity normally involves the use of a "Group Efficiency Factor" and the factors currently used were established primarily from model studies. For pile groups in clay, the possibility of a "block failure" must be considered. There is no established design criteria for settlement of pile groups.

III. OBJECTIVES - The broad objective is to develop design criteria for pile groups by conducting full scale field load tests on groups founded in both cohesive and cohesionless soils. Specific objectives are as follows:

A. To instrument the group so that the action of individual piles can be determined

B. To develop group efficiency factors for different pile spacings and for different pile shapes

C. To investigate the development of block failures in cohesive soils, and

D. To relate the settlement of the pile group to that of a single pile in the group.

IV. CURRENT ACTIVITIES -

A. No Highway Research in Progress areas have been scanned in preparing this statement.

B. Suggested key words: pile groups, field load tests, bearing capacity, settlement

C. Related research would include any research currently being done on single piles and any model studies on pile groups or field performance studies of in service pile group foundations.

V. URGENCY - The proposed research would be a long term effort to develop reliable design criteria for foundations on pile groups which in turn would reduce foundation costs. Currently used design criteria are based primarily on model studies and have not been verified by full scale field performance tests.

The cost of this research would be high, probably $500,000 or more and should probably be at least a 5-year study. The cost could be reduced by testing actual foundations under actual loading conditions.

PROBLEM NO. 61 - COMMITTEE A2K03

I. NAME OF PROBLEM - EFFECTS OF DIFFERENTIAL SETTLEMENT ON STRUCTURES

II. THE PROBLEM - A great deal of money is often expended on the special treatments for the support of structural foundations in order to eliminate settlement, so as to avoid the possibility of the occurrence of differential settlement across as well as between structural elements. Steel frame structures may be able to withstand greater foundation deflections than the more rigid reinforced concrete structures, and therefore the foundation support for these two types of structures may differ even where the loadings are the same. Simply supported deck slabs of bridges may permit greater movements across and between substructure elements that would be acceptable for continuous span bridge decks. A thorough evaluation of the literature, and a survey and compilation of experience should be made to ascertain applicable safe limits (or angular deflections) for differential settlement for various types of structures and framing systems.

III. OBJECTIVES - The objective of this research would be to establish the degree of differential settlement that can be introduced into the design of specific types of structures and support systems without adversely affecting the utility and safety of the structure. The goal would be to establish a set of criteria, which if exceeded, would require special foundation treatment to limit differential settlement.

IV. CURRENT ACTIVITIES - Work has been reported in matters related to the effects of differential settlements on building frames and exteriors by L. Bjerrum, and the results of others have been presented in various textbooks; however, I have no idea of the Highway Research in Progress, HRIP, work.

Suggested key words: differential settlement, structural distortion, stress redistribution

I have no idea of related research activities in HRIP.

V. URGENCY - This would be urgently required with regard to the effects of open cut excavation and tunnelling operations, on adjacent structures, as is commonly a problem in subway construction. Today, considerable money may be involved in the support of structures, which might be reduced if the data were available on how the foundations of such structures, and the structures themselves, would react to induced differential movements.

It is estimated that the required research could be accomplished and the results compiled by one man in one year's time, allowing adequate funds for travel and communication, as well as special measurements. A budget of $50,000 would be ample.

PROBLEM NO. 64 - COMMITTEE A2K03

I. NAME OF PROBLEM - SOIL: PILE LOAD TRANSFER IN PILE GROUPS

II. THE PROBLEM - Field tests on single test piles have shown that the transfer of load from a pile to the soil or vice versa can be predicted using the effective stress approach. Very few, if any, field tests have been performed on groups of test piles. Since most engineering structures that use pile foundations are supported on groups of piles, a field test program is urgently required in order to find correlation between the behavior of pile groups and single piles. Such correlations would provide improved design methods and consequently more economical pile foundations.

III. OBJECTIVES - To carry out a field testing program on various groups of piles in different soils to study the stress transfer in positive and in negative skin friction.

IV. CURRENT ACTIVITIES -

A. Research on single piles or pile groups is currently under way in Canada, England and Sweden.

B. Key words: piles, pile groups, effective stress, positive friction, negative skin friction or downdrag, pile tests

V. URGENCY - Much information on the behavior of single test piles is available and has been published. This knowledge cannot be applied directly to the design of pile foundations because it has never been correlated with the behavior of pile groups. Unless this is done soon, the present experience will remain academic. The profession needs this correlation now to improve the design of pile groups.

Cost estimate: $150,000 - $200,000

PROBLEM NO. 63 - COMMITTEE A2K05

I. NAME OF PROBLEM - FRACTURE ANALYSIS OF PAVEMENT SYSTEMS

II. THE PROBLEM - Pavement failures are related to the development of cracks and/or excessive deformations due to repetitive loads or

environmental conditions. The analysis and prediction of failure would be aided by the development of procedures for explaining the initiation, propagation and accumulation of cracks.

III. OBJECTIVES - The objective is to develop theoretical information on the development of cracking in pavements on the basis of fracture-mechanics principles. Specific objectives include the development of theoretical procedures for predicting the initiation and propagation of cracks and the influence of cracks on stresses and displacements throughout the layered system.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progess areas 25, 26, 62 and 63 have been scanned in preparing this statement.

B. Suggested key words: fracture mechanics, pavements, cracking

C. Many projects are monitoring the development of cracking patterns in the field, and laboratory studies of fatigue cracking are being conducted, but little study is being made of theoretical failure analysis.

V. URGENCY - The study of fracture mechanics is considered highly important to the development of methods for predicting pavement performance and thus to the design of pavement systems. It was one of ten research needs identified at the Workshop on Structural Design of Asphalt Concrete Pavement System at Austin, Texas, December 1970.

PROBLEM NO. 64 - COMMITTEE A2K05

I. NAME OF PROBLEM - STOCHASTIC ANALYSES OF PAVEMENT SYSTEMS

II. THE PROBLEM - The reliability of a pavement system may be evaluated better by procedures that take into account the statistical variations of load, environment, pavement geometry and material properties. Information is required on the statistical variation of the preceding parameters so that stochastic techniques can be used for the solution of appropriate boundary value problems. Also, information is required on relevant construction, maintenance, and failure costs so that probabilistic approaches can be used to obtain optimum economic designs.

III. OBJECTIVES - The primary objective is to obtain solutions for the probability of occurrence of various stress strain-displacement responses of pavement systems. Secondary objectives are to assemble statistical data on loads, geometry, environment, material properties and costs.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 25, 26 and 63 were scanned in preparing this statement.

B. Suggested key words: pavement systems, stochastic processes, construction maintenance

C. Limited work at Illinois, Ohio State, Purdue, Texas and MIT has begun to apply stochastic concepts to the analysis of pavement systems. This work was discussed in a symposium at the 1975 TRB Annual Meeting.

V. URGENCY - Because of the natural variability of the various factors influencing pavement design and performance, it is considered very important that statistical data on variability be gathered and stochastic methodology be applied to the analysis of pavement design.

PROBLEM NO. 65 - COMMITTEE A2K06

I. NAME OF PROBLEM - EFFECTIVENESS OF DAYLIGHTED SUBBASES

II. THE PROBLEM - Wide shoulders and low back slope gradients on high type roadways have greatly increased (a) the length of drainage path, (b) the quantities of drainage layer aggregates required and (c) the size of the exposed face of the daylighted layers over those of most pavements built 15 or more years ago. Also, current specifications for drainable aggregates often permit very slow draining materials (1 ft/day or less) to be used in daylighted layers. As a result, the new geometrics and low permeability materials are causing water to be retained in pavement structural sections for times long enough to cause premature deterioration under traffic loads. In addition to the use of slow draining materials, there have been frequent reports of blockage of the outlet faces of daylighted subbases by landscaping topsoil. There is a need to determine ways to increase the effectiveness of daylighted subbases.

III. OBJECTIVES - To develop improved criteria for the use of daylighted subbases, with special attention to geometrics, the hydraulics of drainage layers, and relative construction and maintenance practices that can affect their performance.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas on drainage of pavements have been reviewed in preparing this statement.

B. Suggested key words: drainage blankets, drainage systems, drainage practices, daylighting, subdrains, subsurface drains, subbase materials, permeability, landscaping

C. Related research activities are concerned with open-graded drainage blankets, permeability of base course materials, relative permeability of adjacent pavement layers, shoulder drainage, and the opening and closing of longitudinal cracks between concrete pavement slabs and the shoulder.

V. URGENCY - Research studies to date indicate that, probably, millions of dollars are being ineffectively expended annually on daylighted pavement sections. Improved design criteria and construction practices are urgently needed to use these expenditures more wisely and

prolong the life of highway pavements.

Estimated cost - $150,000

PROBLEM NO. 66 - COMMITTEE A2K06

I. NAME OF PROBLEM - PERFORMANCE OF PAVEMENT SUBDRAINS IN A FREEZE-THAW ENVIRONMENT

II. THE PROBLEM - An important factor affecting pavement performance and life is the presence of water in the pavement system. In the northern United States deterioration of asphalt-concrete pavements is the greatest in the late winter and spring when repeated freeze-thaw cycles occur. The excess water in the pavement materials, subbase and subgrade contributes to rapid structural damage to the pavement under traffic loads. Subdrains and/or drainage layers in the pavement are the only available methods for removing this water in a timely and efficient manner. However often the subdrain system is frozen and may be inoperative. The operating effectiveness of subdrain systems under freeze-thaw conditions has never been thoroughly investigated.

III. OBJECTIVES - The over-all objective of this research is to determine the performance of pavement subdrain systems constructed under current practice in a freezing environment. This will involve field instrumentation and monitoring of the freeze-thaw behavior of the pavement, subdrains, and the conduit system to the outlet.

If deficiencies are determined in present installations a research plan should be developed for improved designs.

IV. CURRENT ACTIVITIES - Highway Research in Progress areas have been scanned and no known studies are currently under way.

V. URGENCY - The Federal Highway Administration's "Guidelines for the Design of Subsurface Drainage Systems for Highway Structural Sections" and the Federal Highway Administration's "Water in Pavement" Workshops presented throughout the United States demonstrated the need for drainage in pavements. In northern states the efficiency of pavement underdrain systems may be seriously impaired in the pavement section and at the outlet during the critical freeze-thaw period when a significant amount of pavement distress occurs.

PROBLEM NO. 67 - COMMITTEE A2K06

I. NAME OF PROBLEM - PREDICTING PERMEABILITY OF HIGHWAY MATERIALS FROM PHYSICAL AND CHEMICAL CHARACTERISTICS

II. THE PROBLEM - A major factor contributing to the rapid development of pavement distress is excessive moisture in the pavement structural section. Water is the principal factor causing loss of strength and resiliency in the subgrade and structural section of pavement systems.

In order to decrease the effects of water on pavement systems considerable effort is now being directed toward the design and construction of subsurface drainage systems. However, in the design of these drainage systems, satisfactory effort has not been made to define the permeability characteristics of the existing pavement materials or the drainage materials themselves. Because of the importance of the permeability or hydraulic conductivity properties in effective subdrainage design, it is necessary to develop a quick, efficient, and economical procedure for measuring this property both in the field and in the laboratory.

III. OBJECTIVES - The general objective of this project is to develop a procedure for determining the hydraulic conductivity (permeability) of highway materials from physical and chemical characteristics. The specific objectives are:

1. Determine the physical and chemical properties which directly affect material permeability

2. Establish a predictive permeability model based on physical and chemical parameters

3. Validate the permeability model by use of controlled laboratory or field tests.

IV. CURRENT ACTIVITIES -

A. HPR studies in Illinois, New Jersey and Ohio

B. FHWA RFP for in-situ field permeability test method

C. FHWA Workshop - Water in Pavements

D. Organization for Economic Cooperation and Development - Water in Roads

V. URGENCY - The effects of moisture on pavement systems have been widely documented. In order to design effective pavement subdrainage systems the material hydraulic conductivity properties must be known. Because of the broad range of structural materials and drainage materials used in pavements, a quick and accurate procedure which can be used to predict material hydraulic conductivity based on physical and chemical properties is needed. This need is especially evident where the hydraulic conductivity must be determined on in-situ materials in the field. The benefits that may be derived from the proposed research are primarily economical. The study is foreseen as an important step leading to the goal of designing subsurface drainage systems based on well defined hydraulic parameters.

PROBLEM NO. 68 - COMMITTEE A2K06

I. NAME OF PROBLEM - FILTER CLOTHS AND FABRICS

II. THE PROBLEM - Filter cloths and fabrics made of artificial fibers are being used extensively in Europe and to a lesser extent, in the United States, for earth reinforcement is chiefly to provide support over local soft, wet deposits of soil and humus. In drainage systems, they are being used instead of some of the aggregate in graded filters. However, there are as yet, no established criteria for the use of filter cloths and fabrics and no standard tests for evaluation of their engineering properties. Some qualities which probably affect their suitability for specific applications but for

which there are no standard tests include: tensile strength, resistance to chemical and physical deterioration, equivalent opening size, permeability or percent open area, burst strength, long term response to repeated loads, and absorption.

III. OBJECTIVES - The objectives of this study are to establish engineering criteria for the use of filter cloths and fabrics and to develop laboratory test methods for the evaluation of their engineering properties. The use criteria should be in a handbook form suitable for the designer.

IV. CURRENT ACTIVITIES -

A. There are no current research projects in this area.

B. Suggested key words: filter cloths, subsurface drainage, earth reinforcement

C. Current related research activities include a FHWA contract effort on "Improved Subsurface Drainage and Shoulders," NCHRP Study 4-11, "Buried Plastics Pipe," and "Development of a Subsurface Drainage Manual for FHWA."

V. URGENCY - Silting and clogging requires replacement of millions of dollars worth of subsurface drainage systems each year. There is an immediate need to improve graded filter systems to reduce current and future maintenance costs of both subsurface drainage systems and of pavements, slopes and other highway structures they are designed to protect.

Estimated Cost to Accomplish - $150,000

PROBLEM NO. 69 - COMMITTEE A2L01

I. NAME OF PROBLEM - EVALUATION OF EQUIPMENT AND PROCEDURES FOR SAMPLING SAND AND GRAVEL DEPOSITS

II. THE PROBLEM - The difficulties encountered in attempting to obtain representative samples of cohesionless or nearly cohesionless sands and gravels have been recognized for many years by those responsible for locating natural sources of these materials. These difficulties may be subdivided as follows:

A. Gradation changes caused by faulty sampling equipment and techniques

B. Contamination of overburden materials as sample is brought to the surface

C. Mixing and loss of identity of materials from different subsurface units

D. Inability of equipment to bring samples to the surface. This occurs most frequently when the bed lies below the water table.

III. OBJECTIVES -

A. Determine the ability of presently available equipment to obtain representative samples of sands and gravels above and below the water table

B. Develop, if possible, new equipment and techniques capable of obtaining representative samples of sand and gravel under all conditions.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 31, 32, 33, 34, 35, 61, 62 and 64 have been scanned in preparing this statement.

B. Suggested key words: subsurface exploration, borings, sampling, soils, soil gradation, sand, gravel, aggregates

C. No studies meeting the overall objectives of the proposed problem statement were discovered. However, related research titled "Evaluation of International Literature on the Sampling of Aggregates" is currently being conducted at Darmstadt Technical University, Germany. At present the Darmstadt study is confined to review of literature, but studies of actual technical and statistical problems encountered in sampling natural aggregates are contemplated.

V. URGENCY - This problem is considered to be of continuing urgency in the area of soil and aggregate exploration.

PROBLEM NO. 70 - COMMITTEE A2L01

I. NAME OF PROBLEM - EVALUATION OF GEOPHYSICAL METHODS AND INSTRUMENTS AS APPLIED TO SUBSURFACE EXPLORATION FOR TRANSPORTATION CORRIDORS

II. THE PROBLEM - There have been numerous developments in geophysical instrumentation and interpretation techniques in recent years. Some techniques and instruments have been tested in detail over a variety of geologic conditions. Others have had a minimum of field testing to establish their potential usefulness and/or limitations in subsurface exploration.

The problem may be subdivided as follows:

A. Analysis and comparison of geophysical methods and instrumentation as applicable to subsurface exploration

B. Analysis and comparison of interpretive techniques with special emphasis on transportation applications

III. OBJECTIVES - Specific objectives are:

A. Determination of those geophysical methods most appropriate for transportation applications

B. Evaluation of modern geophysical instruments in regard to their applications and limitations

C. Examination of new interpretive techniques and comparison with established procedures.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 21, 35, 61, 62 and 63 have been scanned in preparing this statement.

B. Suggested key words: geophysics, subsurface exploration, depth to bedrock, physical properties

C. Although some research is presently being undertaken on minor aspects of this proposed problem statement, no studies meeting its overall objectives were discovered.

V. URGENCY - The use of geophysics for subsurface exploration is increasing. Knowledge of appropriate methods, equipment, applications, and interpretation will help the practicing engineer select the appropriate geophysical technique for the problem at hand. The problem is considered to be of continuing interest in transportation engineering.

PROBLEM NO. 71 - COMMITTEE A2L04

I. NAME OF PROBLEM - FROST RELATED PAVEMENT DISTRESS MANIFESTATIONS

II. THE PROBLEM - Frost action affects the performance of rigid and flexible pavements in many different ways. The service life of pavement surfaces can be significantly shortened by distresses such as cracks, heaves, boils, bump, and other manifestations resulting from frost action. With the mechanisms of frost action now becoming fairly well known, it is believed that certain pavement distress manifestations can be logically related to frost action effects. For example, pavement edge cracking especially develops because of excessive softening which occurs on thawing of very wet granular bases near pavement edges. The performance of rigid pavements are greatly affected by differential frost heave and "frost tenting" at the joints.

III. OBJECTIVES - An objective examination of distress manifestations together with accompanying data on materials, moisture, temperature, pavement movement, and traffic, may reveal the links between frost action and distress in rigid and flexible pavement systems. Knowledge of these links may eventually lead to solutions which will inhibit or decrease incidence of specific forms of pavement distress.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress, area 64 Soil Science

B. Suggested key words: distress manifestations, frost action

C. Frost action research is in progress with respect to frost penetration, frost susceptibility of different materials, frost heave, loss of stability on thawing, and insulation of subgrades.

V. URGENCY - Lives of pavement structures in seasonal frost areas are relatively short, even though structures are normally built much stiffer than those in non-frost areas. If lives can be extended by even one year by elimination or decrease in certain frost related distress manifestations, and the sooner remedial action on the basis of research findings is implemented, the greater are the economic advantages.

PROBLEM NO. 72 - COMMITTEE A2L04

I. NAME OF PROBLEM - SURFACE AND PAVEMENT DRAINAGE IN FROST AREAS

II. THE PROBLEM - During the winter months in frost areas, excessive amounts of surface moisture become available in the form of snow, sleet, ice, and saline solutions, which often cannot be drained away from the pavement structure by conventional drainage systems such as ditches and subdrains. As the ditches and subdrains become blocked with snow and ice large amounts of surface water infiltrate into the pavement structure. The freezing of this free moisture results in serious differential heaving both transversely and longitudinally within the pavement and shoulders, as well as softening of the bases and subbases.

III. OBJECTIVES -

A. To examine the present drainage systems and assess their suitability as a means of quickly directing surface moisture away from pavements, shoulders, and structures during the critical winter months when snow builds up and freezing temperatures make the conventional drainage systems inoperable

B. To develop a roadway surface that is impermeable to surface moisture and which, at the same time, directs this moisture away from the driving surfaces

IV. CURRENT ACTIVITIES -

A. "Roadway Design in Seasonal Frost Areas." This report was prepared under NCHRP Project 20-5 "Synthesis of Information Related to Highway Problems."

B. "Water: Key Cause of Pavement Failure" - H. R. Cedergren and K. A. Godfrey, Jr.

C. "Seasonal Strength of Pavements" - George W. Ring

V. URGENCY - This excessive surface moisture results in deterioration of pavements and softening of bases and subbases under pavements and shoulders. A reduction of this excessive moisture or waterproofing of the roadway surfaces during the winter months could result in longer pavement lives and possibly a reduction in pavement structural thicknesses in seasonal frost areas. Both of these potential benefits would result in tremendous economic savings to road building agencies in the northern states and provinces.

PROBLEM NO. 73 - COMMITTEE A2L06

I. NAME OF PROBLEM - MOISTURE INDUCED STRENGTH VARIATIONS IN PAVEMENT SYSTEMS AFTER CONSTRUCTION

II. THE PROBLEM - Moisture is a fundamental variable in all problems of soil stability. It has special significance in pavement systems since subgrades are generally constructed in the surface soil which is usually subjected to large moisture content variations and strongly influenced by surrounding climatic

conditions. It is for this reason that the problems of moisture movement in soils, moisture accumulations under pavement surfaces, and subgrade-moisture control are of prime importance relative to pavement construction, design, behavior, and performance.

The importance of including moisture effects in pavement design is indicated by the fact that more than 50 per cent of the flexible pavement failures at the AASHO Road Test occurred during the spring when moisture accumulations in the pavement system were the greatest. Numerous research studies in the field and laboratory have also shown that moisture content can have a pronounced effect on strength and deformation properties of pavement soils and materials.

The engineering problems associated with the behavior of pavement soils and materials responsive to moisture changes indicate that further study is required in reference to strength variations in pavement systems after construction.

III. OBJECTIVES - The general objective of this project is to develop a procedure for determining moisture induced strength variations in pavement systems after construction. Specific objectives are:

1. Determine the magnitude of moisture induced strength variations which can occur in various pavement soils and materials for a known set of conditions

2. Develop procedures for predicting the magnitude of strength variation which can be expected to occur in the field based on intrinsic pavement conditions, material properties, climatic conditions, etc.

3. Develop procedures for utilizing the study findings in pavement design

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress at the University of Illinois entitled, IHR-604 - Moisture Movement and Moisture Equilibria in Pavement Systems, and IHR-605 - Subgrade Stability

B. Transportation Research Studies conducted at Texas A&M University

C. "Seasonal Strength of Pavements," George W. Ring

D. "Water in Roads" Organization for Economic Cooperation and Development

V. URGENCY - Numerous researchers have concluded that meaningful evaluation of the engineering properties of pavement soils and materials requires that the moisture properties be specified.

The benefits that may be derived from the proposed research are primarily economical. The study is foreseen as an important step leading towards the ultimate goal of including moisture in the design of pavement systems. With improved procedures for evaluating strength variations caused by moisture, pavement design techniques can be refined and pavement performance predictions can be improved. These improvements and refinements may result in financial savings in the initial design phase as well as minimizing moisture induced failures of in-service pavement systems.

The research could lead to an optimized design of the pavement system in relationship with its moisture environment; therefore, reducing the detrimental effects of moisture.

PROBLEM NO. 74 - TASK FORCE A2T57

I. NAME OF PROBLEM - DESIGN STANDARDS FOR LOW VOLUME ROADS

II. THE PROBLEM - The design standards for low volume roads are frequently inappropriate, quite subjective, and cannot be defended scientifically. Most of these standards are extrapolated, projected and rationalized from information developed for and from higher type roads. There is an urgent need to develop standards and criteria that specifically relate to the design of low volume roads.

There are over 2 million miles of roads in the United States carrying less than 400 ADT. Each year many thousands of miles of low volume roads are added to this extensive system. There are over 30,000 agencies in the United States that are involved with low volume roads. Because of this extreme decentralization, it is difficult, if not impossible, to reliably estimate the total investment or annual expenditures for low volume roads. Nevertheless the United States already has a multibillion dollar investment in its low volume road system. Each year a significant portion of the country's gross national product is committed to the design, construction and administration of low volume roads. It is alarming to contemplate the continuing development of a low volume road transportation system in this country may be based on extrapolated and sometimes irrelevant design criteria and standards. Appropriate design standards should fully recognize the extreme cost sensitivity of low volume roads. The standards need to be not only technically sound but cost effective as well. For example, the following research needs have been identified that relate to design standards. These needs are by no means meant to be all inclusive or comprehensive. They are but the "tip of an iceberg" of research needs for appropriate, technically sound and cost effective design standards for low volume roads.

Level of Service: There is a need for a methodology that relates the selection of the level of service and design speed for a low volume road with the related costs and benefits associated with the selected design speed and service level.

Geometry: There is a need for determining an optimum turn-out spacing for single lane roads which would be consistent with safety and economy.

There is a need for identifying and quantifying the parameters, such as traffic volume and geometric which require changing from a single lane design to a double lane design.

Hydraulics: There is a need to develop a systematic approach for selecting the design flood frequency for low volume roads which would consider the interrelationship of the costs of various size drainage structures and the costs of interfering with traffic.

Materials: There is a need to evaluate existing highway material specifications to determine whether they are appropriate, relevant and economically feasible for low volume roads.

Pavement: There is a need to develop a pavement thickness design method for specifically determining the thickness of aggregate surfacing and other low type pavements for low volume roads.

There is a need for procedures to (a) evaluate the remaining structural pavement capacity in existing low volume roads and (b) design cost effective surface overlays for such roads.

III. OBJECTIVES -

A. To analyze commonly used design standards for low volume roads with respect to their applicability, technical soundness and cost effectiveness for the low volume road situation. All standards that govern or control low volume road design should be examined, including but not limited to, the standards that affect design speed, road geometry, capacity, surfacing thickness, drainage and materials.

B. To identify those standards that are inappropriate for the low volume road situation.

C. To prepare a systematic approach and methodology for accumulating the necessary information and data base from which new and revised standards can be developed for those present standards that are deemed inappropriate for the low volume road situation.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 15, 22, 23, 25 and 26 have been scanned in preparing this statement.

B. Suggested key words: low volume roads, design standards, design criteria, design speed, design capacity, traffic, road geometry, surfacing thickness, drainage design, and construction materials

C. Related research activities: No known research activity that is making a unified assessment of the applicability of commonly used standards for low volume roads

V. URGENCY - The overwhelming majority of roads in the United States are low volume roads. Every day, many more miles of low volume roads are being designed, and built and added to this system. It is urgent that the standards that control or govern the design of these roads be appropriate and cost effective. The existing standards should be analyzed to determine their appropriateness and cost effectiveness. For those standards found to be lacking, steps should be taken to develop the necessary data base and information so that more realistic standards can be developed.

PROBLEM NO. 75 - TASK FORCE A2T57

I. NAME OF PROBLEM - SAFETY CRITERIA FOR LOW VOLUME, LOW SPEED ROADS

II. THE PROBLEM - In the United States, the safety criteria for low volume, low speed roads are directly or indirectly traceable to four publications -- (1) A Policy on Geometric Design of Rural Highways, AASHTO, 1965, (2) Highway Design of Operational Practices Related to Highway Safety, AASHTO, 1974, (3) Manual of Uniform Traffic Control Devices, FHWA, 1971 and (4) Geometric Design Guide for Local Roads and Streets, AASHTO, 1971. The safety criteria contained in these publications may not be applicable or relevant because low volume, low speed roads are extremely cost sensitive. There is a need to specifically consider the safety requirements for roads carrying very low volumes of traffic at very low design speeds. For example, for a road with a design speed in the range of 10-15 mph and a projected traffic volume of around 100 ADT, a series of simple, direct questions could be asked:

1. How much, if any, clear roadside recovery area is needed?

2. Assuming the road is aggregate surfaced, what factors should be used in determining stopping distances, resistance to skidding and superelevation requirements?

3. What effect, if any, will a rough riding, aggregate surface have on vehicle control and driver safety?

4. What are the warrants and design criteria for installing guardrail, guide posts, and bridge railing? Should they be installed at all? Where?

5. What should the requirements be for installing signs containing warning and regulatory messages? How high should they be? What size? Should break-away signs be required?

Ignoring safety requirements for low volume roads has the potential of wasting the greatest resource of all -- human lives. On the other hand, to impose safety requirements on low volume roads that may be only applicable to higher type roads is wasteful of another important resource -- dollars.

III. OBJECTIVES -

A. To analyze the commonly used existing safety guidelines, standards and requirements with respect to their applicability and relevancy for roads having extremely low design speeds and traffic volumes. Existing safety guidance will be analyzed to determine whether such guidance is delivering the desired safety performance in a cost effective manner.

B. To identify those safety guidelines, standards and requirements that are deemed inappropriate for low volume, low speed roads.

C. To prepare a systematic approach for accumulating the necessary information and data base from which new or improved safety guidelines, standards and requirements can be developed.

D. To recommend interim safety guidance criteria appropriate for low volume, low speed roads. Final safety guidance criteria will be developed from the analysis of information collected over a long time basis as shown in Number 3 above.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress area 51 was scanned in preparing this statement.

B. Suggested key words: low volume roads, low speed roads, safety standards, safety criteria, design speed, stopping distance, sight distance, driver response, guardrail, guide posts, bridge railing, fixed objects, roadside recovery area.

C. Related research activities: There is no known research activity which make an overall assessment of the applicability of present-day safety guidelines, standards and requirements for low volume, low speed roads.

V. URGENCY - Imposing high type safety guidelines standards and requirements on roads carrying extremely low volumes of traffic at very low speeds results in expenditures of public funds that may not be cost effective. At the same time, the expenditures may not result in a road having any increased safety history or performance. Yet frequently legal restrictions prevent federal and state participation in low volume road construction or maintenance unless the existing safety standards and requirements are met. It is probable that many millions of taxpayer dollars have been and are continuing to be spent needlessly to achieve inappropriate safety requirements for low volume, low speed roads. It is urgent that this situation be thoroughly analyzed to prevent continued loss of these dollars and to take the necessary steps to produce cost effective safety benefits for low volume, low speed roads.