160

TRANSPORTATION RESEARCH CIRCULAR

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RESEARCH PROBLEM STATEMENTS

DESIGN AND CONSTRUCTION OF TRANSPORTATION FACILITIES GROUP

W. B. Drake, Chairman, Group 2 Council
L. F. Spaine, Secretary

STANDING COMMITTEE ON RESEARCH NEEDS

T. D. Larson, Chairman

E.F. Nordlin, R.F. Varney, R.E. Hay, D.E. Peterson, M.R. Thompson, R.C. Deen
B.F. McCullough, M. Herrin, F.M. Drake, L.D. Sandvig, D. Hampton

CONTRIBUTING COMMITTEES	CHAIRMAN
A2A02 - Geometric Design	B.H. Rottinghaus
A2A03 - Hydrology, Hydraulics and Water Quality	S.V. Fox
A2A04 - Safety Appurtenances	E.F. Nordlin
A2A07 - Shoulder Design	J.F. Nixon
A2B05 - Pavement Condition Evaluation	K.H. Dunn
A2B06 - Theory of Pavement Design	W.R. Hudson
A2C05 - Dynamics and Field Testing of Bridges	R.F. Varney
A2D02 - Characteristics of Nonbituminous Components of Bituminous Paving Mixtures	W.H. Gotolski
A2E01 - Performance of Concrete - Physical Aspects	W.P. Chamberlin
A2E02 - Performance of Concrete - Chemical Aspects	C.F. Crumpton
A2G01 - Mineral Aggregates	W.B. Ledbetter
A2G03 - Sealants and Fillers for Joints and Cracks	D.E. Peterson
A2G04 - Adhesives, Bonding Agents and Their Uses	F.S. Kinney
A2J03 - Lime and Lime-Fly Ash Stabilization	M.R. Thompson
A2K06 - Subsurface Drainage	G.W. Ring, III
A2L01 - Exploration and Classification of Earth Materials	R.L. Schuster
A2L06 - Environmental Factors Except Frost	W.G. Weber, Jr.

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL NATIONAL ACADEMY OF SCIENCES - NATIONAL ACADEMY OF ENGINEERING
2101 CONSTITUTION AVENUE, N.W. WASHINGTON, D.C. 20418

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 seventeen of the Group's committees. They should not be considered an all inclusive recognition of research needs with the scope of Group 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 three priority categories:

A. The top priority statements from each Section

B. The top priority statements from each committee excluding Category A.

C. All 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.

Introduction - Continued

The listing of a majority of the statements under Category C is not intended to downgrade the importance of finding solutions to those problems but merely to indicate the relative urgency associated therewith.

Following is a list of the results.

RESEARCH PROBLEM STATEMENTS

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A2B06	Relationship Between Pavement Distress and Pavement Performance	3
A2C05	Loading History of Transverse Members and Deck Elements on Bridges	4
A2C05	Field Testing of Modern Rapid Transit Structures Under Service Loads	5
A2D02	Reducing Dependence on Moisture Control in Hot Mix Plant Operations	6
A2E02	Chemical Reactions in Portland Cement Concrete Involving the Possible Hydration of Some Substances Forming Unstable but Deleterious Phases at Low Temperatures (near 0°C).	7
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Research Problem Statements - Continued

Research Problem Statements - Continued

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PROBLEM NO. 1 - PRIORITY CATEGORY A (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 as so 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 preparation 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 - PRIORITY CATEGORY A (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. 3 - PRIORITY CATEGORY A (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 non-serviceability and failure, (b) establish suitable weighting functions to judge the relative importance of 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; and

(3) 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. 4 - PRIORITY CATEGORY A (A2C05)

I. NAME OF PROBLEM - LOADING HISTORY OF TRANSVERSE MEMBERS AND DECK ELEMENTS ON BRIDGES

II. THE PROBLEM - During the past ten years extensive studies have been undertaken to determine the stress cycles for various types of longitudinal bridge members. Much of this work has concentrated on simple and continuous spans of moderate length. The vast majority of these studies have indicated that actual truck traffic induces stresses into the structure that are substantially less than the assumed design stresses.

Only a few studies have been undertaken on transverse members and details that are primarily subjected to wheel and axle loadings. Since these members are subjected to substantially higher numbers of stress ranges, there is greater probability of fatigue crack growth. Only a few studies have been made to define the stress history of transverse members. The 1974 interim AASHTO specification provides for different design provisions for members that are wheel load dependent. Additional field studies are desirable to better evaluate and assess the response of transverse members and details that are susceptible to wheel loads.

Additional studies are needed to determine whether or not the ratios of actual stress ranges in a structure to the design stress ranges are comparable in longitudinal and transverse members.

III. OBJECTIVES - To determine the loadings and resulting stress in transverse members and other deck elements of bridges subjected primarily to wheel loads from truck traffic.

IV. CURRENT ACTIVITIES -

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

B. Suggested key words for this problem are: loading history, fatigue, field testing, wheel loads, bridges.

C. Related research to this problem are all bridge loading history studies, as well as the laboratory fatigue tests on structural bridge members.

V. URGENCY - It is urgent to pursue this research, since recently there have been a number of discoveries of fatigue cracks in transverse bridge members.

A. The total cost of this research could be between $200,000 to $300,000, since several field tests must be made under varying traffic and design conditions.

PROBLEM NO. 5 - PRIORITY CATEGORY A (A2C05)

I. NAME OF PROBLEM - FIELD TESTING OF MODERN RAPID TRANSIT STRUCTURES UNDER SERVICE LOADS

II. THE PROBLEM - There is an urgent need for more information on, and understanding of, the effect of live loads on modern rapid transit structures. The emerging technology of rapid transit in both steel and rubber wheeled vehicles has created unique loading conditions. The frequency of application of the design load has increased beyond that of other modes of transportation, and the ratio of applied live load to structure dead load is much higher. The suspension and guidance systems of the modern rapid transit vehicles are more sensitive to the interaction between vehicle and structure.

III. OBJECTIVES - To make field measurements on modern rapid transit structures under service loads to determine the following:

Maximum stress level at critical locations in the spans and the frequency of occurrence of the stress.

The amount and shape of vertical and horizontal deflection in several adjacent spans.

The amount of live load impact experienced on a span or on an individual member in a span.

After analyzing information gathered, make recommendations for design criteria in the following areas:

fatigue conditions

maximum deflection

allowance for impact

IV. CURRENT ACTIVITIES -

A. No HRIP scans made

B. Key words: transit, damage, fatigue, service behavior.

C. There is generally little if any research underway on the dynamic loading of transit structures.

V. URGENCY - There is a growing need in our urban areas for more modern rapid transit systems to relieve traffic congestion and to provide mobility to all people. Modern technology dictates that much of the transit system will be on elevated structures. To date, there is no structural design criteria established specifically for these systems. More information concerning fatigue, deflection, and impact are needed so that a design criteria can be established.

PROBLEM NO. 6 - PRIORITY CATEGORY A (A2D02)

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

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 % moisture (operations, aggregate properties, aggregate gradations, % asphalt, etc.). While this has served our overall interests to date it threatens to slow the proper consideration of needed developments in hot mix equipment, operations, construction and materials. It could be said the problem is that the % 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 the drum mixer tend to run higher by 1/2 to 3/4 %. The question is whether this 1/2 to 3/4 % 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% level where many state and engineering organizations specify maximums in the 3/4 or 1% range.

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 moisture effects. Part of the problem could be that control of foaming, segregation, tearing, tenderness, stripping, etc. has centered on % moisture when it might advantageously also systematically include other factors. Among these could be aggregate properties, gradations, % 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 due to sampling and testing operations. Then, too, dryness may have been stressed when emissions due to over-drying were less of a concern.

It has been noted 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, % asphalt, mix characteristics, lay down and rolling and method of sampling and testing for moisture.

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.

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 lay down, 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.

IV. CURRENT ACTIVITIES -

Lottman; Schmidt; Immersion-Compression

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

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 where 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 the moisture control information being sought.

VI. ESTIMATED COST

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

(A) Construction.

(B) Properties of bituminous-aggregate systems.

(C) Pavement performance.

PROBLEM NO. 7 - PRIORITY CATEGORY A (A2E02)

I. NAME OF PROBLEM - CHEMICAL REACTIONS IN PORTLAND CEMENT CONCRETE INVOLVING THE POSSIBLE HYDRATION OF SOME SUBSTANCES FORMING UNSTABLE BUT DELETERIOUS PHASES AT LOW TEMPERATURES (near 0°C).

II. THE PROBLEM - In any salt which forms more than one state of hydration the higher hydrate occurs at lower temperatures (Holden & Singer, 1960). There is published literature concerning the formation of a high hydrate phase of calcium chloroaluminate $3CaO \cdot Al_2O_3 \cdot CaCl_2 + 30H_2O$ (Sàvvina & Serb-Serbina 1958, Serb-Serbina, Savvina and Zhurina 1956) in hardened Portland Cement Concrete at temperatures below 0°C. The formation of the chloroaluminate is said by the authors to be detrimental to hardened concrete. Calcium carbonate is known to form a hexahydrate at or near 0°C (Johnson, Merwin and Williamson, 1916). Unpublished research conducted in the Kansas Highway Geology Research Laboratory has isolated relict crystals of the hexahydrate of calcium carbonate from concrete which has been subject to a freezing and thawing environment in the presence of deicing salts. It appears from limited work that this could be a concrete deteriorating reaction if the pressures involved are greater than the tensile strength of the concrete. The reaction is not easily verified in old concrete because the hexahydrate is unstable at temperatures above 0°C and inverts to calcite. A microscopic or X-ray study of concrete samples at room temperature would show no hexahydrate -- only calcite which is found in most concrete -- especially that which has been subject to freeze-thaw processes. The Kansas Studies have identified many different crystal forms of calcite in deteriorated

concrete samples. The questions that naturally arise from this observation are: Why did the calcite form different types of crystals? What conditions were present in the concrete that caused one type of calcite crystal to form in one spot but different types of calcite crystals to form in spots nearby?

It is possible that there are many unknown physico-chemical reactions that occur in concrete at or below 0°C that may be detrimental to the life of the concrete. Many studies have shown the detrimental effect of the freeze-thaw process on concrete. It has been assumed that the repeated freezing of water in the concrete is the mechanism by which this deterioration comes about and this may be true. Recently Dunn and Hudec (1965 Part 1 and 2) have suggested that ordered water in conjunction with clay in rock pores creates pressures on warming and cooling or wetting and drying that may be disruptive to the rock. It is also possible, however, that higher hydrate stages of several substances found in concrete may form at or near the freezing point of water. Library research should be directed to determining what reactions are possible at low temperatures although the published literature on the subject may be scarce and vague.

Related studies conducted by Blaser and Scherer (1969) have shown that salt heave in certain western soils is due to the crystallization of hydrous sodium sulfate where it is present in quantities amounting to only about 0.5%. The heave occurs during a drop in temperature and the hydrous sulfate begins to form. The resultant crystal growth exerts pressure on the soils causing uplift damage to floor slabs, walks and driveways of some building structures (Sodium sulfate is often found as a powdery efflorescence on the bottom surfaces of concrete bridge decks near cracks and pores). Blaser and Scherer point out that the soil expansion is sometimes incorrectly identified as expanding clay rather than salt heave. It is processes similar in nature to salt heave in soils but perhaps involving different substances and different temperatures that is suggested in the research being recommended here.

III. OBJECTIVES - Detailed and fundamental studies of low temperature (near 0°C) chemical reactions between the various constituents of hardened concrete, water, and/or deicing chemicals should be investigated. Such research would involve maintaining the desired low temperature of the specimens while the studies are being conducted. Study of the concrete after it warms up would not detect the substances and reactions which may occur. Cycling of the temperature up and down several degrees either side of 0°C may be desirable, therefore, any study techniques would require low temperature attachments. Some possibilities are low temperature differential thermal analysis, such as used by Dunn and Hudec (1965, Part 1 and 2), low temperature X-ray analysis, low temperature petrographic analysis, low temperature infrared spectroscopy, and any other means suitable to conducting such studies.

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Serb-Serbina, H. H., Savvina, Yu. A., and Zhurina, V. S. The Formation of Hydrated Calcium Chloro-Aluminates and Their Effect on the Structure of Hardened Cement: (In Russian) Doklady Akademic Nauk USSR, 3 (3), pp. 659-662, 1956.

IV. URGENCY - Inasmuch as there has been so little work done in this field of concrete chemical research and the possible reactions are yet unknown, there is no specific urgency. If detrimental reactions are established then the urgency would become more immediate.

PROBLEM NO. 8 - PRIORITY CATEGORY A (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 -

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

2. 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.

3. 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.

4. Develop and experimentally evaluate improved materials and methods for the area of the expansion joint system-overlay interface.

5. Prepare guide specifications that could be used by a highway agency in specifying 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 for this problem are bridges, asphaltic concrete, flexible pavements, bituminous materials, expansion joints, joint sealers, and membranes.

C. Costly attempts have been made by German and Dutch engineers to find a solution to this problem by means of either epoxy or steel bulkheading techniques.

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.

PROBLEM NO. 9 - PRIORITY CATEGORY A (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 - The objectives of this problem are:

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 the 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 for this problem are 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 any agency.

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

PROBLEM NO. 10 - PRIORITY CATEGORY A (A2J03)

I. NAME OF PROBLEM - SOIL-LIME TREATMENT: MIXTURE DESIGN PROCEDURES AND QUALITY CRITERIA

II. THE PROBLEM - Although there are several procedures that are currently being utilized to establish the required lime content for soil-lime mixtures, there is no procedure that has gained widescale acceptance. In most instances, the mixture design procedures are not sufficiently flexible for broad scale application to achieve various objectives (modification, swell control, strengthening).

Quality criteria for soil-lime mixtures have not been well defined. The criteria generally do not account for the wide diversity of applications of lime stabilization in pavement construction.

III. OBJECTIVES - The general objectives are to develop comprehensive mixture design procedures and accompanying quality criteria for the efficient and economical use of lime as a soil stabilizing agent. The procedure and criteria should be capable of considering lime modified soils or lime stabilized soils.

IV. CURRENT ACTIVITIES

A. Highway Research in Progress areas 22, 25, 32, 34, 35, 40, 41, 62, and 90 have been scanned in preparing this statement.

B. Suggested key words for this problem: mixture design, lime stabilization, soil-lime, test procedures.

C. No HRIP entries directly considered the topics of mixture design and quality criteria although several studies would perhaps indirectly contribute to the development of quality criteria. Current soil-lime studies at the California DOT and a Texas Highway Department sponsored study at the University of Texas at Austin on tensile properties of subbases are related activities.

Current mixture design procedures and quality criteria have been summarized in the A2J03 "State of the Art" summary on Soil-Lime Stabilization Construction.

V. URGENCY - There is an increased utilization of lime in pavement construction activities. Based upon the current state of the art relating to mixture design and quality criteria and the judgment of currently active soil-lime researchers, this project area is classified as "urgently needed" and was ranked as the number 1 priority by Committee A2J03.

PROBLEM NO. 11 - PRIORITY CATEGORY A (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, 32, 34, 35, 40, 41, 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), U. S. Army Construction Engineering Research Laboratory (HRIP 62-213510), and the U. S. Army Waterways Experiment Station in cooperation with the U. S. Air Force (Air Force Weapons Laboratory). 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 pavement systems. 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. Two current University of Texas Studies (tensile properties of subbase materials sponsored by the Texas Highway Department and a pavement system analysis effort sponsored by the U. S. Forest Service) also relate to the problem area.

V. URGENCY - Soil-lime mixtures are being used to a greater extent than ever in pavement construction. Considering the current problems 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. 12 - PRIORITY CATEGORY A (A2K06)

I. NAME OF PROBLEM - EFFECTIVENESS OF EDGE DRAIN INSTALLATIONS ON PAVEMENT REHABILITATION

II. THE PROBLEM - Literally thousands of miles of existing pavement structures suffer distress from traffic loadings due to trapped water beneath the roadway. Various methods are available for attacking this problem, all of which involve tremendous manpower and financial investments. One such commonly considered technique is the installation of edge drains at the outside edge of the roadway pavement. The time effectiveness of such a system is not fully understood. Thus, the economy of such treatments versus improved service life of the pavement structure is in need of careful study.

III. OBJECTIVES - The objective of this study is to evaluate, with time, the effectiveness of edge drain installations in relieving infiltrating water from ponding beneath roadway pavements. Such water dissipation would minimize the effects of decreased bearing capacity and thus the reduced life of a designed pavement structure. The study should include evaluation of several installations in various geographical areas. The project is estimated to require a minimum of 2 years study. Develop a manual of suggested optimum economical design and construction practices if it is shown that edge drains can be effective.

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

V. URGENCY - Millions of dollars are invested each year in the rehabilitation of existing pavement structures where trapped water is known to create weakened subgrade support systems. If this money is being spent unwisely, the States and the taxpayer need to know. This is a very practical problem with extremely high payoff to the public.

PROBLEM NO. 13 - PRIORITY CATEGORY A (A2K06)

I. NAME OF PROBLEM - FIELD TEST FOR DETERMINING IN SITU PERMEABILITIES OF BASE COURSES

II. THE PROBLEM - It is now generally recognized that the life of a pavement structure will be greatly extended if water entering the base and subbase is effectively removed in a relatively short time. In order to properly design an economical subsurface drainage system an accurate estimate of the coefficients of permeability of the materials being drained is needed. Presently, coefficients of permeability of granular materials are determined primarily from laboratory tests. It is known that due to the compaction process and the construction of base and subbase courses in horizontal lifts, the horizontal permeability of the system can be (and usually is) much greater than the vertical permeability. Although techniques are presently available for obtaining reproducible results from laboratory permeability tests on highly compacted granular materials, no field data are available for correlation with the laboratory data. The

correlation between the laboratory and field data is needed in order that a subsurface drainage system can be confidently designed on the basis of laboratory data. Therefore, there is a need to develop a reliable field permeability test method in order to provide the required field data. In addition, a field test will provide a basis for determining the requirements for subsurface drainage systems for existing structures.

III. OBJECTIVE - The objective of this study is to develop a reliable field test for determining the in situ permeabilities of compacted base and subbase courses in the horizontal and vertical directions. The test apparatus should be portable and the method require little or no destruction of the existing pavement structure.

IV. CURRENT ACTIVITIES -

A. Suggested key words: permeability, subsurface drainage, field permeability test, subdrains.

B. Research has been conducted and methods are available for estimating the in situ permeability of base course materials where a hole of known dimensions is dug into the materials and a falling or constant head test is performed. There are many uncertainties in such a test and consequently there is little confidence in the results. A test procedure with potential was developed by Washington State University, (Highway Shoulder Permeability: A New Test, Washington State Institute of Technology Bulletin 258, 1961).

V. URGENCY - Results of recent work sponsored by the Federal Highway Administration contain the recommendation that highly permeable materials be used in pavement structures to alleviate problems associated with water in pavements. In order to implement or further evaluate this recommendation good estimate of the permeabilities of the materials is essential. Regardless of the design procedure used the permeability of the materials must be known. Therefore, a method of accurately estimating the permeabilities of base and subbase materials is a high priority research need.

PROBLEM NO. 14 - PRIORITY CATEGORY A (A2L01)

I. NAME OF PROBLEM - USE OF SOIL SURVEYS FOR SECONDARY ROADS AND STREETS

II. THE PROBLEM - How to bring about optimum use of pedological soil surveys in the planning, design, construction, and maintenance of secondary roads and streets, and parking lots, for which engineering soil investigations are not usually made.

III. OBJECTIVES - To develop a method, or methods, for optimum use of pedological soil surveys in the planning, design, construction and maintenance of secondary roads and streets, and of parking lots. The method, or methods should be amenable to standardization and widespread use with clear safeguards against improper use of such surveys.

IV. CURRENT ACTIVITIES

A. Highway Research in Progress areas (10) Specifications, Procedures, and Practices, (14) Maintenance of Way and Structures, (15) General Design, and (20) Special Projects have been scanned in preparing this statement.

B. Suggested key words: pedological, soils, soil surveys, soil data, design procedures, secondary roads, streets, parking lots.

C. Many states are making excellent use of pedological surveys but most such use is in connection with exploration and planning of big highways. Recently the South Dakota Highway Department made a statistical analysis -- range, mean, and standard deviation -- of engineering test data for specific horizons of soil series and has been testing the use of such data, along with soil maps, for highway design purposes. Highway Research Board literature contains many examples of how engineers have made use of pedological surveys; but most of these examples predate the last 20 years of excellent cooperation between engineers and soil scientists. This cooperation has resulted in a vast quantity of engineering data about soil series. These new data, today only partly used, substantially enhance the potential use of pedological surveys.

V. URGENCY - Thousands, perhaps millions, of dollars are wasted each year where secondary roads and streets, and parking lots, are built without benefit of engineering soil investigations and are also without benefit of pedological information even though available. Pedological surveys are completed for about half of the privately owned land in the country, including most of that under rapid development; and they are being completed at the rate of 40 to 50 million acres a year. Appropriate use of pedological surveys can drastically reduce this wastage.

PROBLEM NO. 15 - PRIORITY CATEGORY A (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: In preparation of this statement, a research project in progress at the University of Illinois entitled "IHR-603, Resilient Modulus of Subgrade Soils" was reviewed.

B. Suggested key words: strength, deformation, resilient modulus moisture movement, compaction, performance.

C. Studies concerning the strength of pavement materials and soils have been conducted at several research facilities. The Road Research Laboratory in England has conducted studies concerning moisture and strength for many years. An international road research group of the Organization for Economic Cooperation and Development has just completed a report entitled "Water in Roads" which discussed strength variations in pavement systems caused by moisture.

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. 16 - PRIORITY CATEGORY B (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. 17 - PRIORITY CATEGORY B (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 is expended annually by the Office of Emergency Preparedness for repair and reconstruction of off-system (non-Federal-Aid) roads and streets. Much of the costs incurred by local governments for emergency repairs are disallowed by OEP, so the actual costs are much higher than $40 million annually. In addition to these costs, courts have held highway agencies liable for flood damages and these costs are not accounted for in the above recital. The bulk of the FHWA $100 million ER funds are expended for flood damage repairs. The $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. 18 - PRIORITY CATEGORY B (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. 19 - PRIORITY CATEGORY B (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. 20 - PRIORITY CATEGORY B (A2A07)

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

II. THE PROBLEM - The lack of uniformity in the way highway shoulders are used from one jurisdiction to another and under various circumstances raises a number of questions. The generally accepted definition of a shoulder implies that it would be used for emergency purposes only. Several jurisdictions, however, have found it expedient to use the shoulder in various non-emergency ways. This leads to a lack of uniformity and raises the question as to what the optimum use of the shoulder should be and what width is required to expedite that use.

III. OBJECTIVES - The objective of this study would be to investigate the various ways in which highway shoulders are now being used and to determine the good and bad features being used with a long range goal of developing a policy for shoulder use. Known non-emergency shoulder uses includes:

1. Travel by slow moving vehicles
2. Travel during peak periods
3. Travel during maintenance operations

IV. CURRENT ACTIVITIES - Some studies in this area have been made and should be reviewed as a part of this project.

A. Previous and current activity has been directed at specific shoulder uses and problems rather than determining how to best use shoulders.

B. Suggested key words: shoulder, emergency parking, emergency stopping.

C. No current research deals with this problem.

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 in the marking and delineation of shoulder areas.

PROBLEM NO. 21 - PRIORITY CATEGORY B (A2A07)

I. NAME OF PROBLEM - STRUCTURAL DESIGN OF HIGHWAY SHOULDERS

II. THE PROBLEM - A flush, stable surface right shoulder is considered to be an essential element of a freeway or a high speed highway. Current shoulder design is neither uniform nor rational. Elements which should be considered to achieve optimum structural design of the shoulder would be:

1. Traffic volume and weight considerations probably based on a percentage of the main lane traffic.

2. Soil conditions.

3. Drainage requirements.

4. Type of surface to be provided.

It is also important to optimize the shoulder design as it relates to the traveled way pavement for reasons of economy and also to achieve a proper interaction between the pavement and the shoulder.

III. OBJECTIVES - Search should be made of the proper type highways in several States to find those sections of shoulder that have given several years of adequate service and remain in fair to good condition. For those sections so identified, detailed data then will be assembled on all major factors (identified above) that relate to shoulder design and performance. With similar data for a sizeable number of shoulder sections, analysis then would be made of all pavements to find those correlations that contribute to the successful designs. These conclusions will form positive guides for future designs.

IV. CURRENT ACTIVITIES -

A. Project IHR - 404 - "Experimental Paved Shoulders on Frost Susceptible Soils", which was recently completed by the Illinois Department of Transportation on Interstate 80 in northern Illinois, dealt with performance of four paved shoulder types including bituminous - aggregate mixtures, cement aggregate mixtures, pozzolan aggregate mixtures and portland cement concrete. The major objective of this research was to develop definite information that would permit the selection from among alternative shoulder pavement designs and materials - those that will afford the best service and overall economy of construction and maintenance. A secondary objective was the development of additional information on the interactions of embankment soils, frost, moisture, and deicing operations with shoulder materials and shoulder designs.

NCHRP 14-3 - "Improved Pavement Shoulder Joint Design" is now in progress and deals with water getting beneath the roadway pavement and shoulder through the joint between the rigid pavement and bituminous shoulder. The objectives of this project are:

1. Determine the most suitable currently available procedures (including methods and materials for sealing the joint, subsurface drainage, and other methods for minimizing the effects of water) for alleviating the problems associated with the above mentioned joint.

2. Develop and experimentally evaluate improved systems for minimizing the passage of water through the pavement shoulder joint.

3. Prepare a plan for a field study program that would be undertaken by highway agencies to evaluate promising procedures for sealing the pavement shoulder joint.

B. Suggested key words: pavement cross-section, shoulder, joint sealing.

C. Project IHR - 404 has made available information regarding performance of materials used for shoulders. Limited information regarding shoulder cross-section and designs has also resulted from the above mentioned study.

V. URGENCY - The need for answers in this area is obvious. Results would be immediately implementable.

PROBLEM NO. 22 - PRIORITY CATEGORY B (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 (PSI), 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. 23 - PRIORITY CATEGORY B (A2E01)

I. NAME OF PROBLEM - D-CRACKING OF CONCRETE PAVEMENTS
(Concrete Durability)

II. THE PROBLEM - D-cracking refers to the closely spaced cracks that appear sometimes as early as 4 to 5 years, at the top surface of a pavement slag adjacent and parallel to transverse and longitudinal joints and cracks and at times the free edges of pavement slabs. It appears that the primary reason for the occurrence of this distress is the susceptibility of certain aggregates to damage when critically saturated and frozen. The problem is particularly serious since remedial measures after occurrence are difficult and costly.

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* Walker, R. S., and Hudson, W. R., "Method for Measuring Serviceability Index with Mays Road Meter." HRB Special Report 133 (1973) pp. 68-72.

III. OBJECTIVES - The objectives of this study would include: (1) the development of an understanding of the mechanisms involved in the development of D-cracking and to thus determine the relative importance of material properties and environmental conditions in this problem area, (2) the development of a rapid and effective test procedure to detect aggregates susceptible to such distress, (3) the development of a concrete freezing and thawing test procedure which can be useful in evaluating combinations of materials, and (4) the development of recommendations for the conditions under which susceptible aggregates can be utilized effectively.

IV. REFERENCES - NCHRP Report 12, NCHRP Report 15, HRB Special Report 80, PCA Research Department Bulletin 126, NCHRP Report 100.

V. URGENCY - A significant amount of D-cracking distress is occurring in such states as Kansas, Missouri, Iowa, and Ohio, causing concern about the life of concrete pavements in certain areas. There is a great need to devote time and effort now to the resolution of this problem.

PROBLEM NO. 24 - PRIORITY CATEGORY B (A2E01)

I. NAME OF PROBLEM - CUSTOMIZED CONCRETE DESIGN AND PROPORTIONING

II. THE PROBLEM - Concrete over-design is expensive, particularly in the face of constantly increasing construction costs. The individual ingredients of any concrete mixture exercise a profound influence over the characteristics of that concrete and its ability to perform satisfactorily in service. Yet, in practice, in the design or proportioning of concrete little note, if any, is accorded the characteristics of the ingredient materials. Strict adherence to maximum water-cement ratios and/or minimum cement contents often times result in wasteful use of cement, the single most expensive ingredient in the concrete. A new look at the water-cement ratio concept and its relationship to the physical characteristics of concrete should be encouraged with special regard to customizing of mix design to fit given materials and situations. Good engineering economics can no longer afford unnecessary and wasteful over design.

III. OBJECTIVES - The objectives of the above described study would include:

1. A reexamination of the water-cement ratio concept.

2. The development of mix design and proportioning procedure which enables the designer to take maximum advantage of the characteristics of all concrete ingredients.

3. A reappraisal of the true over-design necessary to insure maximum safety and assurance of adequate performance.

IV. URGENCY - Wastefulness costs money! Our nation's economy has been stretched almost to the breaking point, therefore, unnecessary expense can no longer be tolerated. Construction costs must be controlled and our nation's resources conserved. Customized concrete mix design can help achieve such goals. Its urgency, therefore, is as that for economy and cost control.

PROBLEM NO. 25 - PRIORITY CATEGORY B (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 -

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

2. 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.

3. 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 -

1. 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.

2. 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.

3. 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. 26 - PRIORITY CATEGORY B (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 -

1. Review of aggregate beneficiation techniques with economic considerations.

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

3. 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 -

1. Literature search and review

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

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

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

5. 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. 27 - PRIORITY CATEGORY B (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 - The objectives of this suggested research would be: (1) 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, and (2) 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.

C. 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 - The results of the suggested study would be immediately useful to practicing engineers.

A. General Estimate of cost to accomplish.

PROBLEM NO. 28 - PRIORITY CATEGORY B (A2L01)

I. NAME OF PROBLEM - CLASSIFICATION OF ORGANIC SOILS

II. THE PROBLEM - There is no quantitative basis for defining organic soils. Casagrande and others have indicated that organic soils (such as OL or OH) can be identified by first determining the liquid limit of a soil in its natural moisture conditions (without first air drying), then performing the same test on air-dried material (standard test method). A major reduction in liquid limit indicates an organic soil. This criterion is not really satisfactory since certain clay minerals and hydrous oxides also have irreversible structures. The liquid limit of such clay minerals will also decrease considerably upon over drying. The literature contains only a few publications which deal with the effect of organic material on the engineering properties of soils. Furthermore, in the present AASHTO Soil Classification System, no allowance is provided for the classification of soils containing appreciable organic matter. An investigation is needed to determine the relationship between amount and type of organic matter present in organo-mineral soils (natural or artificial Mixture) and the physical properties of the soil as measured by Atterberg limits, compressibility, moisture-density relations and some appropriate strength parameter.

III. OBJECTIVES - The objective is to develop a rational basis for identification and classification of organic and organo-mineral soils which can be related to their probable engineering performance.

IV. CURRENT ACTIVITIES:

A. References: "Engineering Classification of Organic Soils," A. Arman, Record 310, Highway Research Board, 1970.

B. Suggested key words: Soil classification, organic soils, organic material, Atterberg limits, compressibility, strength, moisture-density relationships.

V. URGENCY - The problem is considered to be very urgent in the area of classifying organic soils.

PROBLEM NO. 29 - PRIORITY CATEGORY B (A2L06)

I. NAME OF PROBLEM - WATER MOVEMENT IN UNSATURATED SUBGRADE SOILS UNDER TEMPERATURE GRADIENTS

II. THE PROBLEM - Pavement subgrade soils are generally non-saturated, and water movement in them conform to the thermodynamic principles of Darcy's Law, where the displacement velocity is a function of the total potential gradient which includes gravitational, capillary, osmotic, and other potentials. The thermodynamic approach to water movements has the advantage in that it demonstrates the importance of including hydrological and climatic conditions in pavement design.

The migration of moisture into the subgrade beneath a pavement surface in response to non-isothermal conditions can cause considerable volume change in the soil and possibly in the pavement system as a whole. Volume change in the pavements caused by frost action is a primary cause of pavement damage in cold climates. Moisture migration through the soil to a freezing zone in response to a temperature gradient causes ice lenses to form which cannot be accommodated by the pore spaces of the soil. The end results are volume increase during freezing and loss of strength and stability during periods of thawing, or a durability type failure in the pavement system. Shrinkage and swell problems in many fine-grained subgrade soils are also attributed to moisture changes. The fact that excessive moisture can accummulate beneath a pavement surface at temperatures less than freezing can oftentimes cause loss of subgrade support or stability and associated pavement failures result.

Moisture movement in response to thermal gradients has substantial influence on the performance of pavement systems. For this reason it is important that methods which can be used to quantitatively predict moisture changes in pavement systems caused by thermal gradients be analyzed and refined for incorporation into design procedures.

III. OBJECTIVES - The general objective of this research is to quantitatively determine water movement in unsaturated subgrade soils under temperature gradients. Specific objectives include:

1. Conduct a literature review to analyze the methods available for determining water movement in subgrade soils.

2. Select a procedure for obtaining quantitative values for water content and temperature distribution in subgrade soils with respect to time and space.

3. Validate the selected procedure by comparing predicted results with experimental data.

4. Predict for various water and temperature conditions how water moves in unsaturated subgrade soils.

IV. CURRENT ACTIVITIES - Moisture movement and moisture equilibria studies have been conducted in the field of soil science and agriculture for some time. In recent years a number of investigators have attempted to analyze moisture movement and moisture equilibria in pavement systems. Active work in this area is now being pursued at Texas A&M at College Station, Texas, and at the University of Illinois at Urbana, Illinois.

V. URGENCY - The numerous pavement problems related to subgrade moisture changes make this research most desirable. It is important to note that improved design and control strategies for moisture problems in subgrade soils can best be developed when the moisture movement process is understood and quantified.

PROBLEM NO. 30 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - ARTERIAL STREET WIDTHS

II. THE PROBLEM - The impact of the nationwide program of constructing freeway facilities through and adjacent to urban areas has pointed up the need to provide adequate distributor streets to feed and receive the high volume of traffic involved. Also, in the smaller communities that do not have freeways or expressways, the arterial street system is relatively even more important because they must perform the dual function of carrying the majority of the traffic and also serve in developing a desirable land-use pattern. Determination of the number of moving lanes for a particular arterial street is only the first step in establishing the proper curb-to-curb street width. Other considerations will involve lane widths, median width, and possible provision for left turn lanes and parking. These considerations are quite variable and often argumentative. There is a need for the establishment of warrants on which to base the design of these facilities.

III. OBJECTIVES - Development of a standard evaluation procedure that will permit planners and designers to determine the most satisfactory street cross section for any given set of conditions. The procedure should be an orderly, vigorously defensible, step-by-step consideration of such factors as traffic volume, turning volumes, property values, land use (present and projected) and intensity of adjacent development.

IV. CURRENT ACTIVITIES -

A. Highway research in areas 15, 22, 53, and 84 have been scanned in preparing this statement.

B. Suggested key words: arterial streets, geometric design, land use, traffic volume.

C. Some related studies have been made in accident analysis, economics, urban land use, etc., but nothing was found that answers the objective stated above.

V. URGENCY - This project is deserving of a high priority as the movement of traffic in our urban areas is a nationwide problem. An accepted evaluation procedure as called for in this objective would be of tremendous value to urban planners and design personnel.

PROBLEM NO. 31 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - HIGHWAY CURVE DESIGN STANDARDS

II. THE PROBLEM - Due to the evolution of vehicles and tire designs there may be some variations in the relationship of curves to superelevation. More particularly to the heavier and higher commercial vehicles currently using the highways. This is becoming of more interest since there is a tendency to increase design speeds on rural freeways. Also of interest is the belief that proper superelevation on descending and ascending interchange ramps may differ. There is some concern regarding the attainment of optimum design of facilities with lower design speeds and the reconstruction of existing facilities. There are varied opinions relative to the selection of spirals versus compound curves and the distribution of superelevation in both situations.

III. OBJECTIVES - Conduct operational studies on interstate highway mainline and interchange roadways to correlate operating data with variations in the design elements of circular curvature, superelevation, grade and transitional curvature and superelevation.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 25, 51, 53, and 55 have been scanned in preparing this statement.

B. Suggested key words: radius, degree of curve, superelevation, spiral transition, highway curves, and turning roadways.

C. Recent studies of vehicle maneuvers on unspiraled curves indicate that most vehicles have a path radius that exceeds the radius of the highway curve at some point on the curve. The common areas of maximum path radius are near the beginning and end of the curve, indicating that spiral transitions to the highway curve may be desirable.

V. URGENCY - This project is needed to provide a factual framework to highway curve design standards.

PROBLEM NO. 32 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - DESIGN OF NARROW MEDIANS, INCLUDING BARRIERS

II. THE PROBLEM - The geometric design elements of narrow medians vary considerably throughout the country. There are a number of types of medians with some including a physical barrier. Some of the variations are due to geographical and climatic conditions as well as traffic volumes and

operating speeds. After considering the many types and combinations of width and barriers, it seems appropriate to study the safety, economy and uniformity to arrive at a universally acceptable design criteria.

III. OBJECTIVES -

1. To assemble and correlate all data concerning traffic operation, safety, economy, etc., and to supplement this data with field testing and special operational studies to supply any missing information.

2. Develop a design criteria for various median widths for all types of multilane facilities including arterial streets.

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: geometric design, narrow medians, median barriers.

C. California is currently conducting some median investigation.

V. URGENCY - A very high priority is warranted by the increased construction of medians, particularly in urban areas where available right-of-way is limited.

PROBLEM NO. 33 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - CRITERIA FOR LONGITUDINAL CHANGES IN DESIGN SPEED

II. THE PROBLEM - The design speed is a major control in the design of highways. The aim in selecting the design speed is to have it logical from the standpoint of terrain, land use, type and volume of traffic and the driver desire. There are many studies showing average speed trends on curves, tangents and grades, however, there are no criteria available on how, where, and at what frequency the design speed may, or should be changed. The concept of keeping a constant design speed should be adhered to, but changes in design speed or compensation in design for increased or decreased operating speed on a given highway must be recognized, and allowance made for it in design.

III. OBJECTIVES -

To determine an acceptable and safe method for varying design speed, including rate and extent of change, to meet terrain conditions along a length of highway. To determine also the criteria for signing, marking or other means to convey to the driver that a change of speed is required. Studies should be made of driver behavior on existing facilities under free flow conditions and also under heavy volume conditions.

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: design speed, design elements, geometric design.

C. No activity is evident in this area.

V. URGENCY - This project warrants high priority.

PROBLEM NO. 34 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - GEOMETRIC DESIGN FOR RIGHT TURNS AT INTERSECTIONS

II. THE PROBLEM - The roadway turning radius for right-turning vehicles at intersections is an important determinant of the traffic operations at that intersection. Thousands of intersections have restrictive right-turn radii. Indications for main-line operating speeds above 30 mph are that the right-turn motorist is faced with a dilemma when trying to negotiate a restrictive right-turn radius. By going slow enough to negotiate the turn properly, he creates a critical speed differential between his vehicle and following vehicles; by negotiating the turn fast enough to minimize this speed differential, his vehicle can severely tax the lateral skid resistance of the tire-pavement interface.

Consideration of a better-than-minimum turning radius is usually required in a design of at-grade intersections where a relatively high volume of traffic turns right. As the turning radius is increased to a certain length, a channelization island becomes necessary and the right-turn movement is given a separate turning roadway. Traffic control measures are normally less restrictive for the separate right-turn lane than for the through and left-turn movements. General observations indicate that improved traffic service is provided by a right-turn lane but a method of determining acceptable warrants for the justification of the additional space and construction cost is needed. A comparison of accident rates is needed to relate the merits of a right-turn lane to those of a minimum radius turn. Study is also required to determine the geometric design features required for separate right-turn lanes considering the various degrees of traffic control.

III. OBJECTIVES -

To obtain and compare data on the traffic operations and safety for various right-turn configurations. The studies should include comparisons of: (1) Accident rates and/or traffic conflicts; (2) radius of turn; (3) pavement cross-slope; and (4) speed change lane designs.

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: righ-turn radius, curb return, right-turn lanes, intersection design, turning roadways, traffic conflicts, and lateral friction demand.

C. Very little data can be found on this subject.

V. URGENCY - Considering the thousands of intersections with restrictive right-turn radii, and the magnitude of rear-end accidents at intersections, this should be a high-priority area of study.

PROBLEM NO. 35 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - SPEED CHANGE LANES

II. THE PROBLEM - Drivers leaving or entering a high speed through highway at an intersection or interchange ramp must change their speed during the maneuver. In order to accomplish this without creating a hazard, it is desirable that the speed changing in the most part, or in its entirety, be confined to an auxiliary lane or area which is removed from the path of the through travel. Auxiliary lanes which are adequate for the necessary range of speed change and, equally important, which encourages proper usage by drivers can greatly increase the safety, efficiency and capacity of at-grade intersections, interchange ramp terminals and the through highway itself. Detailed studies of traffic operation on various existing facilities considering current vehicle capabilities are needed to assemble the facts on which to base desirable designs. Major factors include: the features requiring the need for an auxiliary lane; vehicle performance characteristics; the nature of speed change as practiced by drivers; design speed of through facility; vertical and horizontal alignment of the through facility; and median width of at-grade intersection and costs.

III. OBJECTIVES - To determine from the standpoint of safety and efficient traffic operation the optimum type or types of acceleration and deceleration lanes applicable to at-grade intersections and interchange ramp entrances and exit terminals. This should include: (1) the geometric design of the facilities; (2) the most desirable location of such facilities with regard to the vertical and horizontal alignment of the through highway; (3) the desirable spacing of such facilities in relation to adjacent intersections, interchange ramps, structures, piers or other distracting obstacles affecting the safety of traffic operations; (4) signing and delineation of the speed change lanes.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22 and 54 have been scanned in preparing this statement.

B. Suggested key words: acceleration and deceleration lanes, safety, vehicle operating characteristics, ramps and at-grade intersections.

C. A detailed search was not made but previous work in this field was apparently done over ten years ago and is not believed to be applicable to current vehicle operating characteristics.

V. URGENCY - Work in this area is considered to be a high priority as there is an urgent need to upgrade the operating efficiency of existing facilities as well as provide the most efficient design for new facilities.

PROBLEM NO. 36 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - COLLECTOR-DISTRIBUTOR ROAD

II. THE PROBLEM - Collector-distributor roads have been employed where weaving conflicts will affect the operation on the adjacent freeway lanes. They may be used where it is desired to collect and distribute traffic from several points of access, but where it is desired to limit the points of ingress and egress to and from the main freeway lanes. Collector-distributor roads will usually increase the total highway cost and there is no established warrants based upon their true cost-effectiveness to justify their use to provide the resulting higher level of service to the public. Studies are needed to determine desirable design patterns for maximum efficiency in the use of collector-distributor roads.

III. OBJECTIVES - To establish warrants for the use of collector-distributor roads based upon their true cost-effectiveness with full consideration of the resulting level of service to the traveling public.

IV. CURRENT ACTIVITIES -

A. Highway Research areas 11, 15, 51 and 53 have been scanned in preparing this statement and no relevant information was found.

B. Suggested key words: collector-distributor roads; level of service; geometric design, and freeway ingress and egress.

C. A detailed search of HRIP was not made but brief search did not reveal any related research activity.

V. URGENCY. This is considered to be a problem involving considerable urgency as a number of existing facilities are in need of upgrading as well as the new projects yet to be designed.

PROBLEM NO. 37 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - OPERATIONAL DEFINITION OF DESIGN SPEED

II. THE PROBLEM - Design speed is currently defined as "the maximum safe speed that can be maintained over a specific section of highway when conditions are so favorable that the design features of the highway govern." This definition is abstract and, therefore, does not lend itself to a scientific basis for design. What does "conditions so favorable" mean? Does it mean that the driver with no psychological and physiological problems is driving his mechanically perfect automobile on a deserted roadway under ideal weather conditions?

It is hard to imagine, for "conditions so favorable" and with modern designs of 12-ft. lanes, flat cross-slopes, and relatively flat grades, that any geometric design feature other than horizontal curvature could "govern maximum safe speed." Actually in a physical sense this is true. By eliminating the driver, vehicle, traffic, and environmental factors

from the "design equation," the only design feature that physically governs maximum safe speed is horizontal curvature. If this were true in an operational sense, then the design speed for long level tangent sections would be unrestricted and, where horizontal curvature was introduced, the concept of an overall design speed would be incongruous.

What is required is an operational definition for design speed that encompasses driver, vehicle, roadway, environmental, and traffic limitations and their relationships to the design of a safe, efficient and economical highway facility.

A more meaningful definition might be, "design speed is the maximum safe vehicle speed that can be maintained over a specific section of highway by most drivers for free-flowing traffic conditions and existing pavement surface conditions." This definition implies limitations on the driver, vehicle, roadway and their interfaces. It also implies the dichotomy of dry versus wet (or icy) pavements. Since the wet pavement condition is the single most dramatic change in the safety factor (especially at higher speed) roadways should have two design speeds; one for dry pavements and one for wet pavements. Also, highway speed control should reflect this dichotomy.

III. OBJECTIVES - To develop an operational definition for design speed that optimizes the goals of highway design.

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: design speed, speed limits, geometric design, and operating speed.

C. No activity is apparent in this area.

V. URGENCY - This operational definition is important to the effective design of high-speed highways.

PROBLEM NO. 38 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - REVERSIBLE FREEWAY ROADWAYS

II. THE PROBLEM - Freeways provide a separate roadway for each directional traffic flow. Provision of an adequate number of lanes to accommodate the peak hour traffic in large urban areas often requires an excessive number of contiguous freeway lanes or the use of two separate roadways for each of the two directional traffic flows. The high cost of freeway construction to provide for this short time peak traffic flow has resulted in consideration of the use of a reversible roadway to adequately accommodate peak hour volumes and minimize construction and right-of-way costs. Detailed studies are needed to assemble current information about the experience gained in the design and operation of the few reversible freeway roadways now in operation.

III. OBJECTIVES - Identify criteria for design and operation of reversible freeway roadways based upon studies of existing installations. This should include: (1) the most desirable location of terminals in relation to adjacent freeway terminals; (2) policy on dropping or adding lanes on the directional freeway to which the reversible roadway connects; (3) signing and lane use control in the terminal area; (4) required physical features to open and close the reversible roadway and properly control traffic flow; and (5) geometric design of the transition areas.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 53, 54 and 55 have been scanned in preparing this statement

B. Suggested key words: peak hour volumes, reversible lanes, urban freeways.

C. Recent construction of reversible freeway roadways in Chicago, St. Louis and Seattle provides operating facilities for this study.

V. URGENCY - The mounting peak hour traffic congestion in most urban centers and the high cost of providing additional freeway lanes warrants a high priority for this study that might lead to relief in some locations.

PROBLEM NO. 39 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - CONTROL OF ACCESS BEYOND RAMP TERMINI

II. THE PROBLEM - Because of the Interstate program, thousands of new interchanges have been constructed in recent years. The accessibility provided by this construction has encouraged intense commercial, industrial, and residential development adjacent to the interchanges. To preserve the traffic service provided by the interchange requires access restrictions on the crossroad in the vicinity of the ramp termini. The problem is to determine design criteria for minimizing the conflicts between ramp vehicles and driveway vehicles.

III. OBJECTIVES - To determine desirable spacings between the ramp termini and the access control boundary for various terminal designs and crossroad classifications.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 13, 22, 51, 53, and 55 have been scanned in preparing this statement

B. Suggested key words: access control, driveway spacing, freeway interchange design, and freeway ramp termini.

C. Objective data relating to the traffic safety and operations of crossroads in the vicinity of freeway ramp termini were not found.

V. URGENCY - In many locations the traffic safety and operations of cross-roads in the vicinity of freeway ramp termini are expected to seriously deteriorate as adjacent land areas are more intensely developed.

PROBLEM NO. 40 - PRIORITY CATEGORY C (A2A02)

I. NAME OF PROBLEM - INTERCHANGE RAMP TERMINALS ON MINOR CROSSROADS

II. THE PROBLEM - Ramp terminals have been a continuous source of confusion to drivers ever since the inception of interchange design. There are various situations confronting the driver in each of various design configurations. They may be continuous movements, signal controlled, signed stop or yield, and in some cases, complex channelization. Each situation requires different thought and decision making processes. In some instances, wrong way movements have been noted. The problem centers about the selection of ramp type and the actual design geometrics of the intersection.

III. OBJECTIVES -

1. To develop basic geometric design criteria for efficient and safe ramp terminals, taking into consideration the volume and nature of the traffic, topography, and the capabilities of the crossroad.

2. To determine proper traffic control devices to regulate the traffic movements as well as essentially eliminating wrong way movements.

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: geometric design, interchange design, ramp design, and channelization.

C. No activity is apparent in this area.

V. URGENCY - The problem needs immediate attention and warrants high priority. The Interstate System is near completion, and from all indications, the emphasis will be on high speed, controlled access urban facilities.

PROBLEM NO. 41 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - FLOOD-FREQUENCY PREDICTIONS FOR BRIDGE AND CULVERT DESIGN

II. THE PROBLEM - Highway drainage structures are designed for runoff events calculated to recur on the average of once in a certain number of years. As a basis for design, recurrence intervals of 10, 25 and 50 or more years are assigned depending upon the relative importance of the highway and the degree of risk that can be accepted. In order to determine the design capacity needed for a structure for a given recurrence interval,

the engineer must either resort to a flood-frequency analysis or use ready-made flood-frequency curves from available sources.

Flood-frequency analysis is a mathematical procedure for predicting the probability of future floods on the basis of past flood events. The prediction procedure is based on records of stream flow which in most instances are too short to have included a maximum flood and which do not give a direct indication of the longer recurrence interval needed for design. The solution is obtained by statistical analysis of a series of the observed maximum floods. Mathematical functions are fitted through short term records that are plotted on probability paper and extended beyond the data. Such extrapolation for longer recurrence intervals assumes that floods are distributed according to a particular mathematical function.

A number of flood-frequency techniques have gained wide use and acceptance. Examples are the Gumbel and Long-Pearson Type III methods and their variations. The various techniques can give quite different design discharges. There is a need, then, to compare results and determine which technique, within regions of hydrographic similarity, provides the most reliable and consistent means of predicting design discharges for highway bridges and culverts.

In the aggregate the states in cooperation with the U.S. Geological Survey have spent about $25 million accumulating flood information on about 2,000 small watersheds. A consolidated examination of these observations is warranted to delineate regions of homogeneous flood characteristics. Besides eliminating the artificiality of political boundaries, pooling of data would afford economy of scale in electronic computation. Resultant maps would show which portions of all states are best served by a particular flood-frequency technique.

III. OBJECTIVES

1. To select for comparison those techniques commonly accepted by professional hydrologists and any new promising techniques.

2. To use the maximum of gaged watersheds smaller than 100 square miles for a national comparison of analysis techniques.

3. To recommend the preferred technique region by region, giving consideration to watershed size, physiographic provinces, climatic differences and other factors controlling hydrologic homogeneity.

4. To prepare regional maps of any statistical parameters needed to apply a preferred technique.

5. To present measures of resultant reliability of those techniques selected for comparison.

IV. CURRENT ACTIVITIES -

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

B. Suggested key words: flood frequency analysis, recurrence interval.

C. Related research activities: FHWA Contract Research Studies at Utah State University. WRC Committee on Hydrology sponsored research at the Center for Research in Water Resources, University of Texas.

V. URGENCY - Flood frequency predictions are basic elements in the design of highway drainage structures. The success or failure of a design is often dependent on the accuracy of such predictions. Engineers have frequently been misled into underdesign or applied factors of safety resulting in overdesign. The consequences have been expensive in either case. For the past 10 to 15 years the U.S. Geological Survey in cooperation with many State highway departments has collected runoff data from a large number of small rural watersheds. These data provide a real opportunity for a study and comparison of flood-frequency techniques. The results of such a study would reduce the risk element in the hydraulic design of bridges and culverts and lead to more uniform practice in the prediction of design discharges for such structures.

PROBLEM NO. 42 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - SCOUR AROUND BRIDGE PIERS AND ABUTMENTS

II. THE PROBLEM - The inability to predict and control scour around bridges during floods and from tidal currents has long been a matter of concern to bridge engineers. Failure of some structures in recent years by undermining from excessive scour has emphasized the need for better ways to predict scour and protect these structures. Although model studies of scour at piers date back to 1894, field measurements are needed to correlate laboratory studies. In addition to obtaining field data on scour in bed types represented by model studies, data should be collected on other types of bed material and on clear streams and sediment laden streams, including those subject to ice and drift.

The problem can be divided into two broad areas; (A) the prediction of scour magnitude and (B) the design and evaluation of scour control devices.

A. The prediction of scour magnitude can be further subdivided into:

1. The development of a data collection system for:

a. Research type data collection operations.
b. Routine maintenance inspection and monitoring of structures.

2. The collection of data, its analysis and coordination with model study results for:

a. Clear water type scour

1) at pier and abutments
2) in contracted bridge sections
3) in natural sections.

b. Sediment transport type scour

1) at piers and abutments
2) in contracted bridge sections
3) in natural sections

The data collection system and its associated instrumentation must be designed considering the fluid, sediment and flow characteristics. For example, it is desirable that data be obtained on:

Scour and flow depth
Flow velocity and temperature
Crossing and upstream streambed geometry
Sediment size, specific weight, fall velocity, etc.

B. This second phase of the problem might be accomplished by determining present practice, conducting a laboratory study to evaluate and modify existing schemes and/or devising new methods and field installations to demonstrate the most effective measures for scour attenuation.

III. OBJECTIVES - To develop methods for predicting and controlling general and local scour at bridge openings.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress area 15 has been scanned.

B. Suggested key words: Scour, piers, abutments, bridge contraction, sediment, bed material.

C. Related research studies: FHWA Contract Research Study of prototype pier scour determination. Development of state-of-the-art course on river mechanics at Colorado State University.

V. URGENCY - Many bridge failures can be traced to undermining of abutments and pier foundations. The lack of adequate scour prediction schemes and scour control methods has resulted in loss of life and tremendous economic losses. The designer should be able to apply cost effectivemess by weighing the reduction in risk against the cost involved in obtaining that reduction based on such factors as safety, traffic delays and inconvenience, cost of money, etc.

Being able to predict scour and the behavior of attenuation devices is a necessary first step toward assessing the risk inherent in any design.

PROBLEM NO. 43 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - TEST AND EVALUATION OF EXPRESSWAY DRAINAGE DESIGN

II. THE PROBLEM - A number of expressway storm drainage systems in Chicago have been designed by the principles outlined in a paper by Tholin and Kiefer, Transactions, American Society of Civil Engineers, 1960.

This is an advanced method of design but it has been used very little, if at all, outside of the Chicago area. The validity of the method should be evaluated.

III. OBJECTIVES - To measure the performance of the surface drainage system on selected portions of expressway in the Chicago area under actual storm conditions, measurements to include (a) continuous recording of rainfall over entire drainage area and (b) continuous recording of run-off on subunits of storm drain system for which rates of flow had been computed in the design process.

To compute runoff for the observed storms using equations from the design process.

To analyze computed vs. observed performance of subunits and of entire watershed.

To evaluate the validity of the design method and compare with other computer simulation models such as the EPA model.

To recommend improvements in the design method arising from analysis of performance.

IV. CURRENT ACTIVITIES -

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

B. Suggested key words: storm sewers, "Chicago" method, hydrograph method.

C. Related research activities: FHWA sponsored research in inlet hydrographs at Utah State University.

V. URGENCY - This study is deliberately limited to evaluation of drainage design on expressways by the "Chicago" method. All of the major expressways constructed in Chicago since 1948 have been designed by this method. Evaluation of the method by investigation of the performance of systems so designed would open the way to wider use of the method. The engineer working with urban drainage problems is in urgent need of a more reliable means of designing storm sewers. Verification and/or improvement of the "Chicago" method and adaptation to use elsewhere would be a major advance in storm sewer design procedures.

PROBLEM NO. 44 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - EFFECTIVENESS OF SCOUR PREVENTION MEASURES AT BRIDGE PIERS AND ABUTMENTS

II. THE PROBLEM - Scour around bridge piers and abutments has frequently undermined foundations and caused structural damage or failure. To combat scour, engineers have tried a variety of protective measures, some designed and constructed as part of the original structure and others installed

after high water and serious scour experience. Of the latter, the scour protection may have been formally designed and constructed or the remedial measures may have been applied by maintenance forces as part of a flood emergency. In most cases, there has been no documentation of the effectiveness of scour prevention measures.

It is proposed that studies and field surveys be undertaken to evaluate the efficacy of measures to prevent or control scour. Both effective and ineffective treatments need to be reported and compared. It is anticipated that such documentation would prove invaluable in determining the need for scour protection and would define the types of treatment to be applied for safe-guarding future structures.

III. OBJECTIVES - To search, document, and classify methods of scour protection from the standpoint of both preconceived treatments constructed as part of the original structure and post-construction treatments installed after scour has occurred.

To make field surveys of structures that typify various protective treatments and determine relative effectiveness for a range of exposure conditions. To critically analyze and evaluate the various types of protection and develop recommendations for practices judged most effective in controlling scour at bridge piers and abutments.

IV. CURRENT ACTIVITIES -

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

B. Suggested key words: scour protection, scour prevention, scour at piers, scour at abutments, scour control.

C. Related research activities: none known to be on-going.

V. URGENCY - Either the lack of scour protection or failure of poorly-conceived protection can cause the loss of a bridge, possibly human life. Ill-conceived, ineffective scour protection is expensive and wasteful. Highway engineers can ill afford to waste money and materials on ineffectual methods. A review of methods should result in more prudent design and identify areas of research which would further improve scour control practices.

PROBLEM NO. 45 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - DESIGN OF SEDIMENT BASINS

II. THE PROBLEM - Sediment basins, both permanent and temporary, are being specified for the entrapment of sediment eroded from highway right-of-way. However, the design criteria for such basins is either rule-of-thumb or based on theoretical quiescent, settling basins, with little consideration of the effects of currents.

In addition, the design flow frequency for such basins is not well established. There is a need to base the design flow as well as the general design of such basins on some sort of risk analysis.

Some thought should be given to bypassing high flows without losing all the previously trapped sediment.

III. OBJECTIVES - To develop rational hydraulic and sediment transport criteria for temporary and permanent sediment basins on highway projects. To consider the selection of the design flow based on a risk analysis and provide design criteria for passing flows higher than the design flood.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 15 and 16 have been scanned in preparing this statement.

B. Suggested key words: sediment basins, design criteria, risk analysis, spillway design.

C. Related research activities: NCHRP study on erosion control features. USGS study in North Carolina; HP&R study, Pennsylvania.

V. URGENCY - Sediment basins are being widely used to trap sediment in runoff from highway construction areas. However, design criteria are lacking and many of the basins do not function properly, Also, it appears that many of the other constituents in highway runoff are adsorbed to sediment particles; thus, properly designed sediment basins may be one of the best answers to the problem of improving the quality of highway runoff.

PROBLEM NO. 46 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - CRITERIA FOR THE ANALYSIS OF UNUSUAL EVENTS IN ANNUAL FLOOD PEAK SERIES

II. THE PROBLEM - Highway bridges and culverts are designed to pass a flood event of a magnitude that is expected to be exceeded about once in a specified number of years. Statistical probability analysis of annual flood observations commonly is used to establish a relation between flood magnitude and frequency for gaged sites. Techniques have been developed for estimating flood magnitude-frequency relations at ungaged sites where bridge and culvert design criteria are needed, but these estimating techniques usually are based upon transfer of frequency relations defined for gaged sites. Flood frequency relations for gaged sites therefore are basic elements of highway drainage structure design.

The reliability of any flood magnitude-frequency relation, whether defined by a Log-Pearson Type III probability analysis as recommended by the Water Resources Council or by some other probability analysis, is dependent upon the observed flood record being a representative sample of the floods that can be expected to occur over a very long time period. Records of observed floods are generally of a short duration, yet some

contain an observation of one or more very unusual floods. These unusual floods, sometimes called "outliers," may seriously influence the definition of a flood-frequency relation.

III. OBJECTIVES -

A. To develop procedures for recognizing those unusual events in a flood record that significantly affect the definition of a flood magnitude-frequency relation.

B. To propose guidelines for defining a flood-frequency relation from a gaging record that contains one or more unusual events.

IV. CURRENT ACTIVITIES -

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

B. Suggested key words: outliers, unusual floods, flood-frequency analysis.

C. Related research activities: Research sponsored by the Water Resource Council Hydrology Committee at the Center for Research in Water Resources, University of Texas at Austin.

V. URGENCY - Flood frequency relations are a basic element of highway drainage structure design. The success of a design is dependent upon accurate frequency information. The proposed study would lead to improved accuracy of frequency definition and more uniform practices in the hydrologic analysis for design sites.

PROBLEM NO. 47 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - EFFECTIVENESS OF TEMPORARY EROSION CONTROL METHODS

II. THE PROBLEM - There has been an increasing emphasis over the past several years on the prevention of water pollution due to highway construction and operation. One of the pollutants of concern is sediment. Probably the greatest emphasis to date has been directed at sediment since the damaging effects of erosion on the highway are readily visible and the concentration of sediment in runoff is higher than that of other pollutants.

The highway system is most vulnerable to erosion damage and sediment runoff during the construction period; thus, there have been numerous publications advocating various temporary erosion control measures. In general, these measures are to remain in place until vegetation is established or other permanent controls are installed; then, they are removed or biodegraded.

While many different temporary erosion control measures have been advocated, few have been evaluated. Most are not designed, but are improvised based on field experience. It appears that some measures may not work, or may create more problems than they solve. Failures of several of the commonly suggested methods are often observed on highway projects.

III. OBJECTIVES - To evaluate the temporary erosion control methods commonly proposed by means of laboratory or field studies, in order to determine their efficiency, practicality, ease of construction, and durability and to develop guidelines for the design, construction and maintenance of those measures proven to be effective.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 15 and 16 have been scanned in preparing this statement.

B. Suggested key words: water pollution control, erosion, temporary erosion control.

C. Related research activities: EPA has developed, under contract, several recent reports dealing with temporary erosion control methods. Most involve gross estimates of efficiency. A new NCHRP research study has just been initiated on the effectiveness of erosion control methods for roadside development.

V. URGENCY - There is a pressing need to evaluate the performance of the temporary erosion control methods currently being promulgated. If they do not perform as well as expected, their continued use may result in undue sediment pollution of natural waterways and damage to the highway. In fact, they may act as placebos, curing nothing, but providing a false sense of security.

PROBLEM NO. 48 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - INTEGRATION OF ENVIRONMENTAL CONSIDERATIONS WITH CULVERT HYDRAULICS AND ECONOMICS

II. THE PROBLEM - The total solution for a highway culvert provides a reasonable integration of environmental factors, culvert hydraulics, culvert economics, flood characteristics, and local highway geometry.

III. OBJECTIVES - Many of the tangible factors such as culvert hydraulics, culvert outlet protection, culvert life, first or local contract costs, risk analysis, estimates of local flood characteristics (peak/frequency/volume), local highway geometry, existing upstream improvements, and mathematical approximation of available upstream storage are available or defined but are not integrated into a single design approach. Less tangible factors such as second or maintenance costs, traffic volume (delay and detour costs), loss of life, future litigation costs, upstream flood-plain and culvert silting, inundation/vegetation loss, esthetics, and future upstream improvements need additional definition and integration into the total culvert solution. The complexity of such a total solution dictates the use of computer technology formatted so local judgment can be easily and effectively employed wherever intangible factors cannot be quantified.

There is also an immediate need to evaluate existing facilities upon quantification of the environmental and economic parameters. This

need dictates an additional flexibility requirement for the computer technology.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 15 and 16 have been scanned in preparing this statement.

B. Suggested key words: culvert design, intangible factors, environmental factors, economic parameters.

C. Related research activities: FHWA contract research with Water Resources Engineers - Evaluation of the Flood Risk Factor in Design.

V. URGENCY - With very strong national attention being focused on the immediate need to preserve and enhance the environment, with rapidly increasing construction and maintenance costs, and with less monies becoming available for actual highway construction, it is imperative that reasonable techniques allowing the most effective use of these available monies be developed and employed immediately.

PROBLEM NO. 49 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - ENERGY DISSIPATION AT CULVERT OUTLETS AND STORM DRAIN OUTLETS

II. THE PROBLEM - There is an urgent need to develop criteria for the design and use of simple, practical, economical stilling devices for dissipating the energy of the flow from culverts and storm-drain outlets, up to 144-inch diameter or equivalent size. Damaging erosion of drainage channels often results from discharge of high velocity flow from the outlets of culverts and storm drains. Energy dissipators can be effective in reducing the velocity of flow from culverts to a degree that damage to the channel and channel bank will not undermine the culvert or endanger the highway embankment.

III. OBJECTIVES -

1. To develop criteria which will provide the designer with a basis for selecting the type of energy dissipator most suited to the conditions.

2. There are several complex types of energy dissipators suitable for the more costly applications such as for reclamation, flood control or the larger highway drainage structures. For most highway drainage systems, consisting of commercial culverts or storm drains, simpler more effective and economical devices, including prefabricated modular types, are urgently needed.

3. Designs should be applicable to pipe or box culverts of all shapes operating over a wide range of discharge rates and relations of velocity head to depth of flow at the outlet.

IV. CURRENT ACTIVITIES

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

B. Suggested key words: energy dissipators, stilling basins.

C. Related research activities: no known on-going research in this area.

V. URGENCY - Inadequate outlet designs result in added maintenance or need for subsequent drainage and erosion control facility replacements and improvements. There is also recurring loss due to overdesigns where the design principles are not clearly established for erosion control structures. Erosion at culvert and storm-design outlets is a perennial problem; better guidance and design will help to reduce construction and maintenance costs and enhance safety and esthetics in accord with good engineering practice.

PROBLEM NO. 50 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - RIVER TRAINING WORKS AS RELATED TO HIGHWAYS

II. THE PROBLEM - The highway engineer is often confronted with the problem of stabilizing channels at highway stream crossings. The task may involve training works associated with either a channel relocation or control of channel shifting and bank erosion. Most river training installations are expensive and many have failed to accomplish desired results. A need exists for information on this subject compiled for ready use by highway engineers. Case histories, design methods and details, costs and materials relating to prediction and control of river meanders and undesirable channel shifting should be studied and presented in a form useful to the highway designer.

III. OBJECTIVES - To prepare a state-of-the-art report on river training works with specific application to the highway river crossing problem. The study and statement should be done with full understanding of river mechanics and alluvial streams.

IV. CURRENT ACTIVITIES -

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

B. Suggested key words: river training, channel stabilization, river meanders, alluvial streams.

C. Related research activities: none known to be on-going.

V. URGENCY - Failure to recognize the need for training works at highway river crossings can result in costly structural failures, some often occurring during or shortly after completion of construction. Guidelines are needed for design and for implementing the hydraulic aspects of the national bridge inspection program.

PROBLEM NO. 51 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - DESIGN OF STABLE AND ECONOMICAL DRAINAGE CHANNELS

II. THE PROBLEM - Hydraulic design procedures have been developed by a number of research agencies for various stable channel linings, including vegetation cover, flexible linings, riprap, pavements, and other treatments. However, no logical, sequential design procedure exists which will lead the designer to the optimum solution for his channel design problem. Involved in such a procedure would be the underlying soil type, the cost of various available linings, the runoff frequency, maintenance requirements, safety, and environmental considerations.

Work is underway on a sequential, uniform design procedure, based on lining availability and cost, using recent research results from several sources. However, hydrologic considerations and risk analysis can only be treated in general terms.

III. OBJECTIVES - To develop a comprehensive stable channel design method, using risk analysis to derive generalized rules for the selection of design flow frequencies.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 15 and 16 have been scanned in preparing this statement.

B. Suggested key words: drainage channels, channel linings, risk analysis.

C. Related research activities: Mississippi State and Louisiana SHD studies on temporary linings. NCHRP study on a riprap design method. SCS studies of erosion resistance of various types of vegetation. SHD erosion control manuals; e.g., New York, Kansas, Vermont. Channel lining manual development by FHWA. Region 15 Demonstration Project on fiber glass roving. FHWA Contract Research Studies on flood risk analysis for bridges and culverts.

V. URGENCY - Many hundreds of miles of highway drainage channel are constructed each year. In many cases, the proposed channel lining is adequate for the flow rates encountered. However, instances of failure and overdesign are very common. By proper design, considering cost effectiveness, there is a great potential for savings through reduced construction and maintenance costs. Benefits to the environment will also result, through a decrease in the sediment contribution from highway construction and operation.

PROBLEM NO. 52 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - SPUR DIKES AT BRIDGE ABUTMENTS

II. THE PROBLEM - Many highway crossings of major streams have long approach fills on the flood plain to reduce structure costs. These fills block

the passage of overbank flow and divert flood plain flow to a bridge opening. Eddies, formed when lateral flow from the flood plain mixes with main channel flow, cause scour at bridge abutments and at adjacent piers and reduce the effectiveness of part of the bridge opening. Spur dikes, projecting upstream from bridge abutments, have been effective in preventing serious problems at these locations, but research data are needed to develop criteria for the design of the spur dikes. Downstream dikes or trailing dikes are sometimes needed to prevent scour by redistribution of flow in the flood plains.

Although existing research data and field observations of existing dikes have been very helpful in the design of spur dikes, additional research information is needed to improve designs and to give engineers more confidence in their performance. Needed research on these structures consists of two parts which can be programmed concurrently. Part 1 includes extensive laboratory testing of various types and shapes of dikes in both fixed and movable bed models. Part 2 consists of field observations and measurements of flood conditions at existing dikes.

III. OBJECTIVES - To expand present data so that adequate criteria can be developed for the design of spur dikes taking into account various types, shapes and orientation, flow distribution, bridge opening and vegetal cover.

To analyze and evaluate performance of prototype installations in the field during and following flood flow.

To define where trailing dikes are needed to inhibit scour at the downstream toe of the abutment fill.

IV. CURRENT ACTIVITIES -

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

B. Suggested key words: spur dikes, bridge abutments.

C. Related research activities: None known to be on-going.

V. URGENCY - Good design criteria and additional field observations of existing dikes will encourage a wider and better use of these structures. It is estimated that the use of spur dikes in conjunction with new bridge construction and remedial work on existing bridges could approach savings of $3 million annually.

PROBLEM NO. 53 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - BEHAVIOR OF CONSTITUENTS IN HIGHWAY RUNOFF

II. THE PROBLEM - Recent and ongoing research is defining the quality of highway runoff in rural and urban areas. Preliminary results indicate that such runoff contains a variety of constituents in a range of concentrations. Many of the materials are exotic, and little research has

been performed to define their characteristics as related to a waterborne sediment laden environment.

III. OBJECTIVES - To define the physical properties of constituents commonly found in highway runoff, including decay rate, adsorption or absorption on sediment, and interactions with soil in ground water transport.

IV. CURRENT ACTIVITIES

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

B. Suggested key words: Highway runoff, pollutants, pollutant characteristics.

C. Related research activities: FHWA and Washington SHD research on quality of highway runoff. Massachusetts SHD study on salt migration in ground water.

V. URGENCY - The quality of highway runoff is being questioned with greater frequency, both by environmental groups and government agencies. Research is underway to define the quality of the runoff, but the next step will be to remove harmful constituents from the water.

In order to do this, the characteristics of the constituents must be known. For example, oils decay on the pavement, certain pesticides are adsorbed to sediment, asbestos may be filtered out by soil infiltration. To develop adequate removal schemes, involving both natural processes and treatment techniques, a great deal more knowledge on the constituent characteristics is required.

PROBLEM NO. 54 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - SCOUR CONTROL IN BRIDGE PIER CONSTRUCTION

II. THE PROBLEM - Scour has sometimes damaged cofferdams or otherwise adversely affected temporary installations needed to accomplish bridge pier construction at underwater locations. A number of methods have been used to counteract the forces of scour. For example, the method using willow mats to protect pier footings from scour, as used before 1893 on the Memphis, Tennessee bridge crossing the Mississippi River, is still in use today even to the dimensions of the mats. Sometimes piers have been constructed by building up an island and sinking a caisson through it. Other techniques have also been employed.

Few of the methods used to combat scour at bridge construction sites have been described in engineering literature. This is because the methods were born more as ideas of innovation and invention than scientific investigation. Many good methods have either been handed down by experience or died with their originators. What is needed is a concentrated effort to document the techniques that have been used and make them universally available to construction engineers.

III. OBJECTIVES -

To examine from published references the nature of scour as related to bridge pier construction.

To compile, through literature search, construction records and interviews with experienced bridge construction engineers, case histories illustrative of various methods of scour control.

To document and evaluate the relative effectiveness of techniques employed.

To develop guidelines for systematic recording of experience with scour on bridge construction projects.

IV. CURRENT ACTIVITIES _

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

B. Suggested key words: pier construction, scour, scour control, scour attenuation.

C. Related research studies: FHWA Contract Research Study on prototype pier scour determination. Development of state-of-the-art course on river mechanics at Colorado State University. Work on channel and contraction scour being performed by the Wyoming Highway Department.

V. URGENCY - Compilation and dissemination of scour problems encountered during construction and their solutions would provide a basis for improving construction procedures and would lead to lower construction costs by reducing the contingency allowance for unanticipated foundation construction difficulties.

PROBLEM NO. 55 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - EFFECTS OF HIGHWAY RUNOFF ON SELECTED PLANTS AND ANIMALS

II. THE PROBLEM - Recent research has shown that a large number of materials are present in highway runoff, mainly in low concentrations.

Many bioassays have been performed using high concentrations of some of the constituents found in highway runoff, but little or no work is available on the low concentrations actually detected. The effects of low concentrations of constituents on plants and animals are more difficult to detect, since they require testing over a long period of time to determine chronic or cumulative toxicity.

Correct selection of the species of plant or animal to be tested and the proper test procedure (flow through or static, etc.) are very important to obtaining meaningful results.

III. OBJECTIVES - To perform bioassays on plants and animals to determine effects of constituents found in highway runoff. Base the constituents tested and the range of concentrations on recent research on highway runoff.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 15 and 16 have been scanned in preparing this statement.

B. Suggested key words: bioassays, plants and animals, highway runoff.

C. Related research activities: FHWA Contract Research Study on quality of highway runoff. Washington SHD study on quality of highway runoff.

V. URGENCY - An increasing number of claims are being voiced that highway runoff is producing deleterious effects on plants and animals, especially aquatic species. Many of these claims are unfounded; however, sufficient information is not available to refute or confirm their accuracy. Research is underway to determine constituents and their concentrations in runoff but more data are needed on the effects of these materials on plants and animals and the consequent impact on the food chain.

PROBLEM NO. 56 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - METHODS OF PREVENTING CONSTITUENTS IN HIGHWAY RUNOFF FROM REACHING WATERCOURSES

II. THE PROBLEM - Much research work is being performed at present on methods of removing sediment from highway runoff. However, it may become necessary, at least at some sites, to remove other constituents from the runoff.

Research is underway on the quality of highway runoff. If this work and other studies on the effects of the materials on plants and animals show that problems exist, it may become necessary to remove certain constituents from the runoff.

Preliminary work indicates that some constituents decay, some are adsorbed to sediment, and some are lost through ion exchange with soils. These characteristics may lead to some conclusions as to possible removal methods. For example, it appears that sediment ponds may be an excellent method of removing contaminants other than sediment, while some oil skimmer designs may be completely unworkable. Natural filtering of runoff through roadside vegetation and soil may be a promising procedure.

III. OBJECTIVES - To derive practical methods of removing problem constituents from highway runoff before such runoff reaches watercourses.

IV. CURRENT ACTIVITIES -

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

B. Suggested key words: highway runoff, pollutants, pollutant removal.

C. Related research activities: FHWA and Washington SHD research on quality of highway runoff. NCHRP study on erosion control methods. Various EPA research studies.

V. URGENCY - If ongoing research defines certain pollutants in highway runoff as being harmful, there will be pressure to quickly derive means of treating the runoff. Some preliminary work along this line should be initiated as soon as possible, so that rash decisions to utilize unworkable treatment methods will not be made.

PROBLEM NO. 57 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - EVALUATION OF CHANNEL ALTERATION DESIGN TO MITIGATE DAMAGE TO FISH AND WILDLIFE HABITAT

II. THE PROBLEM - Alterations to natural stream channels are generally not desirable. However, some channel alterations will still be required because they are the most feasible and practical alternate for a specific segment of highway location.

The best possible methods for minimizing damage to fish and wildlife habitat, and for preserving or restoring a quality stream channel environment, need to be assembled from existing practice and on-going or completed studies and published in the form of design criteria and guidelines.

III. OBJECTIVES - To develop a comprehensive set of guidelines and design criteria which will assure highway planners and designers (and others associated with work in this area) that their projects will result in minimum damage to fish and wildlife habitat and the streamside environment.

IV. CURRENT ACTIVITIES -

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

B. Suggested key words: stream channel alterations, channel changes, fish and wildlife habitat and design criteria.

C. Related research activities: Montana Fish and Game Department study of stream improvement structures on Prickly Pear Creek and the East Gallatin River. Montana SHD study of channel changes designed to restore fish habitat. Utah SHD study of channel changes on the Weber River. FHWA study to evaluate channel changes in Oregon. University

of Idaho's investigation of hydraulic structures used for fishways and the enhancement of fish habitat. Colorado State University study on highway impact on mountain streams. University of Wyoming studies on quantifying fish habitat. Wyoming Game and Fish Commission studies on Rock Creek.

V. URGENCY - A wide range of methods for channel construction have been used in attempts to mitigate damage to fish and wildlife habitat resulting from highway projects. Guidelines and design criteria are needed to identify the best methods to provide possible enhancement or minimum damage and to properly assess environmental impacts.

PROBLEM NO. 58 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - METHODS OF UPGRADING SEWAGE EFFLUENTS

II. THE PROBLEM - The sewage effluent from many treatment plants will not meet the effluent limitation imposed under Public Law 92-500 or stringent water quality requirements required by the State. Most sewage treatment plants at rest areas are sewage lagoons or extended aeration package plants. These facilities only provide secondary treatment at the best and are upset by the wide fluctuations in loading that occur at a rest area. It is necessary to develop a method of sewage treatment or "treatment train" to meet the requirements.

III. OBJECTIVES -

1. To develop a method of sewage treatment that will meet quality standards for new installations.

2. To develop methods of upgrading sewage effluents from lagoons.

3. To develop methods of upgrading sewage effluents from package plants.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 15 and 16 have been scanned in preparing this statement.

B. Suggested key words: upgrading, sewage effluents.

C. Related research activities: The extent of research being conducted by other agencies or organizations is not known.

V. URGENCY - Spray irrigation of sewage effluents from safety rest areas appears to be an attractive method of meeting the 1983 effluent quality requirements established under Public Law 92-500. Design criteria must be developed or compiled from other research to determine the suitability of different soils, application rates, schedule of application, and amount of storage required. It is urgent that these parameters be determined so that spray irrigation can be used as a possible tool for meeting the new effluent limitations.

PROBLEM NO. 59 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - EROSION RESISTANCE OF NEW GRASSES USED IN HIGHWAY DRAINAGE CHANNELS

II. THE PROBLEM - The U. S. Department of Agriculture has performed tests on various grass covers to determine their hydraulic retardance and resistance to erosion, and had published the results, mainly during the 1950's.

Since that time new types of vegetation, such as Crown Vetch and Bahia have come into general use as ground covers and erosion control, New hydraulic and erosion control data are needed on these new types of vegetal cover.

III. OBJECTIVES - To determine the hydraulic retardance and erosion resistance of new grasses and vegetal cover being used along the highway right-of-way. Perform tests similar to those used by the Agriculture Research Service at Stillwater, Oklahoma, using both permissible velocity and tractive force theory. Quality of cover as influenced by climatic and agronomic considerations should be an important variable in this study.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 15 and 16 have been scanned in preparing this statement.

B. Suggested key words: vegetation, retardance, erosion, resistance.

C. Related research activities: SCS publication, "Handbook of Channel Design for Soil and Water Conservation." Mississippi State University tests on sodded channels.

V. URGENCY - New channel design methods presently being developed utilize vegetation as one type of lining. In many instances, vegetation is the best lining choice, since it retards flow, is self healing, and allows infiltration. However, design information is not available for many of the grasses being widely used on highways. Proper design and construction of such grass lined channels has the potential of saving many maintenance dollars and serious safety hazards and esthetic problems can be avoided.

PROBLEM NO. 60 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - DESIGN CRITERIA FOR SAFETY REST AREAS

II. THE PROBLEM - There is an urgent need for the development of criteria for the design and construction of safety rest areas. Design criteria must be developed to determine the number of parking spaces required, number of toilet facilities, water consumption, quantity and constituents of the sewage produced, and the amount of solid wastes produced. The relationship between these usages and the design ADT must be determined for the various conditions that affect rest area usage.

III. OBJECTIVES -

1. To develop criteria that will enable the designer to estimate the number of cars and people that will use a particular rest area site.

2. To develop criteria that will enable the architect to determine the number of toilet facilities required.

3. To develop criteria that will enable the designer to determine the amount of solid waste produced, water consumption, and the quantity and constituents of the sewage produced.

4. To develop criteria that will enable the designer to evaluate the various factors (geographical area, distance from last rest area, adjacent service facilities, etc.) that affect rest area usage.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 15 and 16 have been scanned in preparing this statement.

B. Suggested key words: Design criteria, water supply, sewage treatment.

C. Related research activities: FHWA Office of Research and Development Project 3-E1. Improved Design Criteria for Roadside Rest Areas provides ongoing research in this area.

V. URGENCY - Design criteria are needed for the rational design of water supply and sewage treatment facilities at safety rest areas. Several large rest areas have been undersized for water supply either by selecting an improper and inefficient system or underestimating its use. The need for rest areas is becoming greater as the public becomes more aware of their value.

PROBLEM NO. 61 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - EVALUATION OF SEPTIC TANK SYSTEM DESIGN

II. THE PROBLEM - Sewage effluent limitations established by Public Law 92-500 will require a greater degree of sewage treatment before effluents can be discharged to a receiving stream. Sewage treatment systems that do not discharge directly into a receiving stream have considerable merit. Since septic tank systems have an absorption field that absorbs the sewage, this method of treating sewage is of considerable interest. Unfortunately, the record of septic tank systems for larger installations has been dismal. It would be advantageous to develop design criteria and procedures for using septic tank systems at large installations.

III. OBJECTIVES - To evaluate several septic tank systems that have been designed and constructed with current state-of-the-art knowledge.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 15 and 16 have been scanned in preparing this statement.

B. Suggested key words: septic tank, absorption system.

C. Related research activities: It is believed that there is no ongoing research in this area.

V. URGENCY - Septic tank systems can be a useful tool for sewage treatment, particularly at remote locations; however, their performance at larger installations has been poor. If the state-of-the-art design procedures can be verified so that an adequate service life is obtainable, septic tanks can be used at low volume rest areas if the proper soil conditions exist.

PROBLEM NO. 62 - PRIORITY CATEGORY C (A2A03)

I. NAME OF PROBLEM - TEST AND EVALUATION OF INVERTED SIPHONS FOR SANITARY, COMBINED AND/OR STORM SEWERS

II. THE PROBLEM - The construction of expressways and subways in urban areas usually necessitates numerous adjustments in existing sanitary, combined and/or storm sewers. While this can sometimes be accomplished by re-routing, occasionally the only alternative is to siphon the sewer beneath the expressway but no thorough evaluation of the performance of inverted siphons has been made. There is a distinct need for good information on design procedures and design details which have proved to be successful.

III. OBJECTIVES -

To make a state-of-the-art study and define the nature and extent of the problem.

To select one or more existing installations for intensive observation.

To analyze performance of such installation(s) according to best theory available, including comparison of design and solids transport capacity with actual performance under carefully recorded conditions.

To develop a design manual on inverted siphons for sanitary, combined and/or storm sewers specifically related to the types of problems covered by the study.

IV. CURRENT ACTIVITIES -

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

B. Suggested key words: siphons, sewer, inverted siphons, solids transport, combined sewers, sanitary sewers, storm sewers.

C. Related research activities: none known to be on-going.

V. URGENCY - This study could range from a compilation of design details of a single installation and evaluation of its performance to a comprehensive investigation of many installations. The extent to which good records are available on performance of existing installations will determine the amount of effort required. The short range objective is to provide information for use by designers confronted with the problems of getting a sewer line past a new expressway or subway which cuts through its path. The intent is to direct the effort at the situation where an existing line must be disturbed rather than the one where a new sewer line is being designed. In the latter case, the head losses and deposition problems inevitably involved with the siphon can be taken into account, whereas for the existing line, such losses were not contemplated and therefore, their effect on the overall capacity of the line must be calculated.

PROBLEM NO. 63 - PRIORITY CATEGORY C (A2A04)

I. NAME OF PROBLEM - BREAKAWAY WOODEN UTILITY POLES

II. THE PROBLEM - Wooden utility poles which line the edges of most State and County roads are perhaps the greatest fixed object hazard of all. Vehicles colliding with these poles cost millions of dollars in fatalities, injury and damage to the motorist.

III. OBJECTIVES -

1. Investigate the possibility of modifying existing or devising a new "Breakaway System" which would be adaptable to wooden utility poles.

2. Fabricate and install these devices on a typical pole line and conduct full-scale vehicle crash tests, the results of which would determine if they meet current safety specifications for "Breakaway."

3. Select the most feasible system and install them on the poles.

IV. CURRENT ACTIVITIES - The State of New Jersey has done some preliminary work along this line by adapting its "Breakaway Coupling Unit," used on signs to the wooden utility pole. They have been installed on two poles to determine its feasibility with satisfactory results. No full scale testing has been done at the present time. The State of Pennsylvania is also looking into this matter.

Suggested key words: impact tests, breakaway, poles and design.

V. URGENCY - (1) In my estimation, the solution to the safety hazard created by the wooden utility pole should be given immediate priority because it is the greatest fixed object threat to the motorist today. (2) The research finding can be implemented by Federal and State legislation requiring utility companies to place their cables below ground, move poles a minimum of thirty feet from the travelled way or require Breakaway poles.

PROBLEM NO. 64 - PRIORITY CATEGORY C (A2A04)

I. NAME OF PROBLEM - CONSTRUCTION SITE TRAFFIC BARRIER DESIGN CRITERIA

II. THE PROBLEM - The function of barricades and channelizing devices as set down in the National Manual of Uniform Traffic Control Devices for Streets and Highways needs to be revised. In addition to the functions of (1) warning and alerting drivers of hazards, and (2) guiding and directing drivers safely past the hazards, the barricades should also serve as safety barriers. Accident statistics at construction sites are fragmentary since few states separate these kinds of accidents from others. In the State of Texas where construction site accidents are recorded separately, however, an average of over 1,900 accidents and over 50 fatalities per year were recorded at rural construction sites for the years 1960-1967. It is clear, then, that construction site accidents represent a serious problem.

Traffic barriers at construction sites should prevent errant vehicles from penetrating to the construction site. In addition, because of frequent routing changes, the barrier must also be easily moved. A barrier system that redirects vehicles back onto the roadway will protect both vehicle occupants and construction workers. In current practice, stand-mounted rails, or oil drums are used as barricades. These are easily portable, make good delineators and warning devices, but are useless as safety barriers. For this reason, criteria for portable barrier systems which delineate as well as protect are required.

III. OBJECTIVES -

1. Define the characteristics of accidents at construction sites so as to determine the range of impact conditions to which a barrier may be expected to be exposed.

2. Define acceptable performance modes for the barrier system in terms of containing an impacting vehicle or redirecting it back into the traffic stream.

3. Define a set of construction site barrier design guidelines and from these produce several candidate barrier configurations.

4. Through combined test and simulation exercises, modify the candidate designs into a finalized construction site traffic barrier.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progreas areas 33, 51, 53 have been scanned.

B. Suggested key words: barriers, construction area accidents, construction safety, construction sites, construction zone traffic control, guardrails, impact tests, simulations.

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

V. URGENCY - This research program should be implemented immediately in view of the high accident rates that occur around construction sites. The research findings would be used to specify designs for temporary traffic barriers for construction sites.

PROBLEM NO. 65 - PRIORITY CATEGORY C (A2A04)

I. NAME OF PROBLEM - TRAFFIC SAFETY BARRIERS FOR BUSSES

II. THE PROBLEM - Barrier designs in current use were developed on the basis of performance under the action of passenger vehicles (automobiles). At that time, the assumption was made that it was impractical to attempt to develop and construct barriers capable of withstanding the impact of trucks. However, there is a critical need to determine how currently accepted barriers, for example those shown in "NCHRP Report 118, Location, Selection and Maintenance of Highway Traffic Barriers," will perform upon impact by busses, particularly school busses. It does not seem to me that we are being responsive to the safety needs to the traveling public if some attempt is not made to provide barriers which will restrain and redirect this type of vehicle. The problem becomes more acute as more and more people choose to travel by bus rather than automobile. Furthermore, highway administrators are placed in a very vulnerable position if they must explain to school boards and parent-teacher associations that they really are not sure whether or not their guardrail systems are effective when struck by school busses. The first step toward solving this problem should be an evaluation of current barrier designs under various conditions of bus impact.

III. OBJECTIVES - Evaluate currently accepted highway safety barrier designs under bus impact and recommend necessary modifications to improve performance.

IV. CURRENT ACTIVITIES

A. Highway Research in Progress areas have not been scanned but from my knowledge of on-going research in this county, I don't believe any work on this aspect of the problem is underway or contemplated. Considerable research has been performed in Europe on barriers to redirect trucks.

B. Suggested key words: safety, traffic barriers, guardrail, median barrier, busses, school busses.

C. A brief statement concerning related research activities including those found in HRIP: See (A) above.

V. URGENCY - I consider this problem of utmost urgency and if the solutions are reasonable they would be implemented by highway agencies at once.

PROBLEM NO. 66 - PRIORITY CATEGORY C (A2A04)

I. NAME OF PROBLEM - CLEAR ROADSIDES FOR SAFETY ON LOW SPEED HIGHWAYS

II. THE PROBLEM - A 30 ft. clear roadside is recommended in "NCHRP Report 118, Location, Selection and Maintenance of Highway Traffic Barriers," and has been generally accepted by highway designers for expressways and other high speed highways, particularly in rural areas. However, there is an increasingly greater need for guidance as to minimum clear roadsides for safety on highways restricted to lower speed, particularly urban arterials and primary highways through villages. The actions of environmentalists and taxpayers in general have made it impossible to remove all trees within 30 ft. of the pavement in cities, suburban areas and villages. Moreover, where traffic speeds are restricted, it is difficult to justify removal of all trees and other fixed objects for a distance of 30 ft. from pavement.

III. OBJECTIVES - Establish requirements for minimum clear roadsides for safety for urban and suburban highways and highways through villages.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas have not been scanned in preparing this statement.

B. Suggested key words: safety, roadside, fixed objects.

C. Related research activities: none known to be on-going.

V. URGENCY - As greater emphasis in our highway construction is placed on improving urban and suburban arterials and other relatively low speed highways, it is of utmost importance that research data be available on clear roadsides essential on such highways for an acceptable degree of safety.

PROBLEM NO. 67 - PRIORITY CATEGORY C (A2A04)

I. NAME OF PROBLEM - FIELD MODIFICATION OF EXISTING SIGN SUPPORTS TO BREAKAWAY

II. THE PROBLEM - There are probably millions of sign supports on our roadways that are not of breakaway design. Replacing these posts with breakaway supports is an expensive undertaking. In some cases, the existing supports are of special aesthetic design which would be lost in replacing it with current breakaway supports.

III OBJECTIVES - Methods should be developed to modify the problem with existing sign supports economically by using methods such as partial cutting, slip plates, breakaway couplings beneath the base plate (New Jersey design), etc. The more prevalent existing supports would include circular pipes, large wooden posts and U-channels.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress area 22 has been scanned in preparing this statement.

B. Suggested key words: field modification of existing sign supports to breakaway.

C. Current related research activities include:

51-206858 - Investigation of Daytime Impact on Roadside Obstacles
22-089266 - Evaluation and Testing of Highway Barriers and Other Safety Accessories.

Both of these projects include investigation of existing small sign supports with regard to traffic hazards but do not go into methods of modifying them to improve their safety.

V. URGENCY - With the Federal Government pressing for the removal of booby traps from our roadways, I feel that this work is urgent.

The cost savings that could be realized as a result of such a study could be substantial.

PROBLEM NO. 68 - PRIORITY CATEGORY C (A2A04)

I. NAME OF PROBLEM - PERFORMANCE OF SOIL EMBEDDED GUARDRAIL POSTS

II. THE PROBLEM - For strong-post guardrail systems, a large part of the vehicle collision energy is absorbed by soil deformation. Furthermore, the severity of the vehicle redirection is dependent on the stiffness of the post-soil system. Parameters of the post-soil interaction include (1) post embedment geometry, (2) soil type and condition and (3) dynamics of applied force.

Presently, post embedment geometry has been standardized within states and regions even though soil conditions vary significantly from one site to the next. Consequently, dynamic performance of a guardrail system varys with the site conditions and with the season (i.e., wet/dry, cold/hot).

To assure an acceptable performance level from strong-post guardrail systems, a better knowledge of the post-soil interaction is needed.

III. OBJECTIVES -

A. Establish relationship of soil type and conditions on guardrail performance.

B. Experimentally determine practical range of soil-post interactions.

C. Investigate optimum guardrail post embedment geometry as a function of soil.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress (FHWA) has been scanned and there is no on-going research in this country on this problem.

B. Suggested key words: traffic barriers, guardrail posts, soil interaction.

C. A brief statement concerning related research activities included those found in HRIP: See (A) above.

V. URGENCY - Since guardrail post soil interaction may have considerable effect on the safety performance of strong post guardrail systems, a more rational method of selecting embedment geometry and soil treatment is needed.

PROBLEM NO. 69 - PRIORITY CATEGORY C (A2A04)

I. NAME OF PROBLEM - WARRANTS FOR AND DESIGN OF GUARDRAILS ON LOW SPEED ROADS

II. THE PROBLEM - There is currently no guardrail warrant or design information available covering design speeds in the 20 to 45 mph. range. This information is needed since there is a large mileage of roads with design speeds in this range. It is generally not economically feasible nor does it make good engineering sense to use designs developed for high design speeds on these roads. In an urban or fringe area, space for such installations is usually limited. Also, it doesn't make sense to use a barrier that is more rigid than necessary as this will subject impacting vehicles to unnecessarily high decelerations.

III. OBJECTIVES - A clear concise publication of warrant and design criteria which can be used by designers should be produced. This might be a report similar to, or even a supplement to NCHRP Report 118.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 27, 51 and 53 have been scanned in preparing this statement.

B. Suggested key words: guardrail design, guardrail warrants, guardrails.

C. The research activities underway are all concerned with higher design speeds than those contemplated in this proposal.

V. URGENCY - Low speed city streets and county roads fill a major role in the total transportation system. Designers of these facilities would welcome improved guardrail design criteria, which could be implemented by inclusion in various road agency policies and standards as has happened with NCHRP Reports 54 and 118 for high speed highways.

PROBLEM NO. 70 - PRIORITY CATEGORY C (A2A04)

I. NAME OF PROBLEM - DESIGN OF CONCRETE MEDIAN BARRIER

II. THE PROBLEM - Most highway agencies use a 6 inch top thickness and do not reinforce concrete median barriers of the New Jersey or GM configurations. However, many instances have been observed where chunks of concrete are knocked from the top section of this barrier as a result of impact by trucks. These pieces that are knocked out are not only difficult to replace but themselves constitute a real hazard to traffic in the opposing roadway. It appears that some steel reinforcement or a thicker throat is desirable to prevent such occurrences, but it is virtually impossible to determine theoretically the best way to do this. A series of full scale impact tests is needed to assist designers in determining the optimum throat thickness and the amount and arrangement of steel reinforcement to prevent concrete from being dislodged during severe impact.

III. OBJECTIVES - Establish throat thickness and reinforcement requirements for concrete median barriers to eliminate failure under traffic.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas have not been scanned in preparing this statement.

B. Suggested key words: safety, concrete median barrier, traffic barrier.

C. A brief statement concerning related research activities including those found in HRIP: The FHWA is proposing research on concrete median barriers which may alleviate this problem. Its status at the present time is unknown.

V. URGENCY - The rate at which concrete median barrier is being installed throughout the country makes it essential that information on reinforcement requirements be available as soon as possible.

PROBLEM NO. 71 - PRIORITY CATEGORY C (A2A04)

I. NAME OF PROBLEM - BREAKAWAY PIGGYBACK U-POST SIGN STRUCTURES

II. THE PROBLEM - There are many thousands of small sign structures along our roads which are supported by one or more piggyback steel U-posts. These all constitute a hazard to the motorists, since they are not easily ridden down. Sometimes when these posts are struck, they fail at the bumper line allowing the stub portion remaining in the ground to penetrate the floor or gas tank as the vehicle passes over, creating an additional hazard.

III. OBJECTIVES -

1. Investigate the possibility of designing a compatible "Breakaway" system for these posts using existing or new Breakaway devices.

2. Conduct vehicle crash tests on these posts with the Breakaway modifications to see if they will meet current safety criteria.

3. Select the most feasible device and employ it on the U-posts.

IV. CURRENT ACTIVITIES - The State of New Jersey has done some testing of 4-pound per foot steel U-posts impacting them in multiple numbers with poor safety results. Other States, such as Ohio, have also run tests with questionable results.

Suggested key words: U-posts, lightweight channels, sign supports, lightweight steel, bendaway, base bending.

V. URGENCY - This problem is not as urgent as others such as the wooden pole, but should be considered as soon as possible because of the large number of installations.

The results could be implemented by allowing Federal approval of only installations which are "Breakaway".

PROBLEM NO. 72 - PRIORITY CATEGORY C (A2A04)

I. NAME OF PROBLEM - DESIGN OF DRILLED SHAFT FOUNDATIONS FOR OVERHEAD SIGN BRIDGES

II. THE PROBLEM - Drilled shaft foundations for overhead sign bridges are currently designed on the assumption that the critical failure mode is uplift of the windward column. Shaft lengths are then determined using soil skin friction to resist this uplift. Usual design assumptions for soil frictional values generally result in shaft lengths much longer than needed. Furthermore, small scale model tests conducted by the Texas Highway Department Bridge Division several years ago gave strong indications that the controlling design factor is the restraint of the shafts against rotation and the resulting shearing stress induced in the soil. There is a need to verify this assumption and to develop a design procedure for its use.

III. OBJECTIVES - The development of a rational, economical design procedure and criteria for drilled shaft foundations to resist the sustained, dynamic and static lateral loads, and overturning moments encountered on overhead sign bridges.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 27 and 62 have been scanned in preparing this statement.

B. Key words: design criteria, overhead sign bridge, drilled shaft foundations, overturning loads.

C. No current research activities.

V. URGENCY - The high signing costs under present design procedures indicate the need for refinement to produce a more economical design, The size and number of these structures is also steadily increasing; thus, emphasizing the need for a rational and economical design.

PROBLEM NO. 73 - PRIORITY CATEGORY C (A2A07)

I. NAME OF PROBLEM - SHOULDER DEMARCATION AND DELINEATION

II. THE PROBLEM - Proper functioning of a highway shoulder depends on its being clearly distinguishable from the traveled way. The manner in which this demarcation or delineation is accomplished may vary from one set of conditions to another but at the present time there is no clear understanding as to what factors are important in determining how the shoulder should be treated. At the present time color contrast, texture contrast, paint lines, diagonal cross striping with paint, and with several forms of raised markings are all being used.

III. OBJECTIVES - The objective of this research would be to develop guidelines for the design and maintenance engineers to assist them in determining what form of shoulder demarcation and/or delineation would be optimum for a given set of circumstances. Some of the variables to be considered would be; traffic volume, pavement type, shoulder width and possibly such less distinct variables as; stopping sight distance, roadway illumination, and possibly the nature of the roadside adjacent to the shoulder.

IV. CURRENT ACTIVITIES -

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

B. Key words: delineation, shoulder delineation, edgeline striping, natural contrast.

C. The only known related research is a Kentucky Department of Highways study of concrete shoulders use in general.

V. URGENCY - As more and more highways are being built with wide paved shoulders, positive means of conveying to the motorist the difference between main lanes and shoulders will be needed. This study should determine the best possible delineation for each highway situation.

PROBLEM NO. 74 - PRIORITY CATEGORY C (A2C05)

I. NAME OF PROBLEM - DEFINITION OF DYNAMIC STRESS RANGE FOR FATIGUE ANALYSIS OF STRUCTURES

II. THE PROBLEM - When a vehicle traverses a simply supported bridge, live load stress at a given location moves from zero to a peak value and returns to zero. However, no procedure exists for determining stress range and number of events if the dynamic effects are the same order of magnitude as static ones (as in the case of some new continuous bridges).

III. OBJECTIVES - Stress range is defined as the peak value observed. On a continuous structure, the stress undergoes a reversal and the stress range is defined as the algebraic difference between maximum and minimum values. In either case, the passage is recorded as a single event.

If the structure exhibits dynamic responses to the passing vehicle, the stress histogram may indicate several maxima and minima, resulting from the super-imposition of dynamic effects over static ones. If the dynamic effects are small in relation to the static ones, the former can be neglected by smoothing the histogram curve. There are alternative solutions:

1. Passage of a vehicle can be recorded as a single event with stress-range defined as the difference between the absolute maximum and minimum.

2. Each dynamic excursion can be recorded as an event with the stress-range being the difference between consecutive maximum (peak) and minimum (trough). This implies that the simultaneous static component (the average of the local maximum and minimum) can be used as a floating mean value.

The validity of any definition should be verified by testing. Some modern testing machines are equipped with ramp and wave generators that can be used in tandem to produce the required combination of stresses.

IV. CURRENT ACTIVITIES -

A. No Highway Research in Progress scans made.

B. Key words: fatigue, stress range, dynamics.

C. Related Research: All ongoing bridge stress history studies.

V. URGENCY - The specifications for fatigue design of bridges are being upgraded continually. This research would provide significant incremental data for such upgrading.

PROBLEM NO. 75 - PRIORITY CATEGORY C (A2C05)

I. NAME OF PROBLEM - OVERLOAD RESPONSE OF BRIDGES IN SERVICE, DUE TO PERMIT VEHICLES

II. THE PROBLEM - To monitor the response of bridges, when subjected to permit vehicles (overloads).

III. OBJECTIVES - To determine the effects overloads have on the safety of bridges and the subsequent reduction in service life.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas scanned: None.

B. Key words: overloads, service behavior, damage, fatigue.

C. Related research: (1) Load history of bridges due to random traffic. (2) Development of charts for analysis of bridges subjected to permit vehicles.

V. URGENCY - The trucking industry is constantly requesting increases in legal loads. If examination of bridges under such loads can be performed, the information would be invaluable in response to request for increases in such loads.

Two and 1/2 year study @ $150,000 (Total).

PROBLEM NO. 76 - PRIORITY CATEGORY C (A2E01)

I. NAME OF PROBLEM - THE EFFECTS OF HIGH AIR CONTENT ON CONCRETE PROPERTIES OTHER THAN STRENGTH

II. THE PROBLEM - In recent years as the severity of frost action has been increased by procedures such as the greatly increased use of deicing chemicals, it has been found necessary to incorporate higher levels of air content into concrete in order to provide assurance of freedom from deterioration due to frost action. Some recommendations have been made for the use in structures such as portland-cement concrete highway bridge decks of levels of air content of as high as 8 or 9 percent by volume of the concrete. It has been shown that in normal levels of air content, if there is no change in water-cement ratio the strength will be reduced about 5% per percent of air content added. In Research Problem No. 7 (HR Circular 51, October 1966, p 13) a discussion was given of the problem of providing adequate air content for frost resistance in highway concrete structures where high strength was also needed, as in precast prestressed bridge members. The problem involved here is to study the effects on properties other than strength of concrete of higher levels of air content than have been used in most previous studies. Methods also need to be developed to evaluate the possibility of attaining adequate frost resistance by achieving an effective distribution of entrained air voids of smaller average size, hence at a lower level of air content of concrete by volume.

III. OBJECTIVES - It is necessary to learn the various methods of enhancing the frost resistance of concrete so as to allow the stipulation of an appropriate degree of frost resistance commensurate with the severity of the frost attack to be expected in the environment. Since the current method of ensuring frost resistance is to supply entrained air, it is necessary to learn the effects of varying levels of air content on all properties of concrete.

IV. URGENCY - The problems related to bridge deck deterioration have been described as more urgent than any others relating to the performance of concrete in service in transportation systems.

PROBLEM NO. 77 - PRIORITY CATEGORY C (A2G03)

I. NAME OF PROBLEM - ADHESION OF SEALANTS AND ADHESIVES TO PORTLAND CEMENT CONCRETE PAVEMENTS

II. THE PROBLEM - Liquid type joint sealants have shown a notoriously poor

record in the joints of portland cement concrete pavements. The great majority of failures have been of the adhesive type. In addition, many deck coating systems have failed to adhere to the concrete bridge deck. The definite possibility exists that many of these adhesive failures are caused by the leaching of soluble salts from the concrete against the concrete-polymer interface.

III. OBJECTIVES -

1. To thoroughly study the wet-dry cycle of portland cement concrete, to determine what salts, if any, leach out of the concrete.

2. To identify those salts which might be injurious to the adhesive-concrete bond line.

3. To test the effects of primers on the leaching problem.

4. To identify the sealants and adhesives which are least affected by the leaching.

5. To recommend combinations of primer and sealant which show the greatest potential for in-depth study.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 33 and 34 have been scanned in preparing this statement.

B. Suggested key words: sealants, joints, adhesion, leaching.

C. There has been a great deal of research conducted into the adhesive strength of various sealants and adhesives, but none directed into this specific problem area.

Also, for many years, the resilient flooring industry faced the problem of poor adhesion to concrete slabs below grade. In several publications, the problem was demonstrated to be the leaching of soluble salts from the concrete against the adhesive-concrete interface. One such publication is "Adhesives for Floor Surfacing Materials" by Rohrer, R.B. in "Adhesives and Sealants in Buildings" Publication No. 577 of the Building Research Institute, Washington, D.C. 1959.

V. URGENCY - The scaling of concrete bridge decks has been called, by one HRB Division Chairman, "the most severe problem facing structural engineers today." If the problems in the specific area of this Research Problem Statement were eliminated, coating systems for the bridge decks would be feasible.

Joint sealant research in recent years has been concentrated on the pre-formed compression seal because, although expensive, it demonstrates the best performance record. However, the poured sealants, especially the hot pours are still in wide use. A solution to this specific problem could make the poured sealants competitive and result in the savings of millions of tax dollars over the years.

PROBLEM NO. 78 - PRIORITY CATEGORY C (A2J03)

I. NAME OF PROBLEM - QUALITY CONTROL FOR SOIL-LIME CONSTRUCTION

II. THE PROBLEM - For the most part, soil-lime construction operations are of the "mixed in place" type. The major field construction items are lime distribution, mixing and pulverization, and compaction. 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 soil-lime 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 objective of the research is to develop a comprehensive quality control system for soil-lime construction. The quality control system would (a) include appropriate field testing procedures, (b) consider the extent of the sampling and testing program required for various types of construction, (c) establish appropriate quality criteria for various types of construction, (d) consider tolerances and variability, (e) provide a decision methodology for accepting or rejecting the construction, and (f) provide for periodic surveillance following construction.

IV. CURRENT ACTIVITIES -

A. Highway Research in Progress areas 22, 25, 32, 34, 35, 40, 41, 62, and 90 have been scanned in preparing this statement.

B. Suggested key words: soil-lime, quality control, construction, soil stabilization, quality criteria.

C. Identified research efforts related to this research effort are: (1) a California DOT study concerning an investigation of road mixing, (2) an Air Force Weapons Laboratory sponsored study on soil mixing at MIT, (3) a Texas Highway Department sponsored tensile strength study at the University of Texas at Austin, and (4) past and current efforts in the South Dakota Department of Highways.

V. URGENCY - This research area is considered as a high priority item by Committee A2J03. With an increasing utilization of soil-lime stabilization in various applications, a definite need exists for improved quality control.

PROBLEM NO. 79 - PRIORITY CATEGORY C (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 the 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. 80 - PRIORITY CATEGORY C (A2K06)

I. NAME OF PROBLEM - EFFECT OF FULL-DEPTH ASPHALT CONSTRUCTION ON SUBGRADE MOISTURE

II. THE PROBLEM - Results of field test projects in California, Colorado and Ontario and experience in Michigan and New Jersey have shown that some soils under Full-Depth asphalt pavements become drier with time rather than wetter as sometimes happens under conventional flexible pavements. The design of asphalt pavements depends upon the strength of the subgrade soil, which in turn is influenced by moisture content changes that occur after construction. Conventional design procedures often are based on "soaked" sample conditions to allow for such moisture changes. Savings could be achieved if it can be shown that a drying effect under Full-Depth asphalt pavements could be taken advantage of in the original

design. There is a need for further information on a comparison of changes in soil moisture under Full-Depth and conventional pavements for various types of soil and environmental conditions, and for guidelines for using the information in design.

III. OBJECTIVES - It is expected that this research would include the collection and study of existing data as well as a study of carefully constructed and controlled field sections consisting of both Full-Depth and conventional flexible pavement sections. The objective of the study would be to collect such data as are available (both published and unpublished) on changes that occur in subgrade moisture conditions, and related strength values with time, under both Full-Depth asphalt pavements and under conventional pavements and to recommend how this information might be used to advantage with existing pavement design methods. Field experiments will be conducted to provide necessary data not available from already completed studies.

It is possible that differences may be found between different soil types and different pavement cross section configurations, particularly shoulder design. Some data may be found in which soil strength is defined as resilient modulus as well as R-value and CBR. All of these factors should be considered in the study and their relevance to existing and planned pavement design methods.

IV. CURRENT ACTIVITIES -

No projects meeting the objectives of this project were found in the HRIS summary for March 1972 through February 1973. Related projects will be found in HRIS Abstracts under the title subgrade moisture. The project is relevant to NCHRP areas 1, 4, 9, 10, 14, and 21, and HRIS areas 25, 26, and 62.

Key words: subgrade moisture, pavement design, pavement performance.

V. URGENCY - the information to be collected in this study would produce cost savings by reducing thickness or extending the life of asphalt pavements under appropriate conditions. Properly presented, the findings could be used immediately by highway agencies.

PROBLEM NO. 81 - PRIORITY CATEGORY C (A2L01)

I. NAME OF PROBLEM - CORRELATION OF AASHTO SOIL CLASSIFICATION AND BEARING CAPACITY OR STRENGTH OF SOIL AND AGGREGATE MATERIALS

II. THE PROBLEM - There is considerable published information on the various soil classification systems and on the various tests to determine strength or bearing capacity of soil and aggregate materials. There is, however, a noticeable lack of information relating these classification systems with strength parameters.

III. OBJECTIVES - The objective is to develop the relationship between the AASHTO Soil Classification System and bearing capacity or strength of

soils as determined by CBR, triaxial compression, unconfined compression, R-value, Etc.

IV. CURRENT ACTIVITIES -

A. References:

1. "Predicting the California Bearing Ratio from Compaction and Classification Data," J. L. Jorgenson, presented at 45th Annual Meeting, HRB, Jan. 1966.

2. "Computerized Soil Test Data for Highway Design," R. A. Crawford and J. B. Thomas, Record 426, Highway Research Board, 1973.

B. Suggested key words: soil classification, bearing capacity, soil strength, CBR, triaxial, R-value.

V. URGENCY - The problem is considered to be urgent in the area of relating the performance of subgrade materials with soil classification systems and in the area of pavement design.

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