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Design and Construction of Transportation Facilities: Research Problem Statements

TRANSPORTATION RESEARCH BOARD / NATIONAL RESEARCH COUNCIL

INTRODUCTION

An important function of the Transportation Research Board is the stimulation of research toward the solution of problems facing the transportation industry. One of the techniques employed by technical committees in support of this function is the identification of problems and the development and dissemination of research problem statements. The aim of this activity is to provide guidance to financial sponsors such as governmental agencies, research institutions, industry, the academic community and others in allocating scarce funds and manpower to the solution of transportation problems. The Group 2 Council endorses this activity and has established a Standing Committee on Research Needs to provide guidance and direction to its committees and to coordinate their efforts.

The problem statements in this circular represent a composite of efforts by thirty (30) of the Group's committees. They should not be considered an all inclusive recognition of research needs within the scope of Group 2's activities. Since many of the statements may touch upon the scopes of several other elements of the Board the circular is being distributed to a wide range of interest areas.

RATING PRIORITIES

The problem statements were assembled in a priority rating recommended by each contributing committee.

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

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

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A2A02

PROBLEM NO. 1

I. NAME OF PROBLEM - TRAFFIC REGULATION - USE OF SHOULDER BY OVERTAKEN VEHICLE TO ALLOW PASSING

II. THE PROBLEM - At least two states (Texas and Washington) allow slower moving vehicles to move onto the paved shoulder areas of two-lane roads to permit faster moving vehicles to pass without encroaching on the opposite traffic lane. In Texas, motor vehicle laws allow the passing maneuver of any two-lane road with sufficient paved shoulder width for the slower-moving vehicle to clear the travel lane. The maneuver often takes place at speeds of 55 mph for both vehicles. In Washington, the state DOT designates and signs those routes on which motorists are allowed to make the maneuver; it is reportedly used on more mountainous two-lane roads than on roads with other terrain features. The Texas motor vehicle laws needed clarification before the maneuver became acceptable to law enforcement agencies. The laws in many states may prohibit this type of passing.

This use of shoulders for passing may have greater potential for improved safety than the conventional passing maneuver on two-lane highways where vehicles must enter the opposite lane of traffic in order to pass. Therefore, although Texas has conducted research on this use of shoulder, a broader study is needed to determine the desirability of expanding the use into other areas of the country. In addition, there is the need to test the operational problems, design criteria, and the safety aspects of pulling to the right shoulder to permit other vehicles to pass.

III. OBJECTIVES - To make field studies of selected two-lane highways in Texas and other sections of the country to collect and analyze data in various terrain, climatic features and traffic volumes to determine:

A. Required shoulder design criteria.

B. Safety aspects of this use of the right shoulder for passing when compared with conventional passing on two-lane roads.

C. Operational, safety, and design constraints.

D. The desirability of expanding this use to other areas of the country.

E. Legislative changes to motor vehicle laws.

IV. CURRENT ACTIVITIES - None

V. URGENCY - The project warrants study as the improved safety and increased capacity of this passing maneuver may increase the longevity of many rural highways and may avoid costly reconstruction of many two-lane roads.

PROBLEM NO. 2

I. NAME OF PROBLEM - DETERMINATION OF THE OPERATIONAL AND SAFETY BENEFITS OF SPIRAL TRANSITIONS

II. THE PROBLEM - The procedure for geometric design of the spiral transition between tangent and horizontal curve sections of highways has been available since the 1940's; however, there has been reluctance to use the spiral transition by highway design engineers. To date, the major reason given for not deploying the spiral is, "The benefits of spirals have not been demonstrated to justify the extra expense of building a spiral."

III. OBJECTIVES - The objective of this study is to detemine the effect of spirals upon:

A. Operations, i.e., traffic volume and vehicle trajectory to include erratic maneuvers, lateral placement, and speed.

B. Safety, i.e., the frequency and severity accidents.

The spirals at both the beginning and end of horizontal curves should be included in this evaluation.

The operating and safety effects of spirals should be compared to similar parameters of other transition types, i.e., no transition and the compound curve transition. The costs of construction, maintenance, and accidents due to the various transitions should also be compared.

IV. CURRENT ACTIVITIES

A. There has been no referral to Highway Reseach in Progress in preparing this statement.

B. Suggested key words - compound curves, geometric design, horizontal curves, lateral placement, spiral, curves, and transition curves.

C. To date, most studies of spiral curves have been limited to simulations of the vehicle's dynamic effects. The most recent of these is An Evaluation of Horizontal Curve Design, FHWA-RD-79-48, which found that, with respect to the transition, that a spiral was the best form of transition in terms of having the least perturbation effect on the driver and the most gradual build-up of side friction demand. Other studies which may assist the researchers are:

1. "Side-Friction Factors in the Design of Highway Curves," Research Results Digest No. 55.

2. Influence of Combined Highway Grade and Horizontal Alignment on Skidding, NCHRP Report 184.

3. Highway Geometric Design Consistency Related to Driver Expectancy, FHWA/RD-81-036.

V. URGENCY - This research warrants an immediate and high priority as many states are undertaking RRR projects in which realignment and flattening horizontal curves are being considered; the use of spirals for transitions may eliminate the need for realignment or curve flattening, thus, the cost of a RRR project can be reduced.

PROBLEM NO. 3

I. NAME OF PROBLEM - DESIGN OF URBAN FREEWAY MERGING AND DIVERTING RAMPS AND/OR ROADWAYS

II. THE PROBLEM - Highway interchange ramps have normally been designed in accordance with AASHTO's "Coordination of Lane Balance and Basic Number of Lanes", thus the number of lanes beyond the merging of two traffic streams has been the sum of all traffic lanes minus one. As urban freeways approach capacity, the designed acceleration lanes often prove to be too short and the reduction of one lane of freeway results in congestion, reduction of freeway capacity and congestion related accidents. Operations and traffic engineers in 11 metropolitan areas are solving these congestion problems associated with urban freeways by converting highway shoulders to either full time running lanes or permissive running lanes during rush hours. The general rule is that conversion of shoulder must have potentials for reducing greater numbers of congestion related problems and accidents than will be produced by the resulting lack of full shoulders for normal shoulder use.

The exit ramp of diverting roadways can also cause congestion problems if the secondary highway or street system cannot absorb the traffic. Here, back-ups of traffic onto the main lanes are not uncommon resulting in congestion, lower level of service and congestion related accidents. Operations and traffic engineers have converted shoulders to traffic lanes for two lane exits and storage of traffic to allow smoother flow on the freeway.

There is a need for the development of criteria for the use and the length of acceleration lanes and/or auxilary lanes for both entrances and exit ramps of urban freeways which will allow the safe and efficient flow of traffic into and from the urban freeway. Thus, reducing congestion related accidents of future urban freeways and provide shoulder for emergency stopping. The criteria may be useful for the retrofit of additional lanes or auxilary lanes on older urban freeways or in the reconstruction of older urban freeways.

III. OBJECTIVES - To make field studies and collect and analyze operational data of the major metropolitan areas with urban freeways that have reached capacity. Specifically, observations of those areas that have converted shoulders to provide additional lanes or auxilary lanes will be required.

A. Develop criteria for determining the need for additional lanes and/or auxilary lanes.

B. Determine methodology for the length of additional and/or auxilary lanes that will allow the safe and efficient flow of traffic under capacity conditions (i.e., a fixed length as recommended by AASHTO, to the next interchange, to the next major traffic exit, or to the distance that traffic volumes can adjust to a lane reduction.

C. Develop improved criteria for two lane exit ramps.

IV. CURRENT ACTIVITIES - Many studies in California and Texas have supported the use of freeway shoulders to increase capacity. While the agencies justify both the safety and the economic benefits of converting freeway shoulders and identify the problems shoulder conversions will solve; neither have developed the criteria needed for future designs or retrofit designs to existing freeways.

V. URGENCY - This project warrants an immediate high priority to either prevent future design from being inadequate or reconstruction and retrofit designs from using shoulders.

PROBLEM NO. 4

I. NAME OF PROBLEM - DRIVEWAY INTERSECTION SIGHT DISTANCE

II. THE PROBLEM - Should the intersection of private driveways with public roads have the same sight distance requirements as the intersection of two public roads? Driveways have a wide range of operating characteristics and they tend to be constructed with lower safety and design standards; particularly a specific minimum sight distance is often not required. Since driveway use varies from field driveways with less than one trip per day to high volume commercial driveways, a wide range of design criteria may be appropriate but one of the critical design features, sight distance, should not necessarily change. Information is needed to determine if driveway intersection sight distance should be the same for any type of driveway for a given design speed or functional class of highway. Also, what difference is there for sight distance requirements for two lane or multi-lane highways; left turns in and out; and right turns in and out?

III. OBJECTIVES - The objective is to develop information on the operation of driveway intersections as influenced by sight distance, to be applied to the development of a good, yet practical and cost effective driveway intersection sight distance design policy that is based on field data and research evaluation as compared to theorectical assumptions. The research results should be applicable to suburban areas where the greatest number of driveways are being built.

IV. CURRENT ACTIVITIES

A. Highway Research in Progress areas 21, 51 and 54 have been scanned in preparing this statement. No research projects are known to be in progress.

B. Suggested key words: accidents, driveway design, safety, sight distance.

C. Previous published studies and driveway design standards are available but none of them satisfy the objectives of this proposed research.

V. URGENCY - A significant percent of highway accidents involve driveway turning movements, yet inadequate research is available to use as a basis to develop better intersection sight distance design criteria. Driveway safety should be improved, particularly in rapidly developing suburban areas.

PROBLEM NO. 5

I. NAME OF PROBLEM - SURFACE TEXTURE DIFFERENCES BETWEEN SHOULDER AND TRAVEL LANE

II. THE PROBLEM - Run-off-the-road accidents are a major safety problem on high speed rural highways. Signficant pavement texture differences is known to alert sleepy or inattentive drivers when their vehicle drifts from the travel lane onto the shoulder. Methods of providing good pavement texture differences are needed for both concrete and bituminous pavements that are effective, feasible, durable and maintainable. Texturing methods that could be applied during initial construction, during resurfacing or to existing pavements need to be developed and research performed to verify that the texturing would be cost effective by reducing run-off-the-road accidents.

III. OBJECTIVES - Assemble information from varous highway agencies and literature on potentially effective pavement texturing methods. Conduct research to establish the most effective, maintainable and economical methods of providing pavement texture differences at high run-off-the-road accident locations.

IV. CURRENT ACTIVITIES

A. Literature and current research should be scanned to locate and utilize available information.

B. Suggested key words: pavement, pavement surface, shoulders, accidents, safety.

V. URGENCY - This research will provide highway agencies with more design knowledge to use to improve highway safety. This research would rank as a medium priority for funding.

A2A04

PROBLEM NO. 6

I. NAME OF PROBLEM - GUIDELINES FOR UPGRADING HIGHWAY SAFETY FEATURES

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

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

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

V. URGENCY - This research was ranked at the top in terms of need by TRB committee A2A04, Safety Appurtenances. The need for the research was also underscored in a workshop sponsored by A2A04 in July 1984 on "Tort Claims Involving Roadside Safety Features."

PROBLEM NO. 7

I. NAME OF PROBLEM - DEVELOPMENT OF IMPROVED VEHICULAR ENCROACHMENT DATA

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

III. OBJECTIVES - The objective of this research is to collect vehicular encroachment data for a variety of roadway types and roadside conditions. The data may be derived from observations of encroachments, directly by sensing devices and/or indirectly by visual evidence. It may also be inferred from accident data and/or maintenance records.

IV. CURRENT ACTIVITIES - There are no studies currently being conducted that address the problem.

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

PROBLEM NO. 8

I. NAME OF PROBLEM - COMPILATION AND DISSEMINATION OF THE RESULTS OF RESEARCH ON HIGHWAY SAFETY DEVICES

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

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

IV. CURRENT ACTIVITIES - None

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

General estimate of cost to accomplish: $100,000

PROBLEM NO. 9

I. NAME OF PROBLEM - A RE-EVALUATION OF BARRIER WARRANTS FOR EMBANKMENTS

II. THE PROBLEM - Current barrier warrants for embankments are based on studies reported in HRR 174 and HRR 460. The basic concept is to develop a boundary of equal severity between the barrier and the embankment. These criteria may warrant re-evaluation based on the following:

A. The evaluation assumed heavy-post guardrail with blockouts. For flexible systems (G1, G2, and G3), the equal severity line would be different. This suggests that a range exists for combinations of embankment heights and slopes where a flexible barrier system would be the safest roadside condition.

B. TRR 819 reported a New Mexico study on fatal rollover accidents. The authors concluded that many of these accidents occurred on embankments which did not satisfy the existing barrier warrants. They were especially concerned about the criteria for low embankment heights.

C. HRR 460 used a Severity Index (SI) to establish the equal severity boundary. The SI is a weighted number for longitudinal, lateral and vertical "g" forces. The occupant risk criteria presented in NCHRP 230 may affect the location of the equal severity boundary.

D. The HRR 460 analysis assumed impact conditions of 60 mph and 25^{o} angle of impact, although an evaluation was made of different encroachment conditions. It may be justified to establish various sets of barrier warrant criteria for varying highway conditions. In addition, the presense or absence of rounding at the top and toe of the slope may be a factor in barrier warrants.

III. OBJECTIVES - To re-evaluate the existing barrier warrants for embankments and, if justified, to establish new criteria.

IV. CURRENT ACTIVITIES - Suggested key words: barrier warrants, embankments, and occupant risk. To my knowledge, this activity is not being currently researched.

V. URGENCY - This research deserves moderate urgency. Most likely, the new warrants will not have an extraordinary variance from existing warrants. However, I am aware of some state agencies which have concluded that the existing criteria are not realistic. Implementation could be via standard TRB distribution methods.

A2B02

PROBLEM NO. 10

I. NAME OF PROBLEM - DEVELOPMENT OF SUBBASE FRICTION INFORMATION FOR USE IN DESIGN OF CONCRETE PAVEMENTS

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

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

III. OBJECTIVES - The objective of this research is to determine the coefficient of friction between PCC rigid slabs and the various types of subbases currently being used and anticipated in the future.

A review of all the currently used subbase types would be made for the measurement program. These studies would be made on test slabs and verified to a limited extent by observation on small slabs cost at actual construction projects. Information could be compiled into charts that may be inserted into the design manuals.

IV. CURRENT ACTIVITIES - Suggested key words: coefficient of friction, crack, crackspacing, joint movement, rigid pavements.

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

PROBLEM NO. 11

I. NAME OF PROBLEM - CONSTRUCTION AND EVALUATION OF ROLLER COMPACTED CONCRETE PAVEMENT STRUCTURES

II. THE PROBLEM - Roller compacted concrete has been used primarily in massive concrete structures. Now agencies are considering building pavement structures with roller compacted concrete. These are often

for heavy intermodal transfer facilities. Presently, no design procedures are available to assist in design of these structures, especially for heavy freight transfer equipment.

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

IV. CURRENT ACTIVITIES

A. Roller compacted concrete has been used most widely in heavy duty, intermodal facilities.

B. Suggested key words: roller compacted concrete, response performance.

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

PROBLEM NO. 12

I. NAME OF PROBLEM - EVALUATION OF THE PERFORMANCE OF RIGID PAVEMENT REHABILITATION STRATEGIES: RESTORATION VS. STRUCTURAL REHABILITATION

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

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

IV. CURRENT ACTIVITIES

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

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

C. Suggested key words: restoration, rehabilitation, rigid pavements, performance, life cycle cost.

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

PROBLEM NO. 13

I. NAME OF PROBLEM - EFFECT OF JOINTS ON THE RESPONSE, DESIGN AND PERFORMANCE OF RIGID PAVEMENTS

II. THE PROBLEM - Much of the distresses observed in rigid pavements initiates at a construction joint. The effect of various types of joints on the response, design and performance of rigid pavements have been a subject of extensive studies for more than half a century. However, due to the lack of analytical methods, most of these studies were empirical in nature and the voluminous data collected were not analyzed theoretically. It is only recently that several pavement computer response models based on the finite element methods were developed for the analysis of jointed pavement slabs. To rationally evaluate the effect of joints on pavement response design and performance, a review of previous studies in light of these new response models is needed.

III. OBJECTIVES - The objectives of this research are: (1) to evaluate existing jointed pavement computer models and compare the computed stresses and deflections with experimental measurements; (2) to modify the models, if needed, so that strains, stresses and deflections in jointed slabs can be determined under various field conditions; and (3) to establish design criteria for slabs and joints and predict their performance based on the computed strains, stresses and deflections.

IV. CURRENT ACTIVITIES

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

B. Suggested key words: rigid pavements, joints, computer models, finite element method, design, performance, field measurements.

V. URGENCY - The provision of adequate joints for rigid pavements has been a major problem since their inception. With the advent of high speed computers and the finite element methods of analysis, it is now possible to develop a rational method for evaluating the effect of joints on response, design and performance of rigid pavements. This problem is important not only for the design of new pavements, but also for the maintenance or rehabilitation of existing pavements. The ability to determine pavement response and predict pavement performance based on the existing conditions of slabs and joints will make possible the implementation of remedial measures at an appropriate time with considerable savings.

PROBLEM NO. 14

I. NAME OF PROBLEM - STUDY OF THE EFFECTS OF NONUNIFORM FOUNDATION SUPPORT FOR RIGID PAVEMENT SLABS

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

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

IV. CURRENT ACTIVITIES

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

B. Suggested key words: rigid pavements, distress, foundation support, voids, joints.

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

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

PROBLEM NO. 15

I. NAME OF PROBLEM - VALIDATION OF THE PERFORMANCE OF COMPOSITE DESIGN IN RIGID PAVEMENT STRUCTURES (WITH SPECIAL APPLICATION TO ECONOCRETE COMPOSITE BASE PAVEMENTS)

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

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

IV. CURRENT ACTIVITIES

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

B. Suggested key words: econocrete, composite rigid pavements, aggregates.

V. URGENCY - The composite econocrete pavement system is a viable solution to pavement needs in areas deficient in quality aggregates, offering, in many cases, economical, environmental and energy advantages.

PROBLEM NO. 16

I. NAME OF PROBLEM - A STUDY OF SUBSEALING AS A REHABILITATION TECHNIQUE FOR PORTLAND CEMENT CONCRETE PAVEMENT (PCCP)

II. THE PROBLEM - The FHWA, industry and construction-related associations are currently promoting the use of cement/pozzolan materials to fill

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

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

IV. CURRENT ACTIVITIES

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

B. Some projects that were "subsealed" in 1982 are now exhibiting severe distress in the form of slab breakup.

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

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

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

F. Suggested key words: rigid pavements, warping, curling, pumping, base support, cement, pozzolans and injection.

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

A2B04

PROBLEM NO. 17

I. NAME OF PROBLEM - MATERIALS REQUIREMENTS FOR PAVEMENT REHABILITATION

II. THE PROBLEM - Structural rehabilitation of pavements is being accomplished by numerous techniques. Rehabilitation has foregone the traditional asphalt concrete overlay to include many combinations of material removal, removal and replacement, various forms of recycling, grouting and undersealing and the use of fabrics and membranes. Materials performance criteria and strength requirements are not well-established.

III. OBJECTIVES - The objective is to develop the materials requirements for successful pavement rehabilitation. Specific objectives might include the evaluation of existing limited use applications of new materials in pavement rehabilitation.

IV. CURRENT ACTIVITIES

A. Many agencies are using various relatively new materials in pavement rehabilitation either to reduce reflection cracking, to reduce the required use of asphalt, or to reduce the use of completely new asphalt mixtures. Recycling and the use of new materials with recycled materials is becoming commonplace. Applied research is being conducted in many forms by many states or new materials used in pavement rehabilitation. However, the required engineering properties of these new materials and their performance are not well-defined. Void detection techniques are being utilized to enhance grouting and undersealing practices.

B. Suggested key words: pavement materials, rehabilitaiton, recycling, fabrics.

V. URGENCY - This study is considered of value and importance because of the wide-spread interest in new materials and the increased emphasis of pavement rehabilitation. The asphaltic and portland cement materials will probably be treated in the pending SHRP program but other materials may not.

Level of funding - $300,000

PROBLEM NO. 18

I. NAME OF PROBLEM - REHABILITATION OF CONCRETE PAVEMENTS FOR HIGH VOLUME TRAFFIC

II. THE PROBLEM - Many of the pavements on the completed portion of the Interstate system and the primary system are rigid pavements. Many of these pavements are either past their original design life or the traffic that they have carried is well in excess of what they were expected to carry. For large traffic volumes, pavement rehabilitation strategies for concrete pavements are needed. Evaluation techniques and design criteria for enhancement and prolonged pavement life are necessary. They are necessary to provide the most optimum programming of funds for rehabilitation over the long period. The concept of simple asphalt concrete overlay is no longer an acceptable alternative, but it is imperative that all techniques be considered

and that life-cycle costing and pavement management techniques be applied to the rehabilitation of concrete pavements for the large volume of heavy traffic that is expected.

III. OBJECTIVES - The objective is to develop rehabilitation criteria for concrete pavements subjected to heavy traffic volumes and loads. Design criteria simply do not exist for the effective rehabilitation of concrete pavements for heavy traffic. Some objectives might include the selection of some specific sites on the existing road network to evaluate what types of rehabilitation succeeds and what does not. The ongoing long-term pavement performance (LTPP) monitoring of highway pavements might provide input to this. The rehabilitation should consider not only the increased strengthening but maintenance of the integrity, strength, and supporting characteristics of the existing concrete pavement.

IV. CURRENT ACTIVITIES

A. NCHRP has research in progress on the rehabilitation of concrete pavements. Likewise, there are programs underway in the FHWA administrative contract program and probably numerous projects in the HRP program being carried out by the state departments of transportation. Of particular importance and worth citing is the FHWA Training Course on pavement rehabilitation which, at least in part, addresses concrete pavement rehabilitation.

B. Suggested key words: concrete pavement, rehabilitation, heavy traffic, concrete pavement design, life-cycle cost, concrete pavement evaluation.

C. Efforts currently underway in the long-term pavement performance (LTPP) program on highway pavements should provide information on pavement performance, pavement design and pavement rehabilitation requirements which should enhance the entire pavement management and design process.

V. URGENCY - This study is considered to be of urgent need relative to the state of the condition of many of the concrete pavements on the Interstate and primary systems. Rehabilitation technology is necessary to provide state highway design engineers with critiera for the selection of the proper forms of rehabilitation for concrete pavements in heavy traffic areas. Because of increased funding for rehabilitation, it is necessary that the best and most current criteria be used rather than to continue programs that may not provide the best long-term service or be the best investment of funds available.
Level of funding - $250,000

A2B05

PROBLEM NO. 19

I. NAME OF PROBLEM - SIMPLIFIED PROCEDURES FOR ESTABLISHING THE RESILIENT MODULI OF SUBGRADE SOIL AND GRANULAR MATERIALS

II. THE PROBLEM - The resilient moduli (M_R) for subgrade and granular base materials in pavements are essential elements in their structural analysis and/or design using mechanistic-empirical models. Currently, resilient moduli are used to characterize subgrade soils and granular base materials for use as inputs to mechanistic-empirical pavement models and to assign layer coefficients for the 1985 AASHTO Guide for Design of Pavement Structures. The only standard laboratory procedure available at this time (Jan. 1986) for M_R testing is AASHTO T274. Unfortunately, the testing procedure is very time consuming and requires the services of highly qualified laboratory technicans who are competent in the use of the complex testing equipment. Consequently, numerous state agencies are not equipped to perform this test.

Statement No. 24 in TRB Circular 272 addresses the problem of complexity in materials characterizations in terms of learning through sensitivity analyses what levels of accuracy are required. The proposed simplification of the M_R testing is complementary to the research proposed by Statement No. 24. There is a general consensus for the need to develop simplified procedures to facilitate the evaluation of M_R values. Suggested approaches to the problem include:

A. The correlation of M_R (Ref. 1) with other more readily measured properties (e.g., grain size, LL, PI, etc.).

B. M_R computed on the basis of using the "total" cyclic axial strain from the repeated loading test (in lieu of strain between LVDT clamps).

C. Perform "unconfined" M_R (Ref. 2, pp 36-38) instead of "triaxial" M_R testing for cohesive soils.

D. Utilize rebound measurements (Ref. 4) from rapidly applied/sustained/rapidly released type of loading to eliminate necessity of measuring dynamic deformations.

E. Prediction of M_R from other mechanical testing procedures (direct or indirect).

III. OBJECTIVES - The primary goal of this research is to develop and evaluate simplified procedures suitable for establishing the resilient moduli of subgrade soils and granular base materials. Specific objectives are:

A. Collect, review and synthesize available data and information related to the topic.

B. Evaluate the most promising simplified procedures on the basis of (1) degrees of simplicity, and (2) prediction error. Comparative lab testing, in-situ tests, NDT field evaluation, and/or any suitable combinations of testing procedures may be used for this evaluation.

C. Recommend simplified procedures and develop guidelines for their appropriate utilization in the pavement design process.

IV. CURRENT ACTIVITIES

A. Suggested key words: resilient modulus, repeated loading.

B. Related research activities: Many highway agencies, research/testing laboratories and universities are presently engaged in the resilient modulus testing of granular base materials and subgrade soils, and virtually all such agencies will eventually need to be. Many "local" procedures of varying degrees of complexity and equipment requirements have been developed and utilized.

V. URGENCY - Resilient modulus testing is becoming the "standard" procedure for AASHTO based pavement design and mechanistic-empirical design procedures. Substantial investment in equipment and manpower will be required in the future to meet our need for resilient modulus testing. It is essential that standard procedures be adopted which are sufficiently accurate, manpower efficient, economical, and appropriate for pavement evaluation and design applications.

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PROBLEM NO. 20

I. NAME OF PROBLEM - EVALUATION OF DYNAMIC RESPONSE OF PAVEMENT STRUCTURES WITH REGARD TO CURRENT METHODS OF ANALYSIS

II. THE PROBLEM - The loads applied by traffic and by most deflection measurement devices on pavement structures are dynamic in nature. Up to the present time, analysis of the data obtained from dynamic loading has been based on either empirical approaches or static models. Empirical correlations are restricted to conditions similar to those from which they were originally developed, while the inertia of the pavement is not a factor in the static analysis. Pavement response to dynamic loading may be highly dependent on the frequency and/or the mode of loading. Several computer programs, which, in fact, are based on static analyses (such as Chevron, VESYS, BISAR,

BISTRO, etc.), are currently used in analyzing the dynamic response of pavement. Dynamic effects such as inertia forces, resonance and radiation damping of the multilayer pavement system cannot be incorporated in a static analysis. Moreover, replacing Young's modulus in a statical analysis by the resilient modulus or the dynamic modulus is insufficient to recover the inertial effect of the pavement static structure.

The inverse problem of determining material properties from the response of the pavement structure to surface loading (from nondestructive testing devices) has not been fully resolved. No direct theoretical solution is available in the literature to determine the material properties of a multi-layered system if the surface deflections and the layers thicknesses are known. Therefore, it is necessary to employ iterative schemes based on the fact that surface deflections remote from the loaded area are primarily governed by the stiffness of the deeper layers. The predicted material properties are very sensitive to minor changes in the surface deflections. Thus, under certain conditions, if a static analysis is used in back-calculation the material properties from dynamic surface deflections, significant error magnifications may result.

Also, the frequency-dependence of the dynamic reponse of pavements which can be measured using either variable cyclic loading or drop weight non-destructive devices, can be analyzed to determine the viscoelastic properties of each layer in a pavement. These properties have been found to relate directly to the fracture and permanent deformation properties of these layers, both of which would be very beneficial to determine directly from field tests; perhaps these may provide a direct method of estimating the remaining life of a pavement.

The performance of a pavement is governed by other factors including but not limited to the variation in moisture content in the subgrade, environmental conditions, construction practice, and nonlinearity of material properties, which are usually difficult to incorporate in theoretical analyses. Research is needed to evaluate the significance of considering the dynamic response of pavements with regard to other factors involved in the pavement performance

III. OBJECTIVES - The objective is to provide a rational, mechanistically-based interpretation of the response of the flexible and rigid pavement systems under dynamic loadings applied by traffic and deflection measurement devices. The effect of the inertia and the viscoelastic properties of the pavement system as well as the inertia of vehicles and deflection measurement devices should be considered under various modes of loading, material properties and layer thicknesses. The existing methods used to analyze the structural condition of pavements need to be evaluated with regard to dynamic methods of analysis. In addition, dynamic analysis techniques need to be verified on in-service pavement systems using independent measurements obtained by traffic and different deflection measurement devices. If dynamic analyses prove to be significant with regard to other factors involved in the pavement performance, computer programs, design charts and/or dynamic factors need to be developed to provide relatively easy and fast procedures that can be used by various highway agencies.

IV. CURRENT ACTIVITIES

A. Suggested key words: dynamic loading, pavement response.

B. Related research activities: Preliminary theoretical work (1-4) shows that pavement deflections generated by dynamic deflection measurement devices may be significantly different from those obtained under static loading conditions. Static analysis of dynamic pavement deflections may yield misleading results if the operating frequency of the loading device is approximately equal to the resonant frequency of the pavement system. The resonant frequencies of typical pavement systems fall within the common range of the operating frequency of the vibratory devices currently used. The effect of resonance, however, is reduced with a transient type of loading such as that caused by traffic and by the Falling Weight Deflectometer. The depth to bedrock was also found to be signficant in reflecting the waves generated by dynamic loadings. The evaluation of the out-of-phase response which results from the combined effect of the inertia forces and the material damping may be used to determine the viscoelastic properties of each layer.

Experimental research performed on in-service pavements (5-6) emphasizes the difference in pavement response under various modes of loading (static, harmonic and transient) and under various frequencies of harmonic loading.

VI. URGENCY - An urgent need presently exists to enable highway engineer to understand the nature of the dynamic response and the viscoelastic effect of the pavement system so that the rehabilitation of existing roads can be based on more rational concepts.

Estimated cost: $200,000

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5. M.S. Hoffman and M.R. Thompson, "Nondestructive Study of Selected Nondestructive Testing Devices," TRB, Record 852, 1982.

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A2B06

PROBLEM NO. 21

I. NAME OF PROBLEM - CRITERIA AND PRACTICAL ALTERNATIVES FOR RESTORING RUTTED PAVEMENT SURFACES

II. THE PROBLEM - Nationwide there appears to be an increasing concern with premature pavement rutting said to be accelerated by high tire pressures acting in combination with mix design factors which predispose mixes towards instability. Concern stems from transient loss of steering control as a vehicle moves sideways across the rutted pavement, and from the potential for hydroplanning on the substantial depths of water which may lie at the bottom of the rut.

Apart from these ruts, pavement serviceability may still remain quite high. Nevertheless because of safety concerns, rutted pavements need to be restored.

III. OBJECTIVES

A. Determine the factors which make ruts unsafe and propose criteria for restoring rutted pavements.

B. Assess the contribution of high pressure truck tires to the progression of rutting at sites in various climatic environments.

C. Discuss relative merits of different alternatives for restoring rutted pavements, including criteria for stability of mixes to resist future rutting.

IV. CURRENT ACTIVITIES

A. Suggested key words: flexible pavement, premature failure, high pressure tires, rutting

B. FHWA and the Texas Highway Department have initiated studies on rutting related to high tire pressure, and have sampled truck tire pressures. Other sources of information are probably available.

V. URGENCY - This appears to be rapidly emerging issue which should be addressed as expeditiously as possible. It is estimated the study could be accomplished for $500,000 in the three phases:

1. Literature review and study design,	$100,000
2. Field and laboratory work based on the study design above,	$300,000
3. Evaluation and report preparation,	$100,000

This work must be closely coordinated with the SHRP program. It is also recommended that a small advisory committee of State/FHWA personnel be included and their travel expenses funded as part of the project. Their role, to bridge the gap between research and practice, and to ease implementation of findings.

PROBLEM NO. 22

I. NAME OF PROBLEM - A SYNTHESIS COMPARING CURRENT PRACTICES IN VISUAL CONDITION SURVEYS AND DATA RECORDING SYSTEMS FOR TIMELY AND COST-EFFECTIVE MAINTENANCE

II. THE PROBLEM - Most states presently make some kind of visual condition survey either for a performance evaluation alone, or to supplement roughness, skid and other objective measurements. Each state has different pavement distress problems depending upon their pavement design, materials, traffic and environment.

To assess what steps are needed to arrive at some measure of uniformity, it would be useful to know and understand the various schemes currently used to report on visual surveys, their cost, effectiveness, and ease of use.

III. OBJECTIVES

A. Compile a synthesis comparing current practices in visual condition surveys and Data Recording Systems which are aimed at providing the data needed for timely and cost-effective maintenance.

B. Discuss requirements for uniformity.

IV. CURRENT ACTIVITIES

A. Suggested key words: visual condition survey, condition data systems

B. Related research activities: In formulating pavement management systems, agencies have to determine how visual surveys are to be used in decision making processes. Many agencies have already published visual condition system manuals.

V. URGENCY - A visual condition system which can be widely accepted for uniform reporting is of great value to all agencies for their pavement management system. The work may well be useful in the SHRP Long Term Pavement Performance activity.

PROBLEM NO. 23

I. NAME OF PROBLEM - AUTOMATED HIGH-SPEED PAVEMENT CONDITION DATA ACQUISITION AND EVALUATION SYSTEMS BASED ON IMAGE PROCESSING TECHNOLOGY

II. THE PROBLEM - Ideally pavement condition evaluation of highway systems for pavement management purposes should be based on detailed measurements of distresses over the whole length of each section in the network. However, evaluations are currently carried out in a variety of ways varying in preciseness all the way from on-the-run windshield surveys, through visual assessments at slow speed enhanced by detailed observation at frequent stops, to detailed measurements

within a short sample length repeated at intervals along the length of a road section. These less-than-ideal procedures are practiced because of cost and manpower savings. Because of these various procedures, there is also uncertainty associated with aggregating evaluations made in different jurisidictions.

Image processing technology would appear to be a feasbile approach to resolving this problem. Pictures of the pavement and measurements of roughness over the whole section, can be acquired at highway speeds. The pictures would be analyzed by standard algorithms to recognize and measure distresses and in combination with roughness measurements can be manipulated to produce an evaluation of condition of the section. Appropriate algorithms and software need to be developed and refined, as well as hardware for both acquisition and analysis.

III. OBJECTIVES - To examine the hardware requirements for acquiring the necessary data (pictures) at highway speeds, for analysis by image processing technology. Develop appropriate algorithms to recognize and measure pavement distresses, and create the necessary software to analyze the data, and evaluate pavement condition. Assemble the equipment, carry out necessary development work, and demonstrate the process.

IV. CURRENT ACTIVITIES

A. Suggested key words: image processing, pavement condition surveys, pavement management.

B. Reports on research work in the use of image processing for pavement condition evaluation carried out at the University of Nevada, Reno, and at the University of Waterloo, Ontario, were presented to TRB Committee A2B06, January 1984.

V. URGENCY - Many agencies are already using condition surveys for their pavement management systems, and others intend to use condition surveys in the near future. Automated data acquisition and evaluation systems based on image processing technology can, if available, enhance processes already in place and by the comprehensiveness of this new procedure convince other agencies to utilize condition surveys in their pavement management process.

PROBLEM NO. 24

I. NAME OF PROBLEM - CONSISTENCY OF HIGHWAY-RELATED DATA ACROSS TRANSPORTATION AGENCIES

II. THE PROBLEM - Data collection philosophies incorporated in current national programs conflict with traditional approaches employed by State Highway Agencies (SHA's). SHA's are accustomed to each having the freedom of choice regarding the pavement data items collected and the data collection method (type of test, evaluation equipment etc.). Developing national programs, such as FHWA's Long Term Monitoring (LTM) Pilot Project and the AASHTO Strategic Highway Research Program (SHRP), are stressing consistency of data items and collection

techniques across SHA's to insure that meaningful evaluations of the national system can be performed.

Documentation and recommendation resulting from national task forces stress the need for strong management of these programs to insure consistency of the data. Absence of this consistency renders the collected data ineffective for assessing performance of the national highway system. Discussions by SHA representatives at some of the TRB committee meetings suggest resistance on the part of the SHA's to requirements which would cause them to alter their current practices.

Some workable compromise to this conflict will be required to preserve the SHA internal programs and to insure success of the national programs.

III. OBJECTIVES - The objective of this research is to identify the requirements which would insure consistent data across SHA's. We could hypothesize that the two extremes are represented by (1) each SHA "doing its own thing" with the resulting total lack of consistency and (2) the same 4-person evaluation team with an "XYZ Measure-It-All" evaluation device collecting data on all the pavements in the country during a 2-hour period on a Thursday morning with apparent total consistency in the data.

The research team would have to quantify the midway point between the two extremes which would permit flexibility to the SHA's in controlling their data collection activities while preserving the integrity of the data bases being built for the national monitoring programs.

IV. CURRENT ACTIVITIES

A. Highway research in progress: Per the Draft Triennal Report for Committee A2B06, Monitoring, Evaluation, and Data Storage (report through 31 January 1985), there is an FHWA project addressing Research Problems No. 26 in the Transportation Research Circular Number 272 (February 1984). The research problem is Consistency of Highway Performance Monitoring System (HPMS) Data Across States. The project envisioned in this research needs statement would have a broader scope, looking at all types of data collected, stored, exchanged, analyzed, and reported by SHA's.

B. Suggested key words: pavement management, pavement monitoring, highway performance, data compatibility, standardization, condition evaluation.

V. URGENCY - Based on the presentations at the 1985 annual Transportation Research Board meeting and at the A2B06 committee meeting, this is recognized as a significant problem within the transportation community. It warrants immediate attention since we will continue to collect incompatible data until progress is made in this area.

A2C02

PROBLEM NO. 25

I. NAME OF PROBLEM - MATERIAL PROPERTIES OF HEAT STRAIGHTENED STEEL BRIDGES

II. THE PROBLEM: Every year several steel bridges are impacted by oversize loads. These impacts severely deform the lower flanges and webs of girder bridges and the intermediate members of truss bridges. An expensive method of repair is to replace the damaged girder which requires removal and replacement of the concrete deck slab. A less expensive method is to use heat straightening to restore the girder shape. However, there is a question about how the material properties of the girder are affected, particularly fatigue and strength.

III. OBJECTIVES - Determine the fatigue life and strength properties of heat straightened steel compared to regular steel for Grades A36, A572, and A588.

IV. CURRENT ACTIVITIES - Related work is being done at Louisiana State University.

V. URGENCY - Routine

A2C03

PROBLEM NO. 26

I. NAME OF PROBLEM - IMPROVED ESTIMATION OF PRESTRESS LOSSES IN EXISTING BRIDGE MEMBERS

II. THE PROBLEM - Recent testing of prestressed concrete bridge members removed from existing bridges had yielded information indicating that the actual loss of prestress in these members was considerably lower than that predicted by current estimation procedures. The observation implies that these members may possess higher load carrying strength than currently recognized, particularly regarding serviceability limitations. Improved estimation procedures are needed to achieve better agreement with information collected under realisitic service conditions.

III. OBJECTIVES - To develop improved procedures for the long-term estimation of prestress losses in existing bridge members.

IV. CURRENT ACTIVITIES

A. Highway Research in Progress Area 25 has been scanned in the preparation of this statement.

B. Bridges, prestressed concrete, structural analysis, shinkage, creep, relaxation.

C. None to the proposer's knowledge.

V. URGENCY - Results of this study would have a substantial impact on the evaluation of structural adequacy of existing prestressed concrete bridges. The more realistic evaluation of load carrying capacity of these bridges could lead to significant economy in the maintenance and operation of these transportation facilities.

PROBLEM NO. 27

I. NAME OF PROBLEM - FATIGUE BEHAVIOR OF TENDON ANCHORAGES AND COUPLING JOINTS IN POST-TENSIONED CONCRETE BRIDGES

II. THE PROBLEM - Stress ranges in uncracked fully prestressed concrete members are generally well below critical fatigue stress ranges of post-tensioning tendons (see report of ACI Committee 215, 1974). However, if partial prestressing is used or cracking occurs due to design inadequacies the cyclic stress range due to traffic and temperatue loading can increase signficantly. Lower grade steels used for tendon anchorages and couplers create sudden changes of geometry in the tendon and with it, stress concentrations and lower fatigue life limits for the built-in anchorage-tendon or coupler-tendon system. The lower fatigue life in these tendon areas is a potential danger for premature failure due to stress crack corrosion fatigue. European practice as reflected in the recommendations by the FIP Commission on Prestressing Steels allows less than 1/2 of the allowable stress range of the tendons in the anchorage or coupler tendon system. These recommendations were based on premature tendon anchorage failures in bridge structures.

III. OBJECTIVES - To develop AASHTO Standard Specifications for fatigue design of post-tensioned concrete bridges. Comprehensive Design Guidelines have to be developed to determine realistic cyclic loading ranges due to traffic and temperature effects on the possibly cracked bridge section. Stress limits for safety fatigue ranges have to be established, both for the tendon as well as for particularly sensitive components such as coupler-tendon and anchorage tendon systems.

IV. CURRENT ACTIVITIES - A major research effort in this area is underway in Europe (particularly West Germany, France and Switzerland) with pending code revisions for the design of intermediate anchorage and coupling zones of post-tensioned bridges. However, different traffic load conditions necessitate an independent research effort into U.S. conditions and to formulate the findings in conformity to U.S. design practice.

Related NCHRP research projects already concluded or still in progress are:

No. 4-7 Fatigue Strength of High Yield Reinforcing Bars

No. 12-30 Determination of Design Fatigue Load of Cable Stays

No. 10-29 Anchorage Zone Reinforcement for Post-Tensioned Girders

However, none of the above projects directly addresses the limited fatigue capacities of post-tensioned coupler and anchorage tendon systems.

V. URGENCY

A. Economical construction methods such as incremental launching or

span by span construction with travelling self supporting falsework rely on the utilization of tendon-couplers or intermediate tendon-anchorages with a reduced fatigue life.

B. Existing post-tensioned bridge structures which show excessive cracking have to be re-evaluated with respect to their increased cyclic stress ranges due to the sometimes significant stiffness deterioration.

C. Bridge rehabilitation and strengthening resorts to exterior tendons where the full cyclic traffic loads are transferred to the anchorages which necessitates proper design criterias.

The lack of design information for safe stress limits in tendon-anchorage and tendon-coupler zones as well as insufficient information on realistic cyclic design loads as shown by above examples suggests the immediate need for comprehensive design guidelines to ensure the structural safety of our post-tensioned concrete bridges.

PROBLEM NO. 28

I. NAME OF PROBLEM - DEVELOPMENT OF LARGER PRESTRESSING FORCES

II. THE PROBLEM - Results from a recently completed FHWA project entitled "Applications of High Strength Concrete for Highway Bridges" show that the span length of girders containing high strength concrete is limited by the available prestressing force. Higher forces can be obtained within a given cross-section by reducing clear distance between strands, reducing concrete cover or increasing tensile strength of strand. However, other problems may occur as a result of these changes.

III. OBJECTIVES - To determine methods of obtaining large prestressing forces within a given cross-sectional area without development of detrimental effects. Methods to be considered include closer strand spacing, less concrete cover, high strength steels, and special reinforcement details.

IV. CURRENT ACTIVITIES

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

B. Suggested key words: bridges, high strength concrete, prestressed concrete.

C. FHWA Contracts DOT-FH-11-9510 and DOT-FH-11-9598.

V. URGENCY - The greater availability of high strength concretes now makes it more feasible to produce longer span prestressed concrete girders. However, for maximum efficiency, methods to obtain high prestressing forces are needed. Successful implementation of the results will lead to reduced cost in bridge construction.

PROBLEM NO. 29

I. NAME OF PROBLEM - DISTRIBUTION FACTORS FOR MULTI-BEAM PRECAST CONCRETE STRUCTURALLY DECKED TEE-BEAM BRIDGES

II. THE PROBLEM - The present AASHTO bridge design specifications 1.3.1(D) have no value of "K" listed for precast concrete longitudinally-jointed double-tee, single-tee, or single bulb-tee structurally decked type bridges for determining live-load distribution.

III. OBJECTIVES - To determine application of the multi-beam precast concrete live-load distribution formula in AASHTO 1.3.1(D) to the various types of precast concrete structurally decked tee-beam sections available on the present market, i.e., double-tee, single-tee, and single bulb-tee beams.

IV. CURRENT ACTIVITIES - Precast concrete manufacturers and designers generally use the AASHTO Table 1.3.1(B), S/5.5 (multi-lane) or S/7.0 (single-lane), for live load distribution. However, multi-beam precast concrete structurally decked beams with longitudinal joints with intermittant weldaments and grout keys have not been proven to be transversly continuous when using a non-structural overlay wearing surface such as bituminous material. The application of distribution factors in AASHTO Table 1.1.3(B) is likely not good practice in the above-noted case. The live-load distribution formula found in AASHTO 1.3.1(D) is more applicable if an appropriate value of "K" could be developed.

V. URGENCY - With the increased frequency of replacement of bridges with short spans, the use of precast concrete structurally decked tee-beam sections are economically competitive and are being used by the smaller agencies and owers due primarily to eliminating the construction of a cast-in-place concrete structural deck. The development of appropriate design live-load distribution criteria is needed to keep pace with industry use of these products.

PROBLEM NO. 30

I. NAME OF PROBLEM - DEVELOPMENT OF GRAPHIC DESIGN AID TO COMPARE ACTUAL LOADS AND STRESSES WITH SINGLE GIRDER STRESSES FOR MULTICELL CONCRETE BOX GIRDER BRIDGES

II. THE PROBLEM - Detailed analysis of multicell concrete box girder bridges on sharp skews are generally computerized and are time consuming and costly to perform. Can a simplfied analysis be developed using a graphical solution?

III. OBJECTIVES

Figure 1.

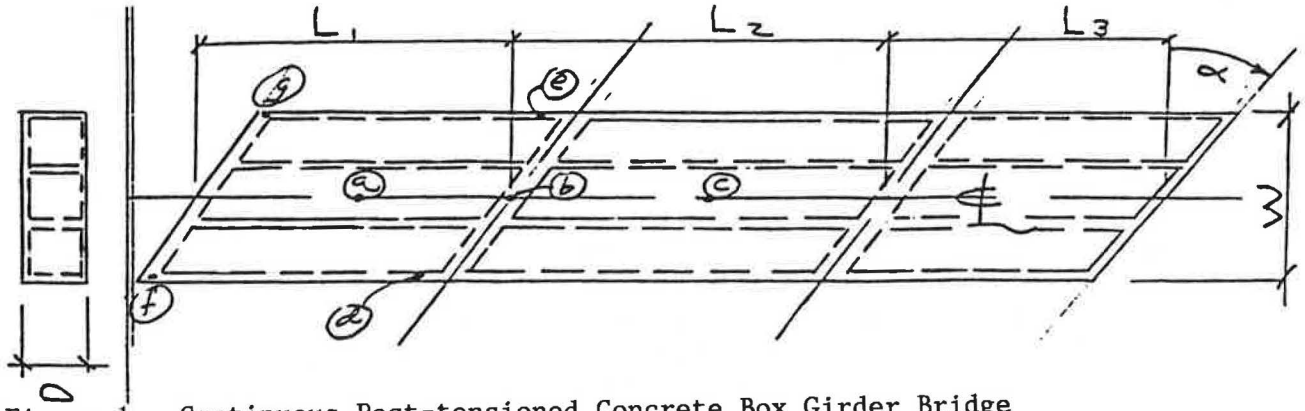
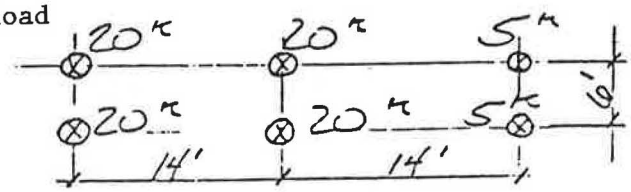


Figure 1. Continuous Post-tensioned Concrete Box Girder Bridge

To compare values for non-skewed (α=0) bridge, computed by conventional beam analysis with values for skew bridge, loading:

1. Gravity load (self weight)

2. Live load



45 T vehicle per lane (incls imp.)

no. lanes loaded = $\frac{w}{14}$

3. Post-tensioning: parabolic draped tendon through each web; effective force in tendon = 0.6 $f'_s A_s f'_s$ = ultimate strength of strand A_s = area of strands in tendon.

The following values are desired:

maximum positive moment at pt. (a)

maximum positive moment at pt. (c)

maximum negative moment at pt. (b)

maximum shears at pts. (d) and (e)

reactions at (f), (g).

The final results should show graphically the relationship:

$$\frac{\text{skewed bridge}}{\text{non-skewed bridge}} \quad \text{*values}$$

as f (α , w, L_1, L_2, L_3)

IV. CURRENT ACTIVITIES - None

V. URGENCY - Savings in manpower would be a long term result. In some cases over-simplified design procedures being currently used could be fine tuned to provide more efficient and longer lasting structures.

A2C06

PROBLEM NO. 31

I. NAME OF PROBLEM - EARTH LOADS ON CULVERTS DUE TO BACKFILL COMPACTION

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

III. OBJECTIVES

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

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

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

IV. CURRENT ACTIVITIES

A. Suggested key words: earth loads, culverts, backfill, compaction.

B. Other research in progress is unknown.

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

PROBLEM NO. 32

I. NAME OF PROBLEM - DESIGN LIVE LOADS FOR CULVERTS

II. THE PROBLEM - Current design specifications for culverts having a shallow depth of cover require that live loading be considered in the design and prescribe empirical procedures for distributing the static

wheel loads through the soil to the exterior envelope of the culvert. These loading requirements do not appear to be consistent with the physical reality of the installation and/or the nature of the actual loading, and in many instances these design procedures lead to appreciable increases in the strength of the culvert which may not be necessary.

III. OBJECTIVES

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

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

IV. CURRENT ACTIVITIES

A. Suggested key words: analysis, culverts, design, live loads.

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

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

PROBLEM NO. 33

I. NAME OF PROBLEM - LIFE CYCLE COSTS OF CULVERT STRUCTURES -- (LACK OF)

II. THE PROBLEM - Culvert designers and planners need an awareness of actual present value of life cycle costs for different culvert structure installations. Requirements for service life of culverts exist in the planning process of some governmental agencies. These service life requirements are not properly utilized because of budgetary fluctuations and various constraints such as:

A. Opposition from material manufacturers based on uncertain results.

B. Annual/biannual funding programs.

C. Variable funds from gas taxes and excise taxes.

D. Political decisions at federal, state and local level.

III. OBJECTIVES - To develop a computer program to equal which determines the life cycle costs of concrete, steel, etc., culverts. The program should include but not limited to the following factors:

A. Durability of culvert structures under erosive and corrosive environments.

B. Actual service life for each culvert material.

C. Guidelines for the design and construction of culvert structures.

D. Maintenance and repair costs over a common projected life span of the structures (50 years or other).

E. The optimum/minimum cost of each structure based on probability factors for inflation, interest rates and structural adequacy.

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

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

A2D01

PROBLEM NO. 34

I. TITLE - LONG TERM EFFECTIVENESS OF ANTISTRIPPING ADDITIVES IN ASPHALT CONCRETE

II. THE PROBLEM - There is a history of concern by highway agencies that all types of antistripping additives in asphalt may not have the desired long-term effectiveness for retention of satisfactory pavement life. The past use of laboratory moisture damage and stripping tests have been indicators, at best, for prediction of long-term effectiveness. Specifications developed from these tests have a disturbing degree of uncertainty. The current generation of laboratory predictive tests, such as the tensile splitting test employed with accelerated conditioning, appear to be more sensitive to additives and are conducive to long-term prediction of performance through employment of various accelerated conditioning methods, perhaps not now currently employed. The chemical-physical changes of the additive asphalt adhesive are not adequately known over a long time in the field, thus these effects cannot be translated to laboratory tests for the predictive long-term properties required by highway agencies.

III. OBJECTIVES

1. Develop and translate the chemistry of the aggregate-asphalt binder interface (interlayer) and of the non-interfacial interlayer to specific phases that take place from mixing to paving to years of pavement exposure in the field.

2. Develop test methods that produce these phases on an accelerated basis in the laboratory. The test methods should include verification of the existence that the representative chemical changes have taken place in the phases designated.

3. Develop and apply the resulting physical change measurements resulting from the chemical changes in the phases, and translate them to basic internal mechanical property changes of the asphalt concrete. Relate these measurements to asphalt concrete field life changes based on moisture resistance of moisture susceptibility.

4. Evaluate above phases relative to a research program incorporating various types of antistripping additives applied in the asphalt or on the aggregate surfaces. Several liquid additives are to be investigated, including older generation and current generation additives. Lime and portland cement are also to be investigated. Determine the pertinent chemical-to-physical property to mechanical property changes that occur in the phases due to additive type, and show their contrast to untreated (non-additive) asphalt binder. Parts of asphalt concrete mixtures may be used, but completely comprised asphalt concrete mixtures shall be used for mechanical properties.

5. Develop an applied method from the research to both modify the accelerated conditioning of laboratory predictive moisture damage test(s) and suggest test result specification levels for ensuring long term moisture damage resistance of asphalt concrete containing antistripping additives.

IV. CURRENT ACTIVITIES

1. Suggested key words: chemistry of asphalt-aggregate interface; additive-asphalt-aggregate bond; accelerated moisture conditioning; mechanical property changes and freeze-thaw cycles; adhesion and cohesion change.

2. Related Research Activity: chemistry of asphalt-aggregate interface (Western Research Inst. at Laramie); saturation and accelerated conditioning of asphalt concrete (Univ. of Idaho, Chicago Testing Laboratory); multiple freeze-thaw cycling (Univ. of Idaho, Carstab Div. of Morton/Thiokol Corp., Western Research Inst. at Laramie, Univ. of Texas); adhesion-cohesion change parameters (Univ. of Idaho, Carstab Div. of Morton/Thiokol Corp.)

V. URGENCY - Significant funds are spent by highway agencies on additives to combat field resistance of asphalt concrete to moisture damage.

Moisture damage appears to be an increasing problem resulting in shortened pavement life. Past and current field test sections with additives and controls have not led to conclusions based on scientific long-term field performance of additives. The lack of what to measure is of concern, as well as how to apply laboratory tests and develop specifications to select only quality additive products that provide long-term satisfactory field performance. A well-conceived laboratory research program that will result in applied methodology and guidelines for highway agencies is now timely and cost effective. Scientific field verification experiments could follow as a separate research project.

A. Project length and cost: 3 yr.; $250,000 (est.)

PROBLEM NO. 35

I. TITLE - METHODS TO MINIMIZE RUTTING IN ASPHALT CONCRETE PAVEMENTS

II. THE PROBLEM - Rutting is one of the leading causes of early failure in asphalt concrete pavements. Asphalts that are too soft, slow setting or highly temperature susceptible can contribute to rutting. Aggregates that are predominantly rounded and smooth textured, contain excessive sand-sized particles or insufficient filler or consist of small top-size particles have been associated with rutting. Chemical reactions between asphalt and aggregate fines in the presence of heat can change the rheological properties of asphalt cement. Paving mixtures containing excessive air voids, voids in the mineral aggregate or foreign materials (such as unburned liquid fuels or liquid antistripping additives) or mixtures that are water susceptible are candidates for rutting. Other considerations include mixing plant types, traffic, environmental and geographical factors.

III. OBJECTIVES - Assemble and analyze significant publications and data regarding rutting in asphalt pavements and prepare a concise document for implementation by highway departments. Rutted and non-rutted pavements across the U.S. should be critically analyzed to accurately determine the source of rutting (subgrade, base or surface). If rutting is in the flexible pavement courses, further investigation should be conducted. Collect samples and data from rutted and non-rutted pavements and conduct carefully coordinated laboratory and field experiments to isolate the cause(s) of rutting. Seek new approaches (tests, standards, techniques and specifications) to identify and control rut-prone mixes. For example, develop stress-strain relationships to be considered in mix design that reflect pavement strengths and demands by traffic and the environment. Develop realistic mathematical models to predict rutting.

IV. CURRENT ACTIVITIES

A. Suggested key words: asphalt concrete pavement, rutting, permanent deformation, plastic deformation

B. Related Activities: Concerns of WASHTO have precipitated two

NCHRP studies which indirectly address rutting: (1) Development of Asphalt-Aggregate Mixture Analysis System and (2) Mechanistic-Empirical Pavement Design Methods. These studies began in 1986. The University of Kentucky developed PAVRUT in 1985. PAVRUT is a model (based upon one mixture) designed to predict pavement rut depth. Based upon preliminary results from the Texas A&M University, certain additives may provide important contributions toward methods to control rutting.

V. URGENCY - In 1984, WASHTO stated that in some states rutting in asphalt concrete pavements "is the most pressing issue presently facing the highway agencies." Findings of this research should be used to develop a concise document for use by highway agencies as a guideline to reduce the probability of rutting in asphalt concrete pavements.

A2D02

PROBLEM NO. 36

I. TITLE - THE EFFECT OF MINERAL FILLERS ON ASPHALT MIX PROPERTIES AND PAVEMENT PERFORMANCE

II. THE PROBLEM - Asphaltic pavements are being placed with fewer fines in the mix than have been placed in years past. The effect of these changes on asphalt concrete field performance has not been fully documented. Throughout the last couple of paving seasons, there has been an increased frequency of reported pavement failures due to rutting and other plastic deformations.

Mineral fillers have been shown to substantially affect the viscoelastic properties of asphalt cements. The viscosity of the asphalt cement affects the stiffness of the asphalt concrete. The mineral fillers can stiffen or extend an asphalt cement or do both. A certain amount of mineral filler is needed in an asphalt mix for stability. A lesser amount of mineral filler can cause stability problems, as well as an increased asphalt demand to meet voids filled with asphalt (VFA) specifications. The increased mix asphalt content can also cause stability problems such as rutting. Inadequate compaction of the asphalt mix due to the stiffening effect of the mineral filler can also result in rutting and other problems.

Research has shown that the effect of the mineral filler on an asphalt cement varies by mineral type, mineral filler bulk volume and asphalt plant type. Less is known about the effects of mineral filler on the asphalt cement temperature susceptibility (VTS), asphalt mix compactability and fatigue.

III. OBJECTIVES

A. Determine the effect of mineral filler source, mineral type, quantity, and gradation upon the compactability of an asphaltic mix. Compactability to be measured by gyratory compactor.

B. Determine the effect of mineral filler source, mineral type,

quantity, and gradation upon asphalt viscosity temperature susceptibility (VTS), and how this relates to compactability.

C. Determine the effect of mineral filler source, mineral type, quantity and gradation on the creep properties of asphalt cement concretes from low temperatures (0°C) to high temperature (60°C).

D. Determine the effect of mineral filler source, mineral type, quantity, and gradation on the dynamic moduli and fatigue lives of asphalt cement concretes.

E. Determine the correlation between the laboratory studies described in objectives, A,B,C, and D and in service pavement performance:

1. during construction,
2. after pavement is opened to traffic,
3. after each year in service.

IV. CURRENT ACTIVITIES -

A. Suggested key words: mineral filler, viscoelastic properties, compaction, asphalt temperature susceptibility (VTS), fatigue life, rutting, pavement distress.

B. There is no known comprehensive research on the problem. Various research studies in the United States and abroad have been completed on certain specific aspects. However, a comprehensive and systematic plan is needed to provide research direction.

V. URGENCY - Congress is passing legislation to increase the allowable truck loads on interstate pavements. Truck tire manufacturers are developing truck tires with higher allowable pressures. Both of these activities result in more stress of a nature that tends to plastically distort the asphalt cement concrete resulting in rutted pavement surfaces. Rutting affects the pavement in both safety and in cost of repair. Therefore, the results of this research are needed to determine the quantity of mineral filler needed to provide a stable asphalt pavement surface under increased highway loadings and also provide a long asphalt pavement service life.

A2D03

PROBLEM NO. 37

I. NAME OF PROBLEM - ASPHALT MIX DESIGN CRITERIA FOR HEAVY TRAFFIC PAVEMENTS

II. THE PROBLEM - Premature pavement failure due to rutting is a major problem in many jurisdictions, (the problem of rutting involves the reduction of riding safety as a result of loss of surface friction and vehicle steering stability). As truck traffic and tire pressure are on the increase, pavement rutting is expected to be more widespread.

Present design criteria, e.g., Marshall properties, do not address the rutting potential of mixes sufficiently. A new set of criteria has to be developed which may involved tests not currently in routine use.

III. OBJECTIVES - The objective is to develop a set of design criteria/requirement which ensure that mix design used are adequate (e.g., not over or under designed) for the heavy loading conditions.

IV. CURRENT ACTIVITIES

A. Suggested key words: rutting, axle loadings, tire pressure, design criteria.

B. The Italian Ministry has a specification for deformation criteria based on the creep test. Ontario MTC is looking into the use of ASTM 3387 method as a possible candidate.

V. URGENCY - The problem is getting more intense each year with more mixtures being put down with certain quality of resistance to rutting. There is an urgent need for these design criteria.

A2E03

PROBLEM NO. 38

I. NAME OF PROBLEM - CERTAIN CEMENT VARIABLES AND THEIR EFFECT ON CONCRETE

II. THE PROBLEM - Cement variables are among the major causes of variation in concrete. These variables occur from a single cement source and increase from multiple sources. Foreign cement imports are steadily increasing due to our changing world economy. The use of varying cement in concrete will increase the difficulty of concrete quality control unless the key cement variables can be determined and reaction methods developed for its use in concrete.

III. OBJECTIVES - It is urgent to develop the relationship of certain cement properties to concrete performance so early determination can allow concrete producer time to react in a quality control program.

Investigate the chemical and physical properties of cement to isolate those which most influence concrete variability in the fresh and hardened state. The concrete variables include water demand, setting times, strength and others. Chemical admixtures and pozzolans offer possible solutions.

IV. CURRENT ACTIVITIES - No search of HRIP has been made.

A. Suggested key words: cement properties, effect on concrete.

B. Related research: N.B.S. Study BSS-2 (1965)
Blaine, Arnie, et.al.
Also, papers by NRMCA and PCA on subject
Fragmented industry research.

V. URGENCY - Over the past ten years the increasing imports of cement, changing cement production (e.g., dry process, coal and other fuel, additions, etc.) and concrete producers using more cement sources have been more apparent. The effect of these inherent cement variables on concrete performance can be better accommodated, if greater reaction knowledge is available to the concrete producer.

A one-year program at a lab such as N.S.B., with five to eight people assigned, should develop sufficient data to provide the concrete construction industry great benefit. Cost may be $300,000 to $500,000.

A2E03

PROBLEM NO. 39

I. NAME OF PROBLEM - SANDWICH PAVEMENT WITH ROLLER COMPACTED CONCRETE

II. THE PROBLEM - The expense of conventional concrete pavements is related to its high cement content, the cost of clean quality aggregate, and base requirements. Performance problems include edge and corner curl, loss of strength from fatigue, and internal shrinkage stresses. Steel fiber reinforced pavements have exceptional fatigue and impact resistance properties, but they are very expensive when placed at thicknesses that minimize curl. Pavements with roller compacted concrete can use less cement and less expensive aggregate, but fatigue life is not necessarily enhanced and the surface is unsuitable for most highways from the standpoints of durability and finish or ride quality.

Better and less expensive concrete pavement systems using less cement and less expensive aggregate are needed which minimize shrinkage stresses, improve fatigue performance, require less base support, and control curl.

III. OBJECTIVES - Analyze, design, construct, and monitor a pavement utilizing the technical advantages of fiber reinforced concrete combined with roller compacted concrete. The section should be designed to benefit from the economy of roller compacted concrete. This can be accomplished by companion pavements with one "sandwiching" roller compacted concrete between two thin layers of fiber reinforced concrete, and one simply topping the roller compacted concrete with fiber reinforced concrete. The time interval between placing the layers would be short enough so that the mixes bond together as a monolithic mass without a joint line. The pavement should be placed on an inexpensive base but have sufficient thickness to carry many passes of heavy traffic.

IV. CURRENT ACTIVITIES

A. Highway and related research in the areas of concrete pavements, curl, shrinkage, and cracking has been reviewed. This particularly included performance, economics, fiber reinforced concrete, and roller compacted concrete.

B. Suggested key words: concrete pavement, curl, economics, fatigue, fiber reinforced concrete, pavement, performance, roller compacted concrete.

C. Limited basic research showing the practicality and potentially excellent performance of combined fiber reinforced and roller compacted concrete has been presented in TR Record 1003, "Composite Concrete Pavements with Roller Compacted Concrete." This concept was presented at the January 1984 TRB meeting and was videotaped in condensed version as being an interesting topic with high potential for value to the transportation community. Adequate basic research has been done and published individually for fiber reinforced concrete and roller compacted concrete mix design and material properties. Sufficient information is available to allow design of compatible mixes which can then be evaluated separately in the lab and in combination using a full-scale demonstration or test section.

V. URGENCY - The demonstration, with adequate testing and monitoring, is urgently needed. Preliminary work shows that it very well could result in an immediately usable method of design and construction for more economical concrete pavements having better performance, less shrinkage (with its related cracking and close joint spacings), better impact resistance, improved fatigue life, and less edge curl.

PROBLEM NO. 40

I. NAME OF PROBLEM - MECHANICAL PROPERTIES OF HIGHWAY REPAIR CONCRETES AT EARLY AGE

II. THE PROBLEM - The age at which repaired concrete pavements and bridge decks are opened to traffic, and the length of the season over which repairs can be done, usually are controlled by the compressive strength of concrete cylinders made from the repair materials and cured at ambient temperature. The minimum strengths that are specified are believed to be adequate to withstand the maximum stress that the repair will be subjected to at an early age, but not so high as to require uneconomical mixture proportions, unreasonable lane closure times or restrictions on construction. Unfortunately, there is very little information on mechanical properties of concrete at early age (<24 hours) to aid the engineer in making a reasonable decision.

Research should be directed to the collection of data on the mechanical properties of repair concrete at an early age as determined by a number of methods including but not limited to nondestructive tests, compressive test on cores, compressive tests on cylinders cured by temperature matched curing, or at ambient temperature, and flexural, tensile and bond tests on specimens cured under different conditions. The relationship among the values obtained by these methods should be studied.

III. OBJECTIVE - The objective of this research is to develop data on the mechanical properties of typical highway repair concretes at ages from final set to 24 hours.

IV. CURRENT ACTIVITIES - The ACI Committee on Hydraulic Cement (225) recently sponsored two sessions on the properties of concrete at early ages. However, highway departments need more information, particularly on mixtures used in pavement and bridge repair.

V. URGENCY - The repair of concrete pavements and bridge decks has increased in recent years and is now a major part of the maintenance expenditures of transportation agencies. The research is urgently needed so that money is not wasted through specifying higher than needed early strength materials and mixtures proportions or by damaging repairs by loading them prematurely or not curing them adequately. It is difficult to quantify the benefits from the research. The research should lead to more economical repair mixtures and construction procedures, to more reasonable lane closure time and to a reasonable compromise between early needs and long-term performance.

PROBLEM NO. 41

I. NAME OF PROBLEM - BOND STRENGTH OF CONCRETE REPAIRS

II. THE PROBLEM - The repair not only of bridge decks but of the substructures of bridges involves the use of many repair materials both proprietary concretes and job produced materials. An important characteristic of these repairs is that they shall be well bonded to the substrate. A test procedure is therefore required that can be carried out in the field to check whether or not good bond is being achieved in these repairs.

III. OBJECTIVE - The research objective is to determine by a combination of laboratory tests and field tests a portable in-situ test method which can be used to determine the bond between repair concretes and the parent concrete in a structure.

IV. CURRENT ACTIVITIES - We have recently been involved in a literature search with regard to the repair of bridge decks and substructures, and find there is little published on this subject. However, a test procedure is under development to measure the bond strength of concrete overlays by means of an uniaxial tension test. Two variations are being studies, one applicable to the laboratory, and one to the field. The two should be correlated.

V. URGENCY - We believe that particularly with attention now focusing more on the bridge elements other than the deck, this aspect of repairs will become more and more important. At this stage it is not possible to estimate a cost to accomplish this objective.

PROBLEM NO. 42

I. NAME OF PROBLEM - FRACTURE TOUGHNESS OF CONCRETE

II. THE PROBLEM - Cracking is a major problem for highway pavements and structure. Cracks may be induced due to loading or due to differential movements. To improve resistance of concrete to cracking

we need to know the relationship between porosity, pore size distribution and fracture processes. There is some indication that tensile strength of concrete is related to not only porosity but also to size of the pores.

Crack-resistance of concrete can be improved by addition of fibers, polymer latex, by decreasing water-cement ratio and by addition of fine mineral admixtures. To evaluate relative merits of these various alternatives, we need a rational method to evaluate fracture toughness of concrete.

III. OBJECTIVES

A. To determine how the resistance to crack initiation and propagation (fracture toughness) is related to pore structure and microstructure of concrete.

B. To determine a method to evaluate fracture toughness.

C. To determine relative merits of various alternatives (fibers, latex, mineral admixture) of improving fracture toughness.

V. URGENCY - Concrete cracking (regardless of the cause) is a major problem. To improve performance of concrete we must know how to measure the resistance to cracking and how to improve it.

PROBLEM NO. 43

I. NAME OF PROBLEM - FREEZING-AND-THAWING RESISTANCE OF VERY HIGH-STRENGTH CONCRETE (W/C <0.30)

II. THE PROBLEM - The use of high-strength and very high-strength concrete is becoming more commonplace. Data are needed on the performance of these concretes (without-entrained air) in ASTM test C 666 Procedure A.

III. OBJECTIVES - Develop data on high strength concrete (without entrained air) by ASTM C666.

IV. CURRENT ACTIVITIES - Some research work is being done in the U.S.A. (WESS) and Canada (CANMET), but data are limited and are not conclusive.

V. URGENCY - Data are needed because of the potential for use of these concretes in highway structures - Estimated cost $40,000

PROBLEM NO. 44

I. NAME OF PROBLEM - NDT DETERMINATION OF STRESS IN TENDON

II. THE PROBLEM - In a variety of prestressed concrete structural members, both precast and cast in place and both pre-tensioned and post-tensioned, there comes on certain occasions a need to know the state-of-stress in the tendon. If the need to know this has been anticipated sufficiently in advance of construction, the tendon may be equipped with one or another sort of suitable strain gages that can be

read remotely at a later time to provide the desired information. However, if the need for the information was not anticipated before construction and the tendon equipped with a suitable strain gage, apparently the only available approach is through the use of nondestructive testing (NDT) methods. Theoretically, the velocity of propagation of some sort of quantum of energy down a tendon may be expected to vary with the state-of-stress in the tendon; however, this is not regarded as likely to be a productive procedure in the present instance. The use of pulse echo techniques where a quantum of energy enters the concrete in a direction perpendicular to the length of the tendon and, in effect, acts as an impulse to cause the tendon to function as a vibrating wire has been tried to a limited extent and found not readily effective.

III. OBJECTIVES - The objectives are incorporated in the statement of the problem.

IV. CURRENT ACTIVITIES

A. HRIP areas have not been scanned.

B. Suggested key words: prestressed concrete, nondestructive testing, state-of-stress, prestressing tendons.

C. Since HRIP has not been scanned, related research activities found therein cannot be discussed. The only related research activity known to the preparer is work done some years ago with funding by the AEC/ERDA/NRC/DOE in connection with prestressed concrete nuclear reactor containment vessels where vibrating wire strain gages were investigated as devices to be attached to post-tensioning tendons so that stress lost due to concrete creep and tendon relaxation could be monitored after construction. Such work was regarded as particularly relevant to the use of unbonded tendons where the opportunity for restoring the stress level by additional jacking at later ages was available.

V. URGENCY - So far as I know this questions has come up on several occasions and it is regarded as urgent by the bridge engineer or other official who is frustrated by his inability to get the information he wants. However, the preparer of this problem statement is unable either to speculate on how widely the need for the technique exists whether the technique can be provided through research or if it can be, how much it would cost either to solve the problem or determine that it can't be solved.

A2E05

PROBLEM NO. 45

I. NAME OF PROBLEM - LONG-TERM DURABILITY OF PORTLAND CEMENT-FLY ASH CONCRETE PAVEMENTS

II. THE PROBLEM - Some surface scaling problems have occurred particularly with some mix designs using fly ash for concrete highway pavements.

Specifically surface salt scaling problems in Virginia have been noted and problems associated with measurements of air content have been recorded when using fly ash in highway pavements, particularly with higher dosage rates.

III. OBJECTIVES - The objective would be to develop an improved standard method for pavement durability measurements to assure that a realistic field validated procedure is utilized in areas where both de-icing salts and freezing and thawing conditions produce potential surface scaling problems in PCC pavements.

A. New designs must be investigated that will minimize freeze-thaw and salt scaling damage.

B. Suggested key words: concrete pavements, durability, freeze-thaw, salt scaling, fly ash, Class F, Class C, de-icers, permeability, chlorides.

IV. CURRENT ACTIVITIES

A. Highway research has been conducted on this subject for many years but limited information is available regarding various mix designs of fly ash concrete for PCC pavements. This lack of information is particularly true for high lime, Class C fly ash and the intermediate lime fly ashes.

B. The implementation of Guidelines for the Use of Fly Ash in Concrete by FHWA raises the awareness of DOT personnel to the question of whether fly ash concrete pavements has the same, better, or worse long-term durability as non-fly ash portland cement concrete pavements.

C. Research at Penn State is studying pastes/mortars containing Class C as well as Class F fly ash. The research is investigating the porosity and permeability to chlorides (FHWA/RD-81/119) of pastes/mortars at specific ages.

D. The Illinois DOT is investigating the scaling of fly ash concrete vs. portland cement concrete. The surface of the concrete and its relationship to mix design may be important.

V. URGENCY - The study of durability of concrete pavement is considered highly important to the expanded utilization of fly ashes as a component in PCC pavement construction. Under the SHRP program for portland cement concrete studies, there is an agreed need to develop improved durability testing procedures and equipment to speed up the process of making accurate measurements of durability. The expanded use of fly ash as a pozzolanic portland cement concrete should indicate that such a study is important to improve long-term pavement performance.

PROBLEM NO. 46

I. NAME OF PROBLEM - CONCRETE CURING, EVALUATION, AND FUTURE DIRECTION RELATED TO HIGHWAY CONSTRUCTION

II. THE PROBLEM - Curing of concrete leads to more durable, frost, and wear resistant highway surfaces. However, the most efficient and effective means of curing remains the subject of much debate. The industry needs acceptable laboratory and field testing techniques in order to evaluate curing compounds and curing methods. Data from tests of this nature can be used as an aid in developing better concrete highways and related structures.

III. OBJECTIVES - The objective is to draft a position paper on curing compounds and curing methods related to highway concrete construction. The scope should include development of acceptable field testing techniques to evaluate curing compounds and curing methods; the determination of the effectiveness of existing curing methods and curing compounds; and the specific application to highway surfaces (tined, untined, horizontal, vertical). Future direction with respect to innovative methods should be of special interest.

IV. BACKGROUND INFORMATION - Several curing methods like wet burlap cure, polyethylene cure, burlene cure and liquid membrane cure (curing compounds) are used to cure highway concrete surfaces. However, some questions about curing compounds and curing methods are unanswered.

No test methods are available to evaluate performance (effectiveness) of different curing compounds. Optimum composition and ingredients of liquid membrane forming compounds to obtain least possible water loss (less than 0.55 Kg per meter square) is not known. The current practice is to tine the highway concrete surfaces which results in increased surface area. However, the same quantity of curing compound is generally applied on the tined area as was being applied on the untined area. Whether the effectiveness of various curing compounds and curing methods depends on temperature, water content, surface texture, wind velocity and humidity or not is unknown. Research in the above mentioned areas will help to decide the effectiveness of various curing methods and curing compounds. Also, it will enable one to tell which curing method to use for a particular construction environment and which curing compound to apply if it is decided to use liquid membrane curing methods.

V. CURRENT ACTIVITIES - Numerous programs for evaluating and specifying concrete curing compounds are published in the literature. Little study is being made to determine the practical value for improved highway durability and service life.

VI. URGENCY - A study of means to improve concrete highways through cost effective curing is important for long range concrete serviceability.

A2F01

PROBLEM NO. 47

I. NAME OF PROBLEM - PAVEMENT SHOULDER DRAINS

II. THE PROBLEM - Many concrete pavements are damaged by surface water infiltrating through transverse and longitudinal joints and cracks

that have lost their seal. Because of the lack of positive drainage the water remains under the slab the same as it would in a "tub." Often damage is extensive before re-sealing. Additional work is then necessary to make the pavement structurally sound.

III. OBJECTIVES - The research objective would be to design a shoulder drainage system that would eliminate the "tub" effect and allow the base to drain. The design would be practical, mostly maintenance free, and non-damaging to the existing bases, subgrade soils and shoulders. Prior any actual laboratory or field studies the initial phase would be a literature search and a summation of the information available. In addition a questionnaire would be sent to the states concerning the use of subdrains, effectiveness, etc. It is anticipated that on the basis of this review actual drainage systems would be designed and installed to determine which are the most effective. These designs would then be available so that agencies could use them on new as well as existing concrete pavements.

IV. CURRENT ACTIVITIES - Many states are using drainage systems, however, there is some question as to their actual effectiveness. Most states have not reported on the success or failure of their design.

V. URGENCY - While it is not the intention of this research to "re-invent the wheel" it is believed that a positive system can be developed. Perhaps through a literature search and field installations a design can be developed that will help eliminate the "tub" effect caused by the infiltration of water and its inability to get away from under the slab. Since much money is being spent or about to be spent on drainage systems of questionable effectiveness, it would be beneficial to the industry to develop a design that does work.

A2F02

PROBLEM NO. 48

I. NAME OF PROBLEM - DRYING BITUMINOUS AGGREGATES WITH COAL

II. THE PROBLEM - For the last 50 years liquid petroleum (#2 thru #6) has been the primary fuel used in drying bituminous concrete aggregates. Since the fuel crisis of the "70's" this source has, even at today's alleged depressed prices, increased in cost approximately 800 to 900%. In addition there has been and probably will again be serious concerns of supply as we depend more on imported fuels.

Environmental considerations also mandate the use of lighter fuels that contain lower concentrations of undesirable chemicals. The use of these lighter fuels also impacts costs.

III. OBJECTIVES - Minimum research objectives would be:

A. Determine monetary savings in fuel material.

B. Calculate capital expense and maintenance cost.

C. Study environment impact - stack emissions, filter bag deterioration, possible noise pollution.

D. Possible effects of residual fly ash on bituminous concrete mixes.

IV. CURRENT ACTIVITIES - Economics - Conservation - Environment

There are approximately 50 coal burners installed on bituminous concrete plants in the United States. Although there is limited published information available there undoubtedly exists significant data that would be available particularly in the area of economics and environment.

V. URGENCY - Considering the potential economic and environmental benefits that may be derived from research on this subject, it would have to be considered a priority topic. In published form, the research data could be instrumental in changing the current and conventional aggregate drying process.

PROBLEM NO. 49

I. NAME OF PROBLEM - EVALUATE THE ABILITY OF LABORATORY TESTS TO PREDICT FIELD PERFORMANCE

II. THE PROBLEM - Results from a number of laboratory tests are currently being used to predict or to evaluate the performance of asphalt concrete mixtures. Sometimes these test results are used directly and other times adjustments are made to reflect more accurately the differences between laboratory and field conditions. In order for these methods to be used in a consistent fashion, there is a need to develop a methodology for predicting field performance based on these laboratory tests.

III. OBJECTIVES

A. To identify the models, including structural properties, most successfully used to predict field performance of asphalt concrete pavements.

B. To evaluate the range of material properties for which each model accurately predicts field performance.

C. To recommend the most cost-effective model(s) for use by states to predict accurately the performance of in-service pavements.

IV. CURRENT ACTIVITIES

A. Suggested key words: fatigue testing, permanent deformation, rutting, fracture, creep testing, field performance, healing.

B. Recent research on these topics has been conducted at Texas A&M University by both Lytton and Little, at Brent Rauhut Engineering on modifications of VESYS, at the U.S. Army Corps of Engineers, at the University of Illinois, and at numerous other institutions.

V. URGENCY - In order to plan effectively for rehabilitation action on major highways, a system for reliably estimating performance and the attendant distresses is urgently needed. Research results could be immediately implemented for those states that adopt the new alternative AASHTO procedures that are based on rational principles of pavement design.

PROBLEM NO. 50

I. NAME OF PROBLEM - EVALUATION OF STRIPPING PROBLEMS UNDERNEATH POROUS FRICTION COURSES AND SLURRY SEAL TREATMENTS

II. THE PROBLEM - Porous mixtures have been used extensively on highways and airfields to improve skid resistance in wet weather. The mixtures have improved skid resistance during wet weather and resulted in a reduction in the number of accidents. Slurry seal treatments are used in a attempt to renew the wearing surface and seal out water, thereby extending the life of the pavement. Some State Highway Departments in the Southeast have stopped using porous mixtures because of apparent stripping problems in the asphalt concrete underneath the porous mixture. Also, acceleration of stripping has been observed under slurry seals. The stripping problem is believed to be caused by water sealed beneath the porous friction course or slurry seal. Research is needed to investigate this problem and to recommend, if applicable, procedures for preventing stripping beneath porous mixtures and slurry seals.

III. OBJECTIVES

A. To determine the cause of stripping problems underneath porous mixtures and slurry seals.

B. To recommend design and/or rehabilitation techniques to insure improved performance of porous mixtures and slurry seals under heavy traffic conditions.

IV. CURRENT ACTIVITIES

A. Suggested key words: porous friction course, slurry seal, stripping, mix design, and asphalt concrete.

B. Work has been done in this area by the Federal Highway Administration, U.S. Army Corps of Engineers, Asphalt Institute, and various state Departments of Transportation.

V. URGENCY - The use of porous mixtures has provided safe travel for motorists especially in times of wet weather. Slurry seal treatments have been used in an attempt to prolong the life of the wearing surface. Problems with performance under heavy traffic need to be determined and corrected so that the use of porous mixtures and slurry seal treatments can be cost effective when compared with other rehabilitation techniques.

A2F04

PROBLEM NO. 51

I. NAME OF PROBLEM - FACIA GIRDER DAMAGE ON BRIDGES

II. THE PROBLEM - Overheight vehicles and vehicles with overheight loads (sanding trucks with raised dump bodies) are doing considerable damage to facia girders on Highway Bridges. Interior girders, diaphragms and slabs are also affected. As designs evolve resulting in lighter members, the problems experienced are exacerbated and could result in structure failure as well as increased cost.

III. OBJECTIVES - To determine the magnitude of the problem in terms of cost and damage consequences and develop design, repair and investigation techniques.

IV. CURRENT ACTIVITIES - Recognition of the problem has led to various schemes to warn drivers of overheight vehicles, however, there does not appear to be an organized research effort at this time.

V. URGENCY - Certainly design criteria for lateral impact of facia girders is needed now and suitable repair techniques and damage influence measurement techniques could be immediately implemented in view of R&R expenditures priority.

PROBLEM NO. 52

I. NAME OF PROBLEM - BRIDGE SLOPE PROTECTION

II. THE PROBLEM - Slope protection under and adjacent to bridges has been constructed in a number of different ways in recent years. In a few situations no protection at all is provided; but normally a concrete poured in place, concrete block, or loose stone is used. It is often difficult to discern when one type slope protection is used in lieu of another except when cost may be the deciding factor. It is not unusual, however, to see similar bridges in similar locations that have entirely different slope protection designs. It is also not unusual to see both concrete and block slope protection systems that have been undermined or that have otherwise experienced considerable movement, cracking, and other such failures that have required maintenance or, at least present an unsightly appearance.

III. OBJECTIVES - The objectives of the research will be to identify the general site conditions and other considerations which would indicate the use of certain types of bridge slope protection. In addition, the general hydraulic design for handling runoff from the bridge deck, approach roadway, and on or around the slope protection should be developed. Construction techniques should be developed that will minimize movements and failures in the various types of slope protection available for use.

IV. CURRENT ACTIVITIES - No work in this area is being conducted to the knowledge of the writer.

V. URGENCY - Construction and maintenance funds could have been saved in many instances had a more objective approach been taken in the design of slope protection for bridges. The sooner a more objective approach to the design of slope protection is taken the sooner savings can be realized.

A2H01

PROBLEM NO. 53

I. NAME OF PROBLEM - SURVEY OF OUTSIDE TECHNOLOGY WHICH MAY BE APPROPRIATE FOR TRANSPORTATION

II. THE PROBLEM - New technology, outside the field of transportation is developing at a rapid rate. Some of this technology may be suitable for application to transportation, however, the current long time lag is unacceptable.

III. OBJECTIVES

A. Produce a "survey" of newly available and coming technology.

B. Develop criteria for assessing applicability of "other" technology to transportation.

C. Apply the criteria to the survey to identify the more promising areas of new technology.

D. Develop a resource list of "contact persons" for the identified techologies.

IV. CURRENT ACTIVITIES

A. New technology, high technology.

B. Minnesota DOT, Caltrans and perhaps others are beginning programs in this area.

V. URGENCY - The sooner this activity begins, the more time and money may be saved.

A2H03

PROBLEM NO. 54

I. NAME OF PROBLEM - RELATIONSHIP BETWEEN AGGREGATE CHARACTERISTICS AND FIELD PERFORMANCE OF BASE COURSES

II. THE PROBLEM - Information on the relationship between aggregate properties and field performance of untreated aggregate base course is generally lacking. The problem concerns base courses designed as structural layers in both flexible and rigid pavements as well as those designed as drainage layers. The optimum use of materials -

considering cost, energy and resource conservation - for various levels of performance may not occur.

The entire realm of problems from defining the purpose of aggregate base course to developing realistic construction specifications should be studied and the technology brought up to date. Performance needs to be defined in terms of basic properties such as, but not limited to, permanent deformations over time as well as resistance to transient deflections. Physical and chemical aggregate properties such as density, gradation, durability, particle shape and texture, permeability and degradation under the effects of dynamic and repetitive loads must then be related to performance requirements. New tests for design and construction control may need to be developed which are more relevant, simpler and less costly than existing tests.

There is a lack of research on the influence of aggregate properties on thickness design. Future thickness design procedures, including provisions in the new AASHTO Guide for Design of Pavement Structures, will increasingly use mechanistic principles. Mathematical models now available may offer the means to analyze the effects of aggregate properties on thickness design, provided detailed characterization of the materials is known. Observation of field performance to verify mathematical predictions is also needed.

III. OBJECTIVES

A. Investigate and define purpose and performance requirements of aggregate base course in relation to present knowledge and needs.

B. Determine the effects and sensitivity of aggregate properties on modulus of resilience in mechanistic thickness design of base courses under various stress and environmental conditions. Verify laboratory and theoretical predictions with field observations.

C. Evaluate design criteria and, if necessary, develop new procedures and test methods to evaluate aggregate base materials for required performance.

D. Develop methods to evaluate costs and energy requirements of aggregate bases for various levels of performance and alternate materials.

E. Evaluate existing field control tests and, if necessary, develop new practical tests to ensure adequate performance of aggregate base.

IV. CURRENT ACTIVITIES

A. Suggested key words: aggregate properties, base course, untreated aggregates, performance requirements, mechanistic design, modulus of resilience, construction control, testing, cost, energy.

B. There is no known comprehensive research on the problem. Several research studies in the United States and abroad have been

completed, or are in progress, on various narrow specific aspects. An important reference is NCHRP Report 100, Research Needs Relating to Performance of Aggregates in Highway Construction (1970).

V. URGENCY - The highway construction industry is facing increasing pressure to reduce material costs and improve efficiency. At the same time sources of high quality aggregate are decreasing. Proper characterization of aggregate base course materials is essential if long-term performance at an optimum cost is to meet the needs of the highway user. Continued emphasis is needed to provide research direction.

PROBLEM NO. 55

I. NAME OF PROBLEM - OPTIMIZATION OF AGGREGATE USE WITH REGARD TO ECONOMICS AND CONSERVATION OF NATURAL RESOURCES FOR VARIOUS ENVIRONMENTS AND LEVELS OF PERFORMANCE

II. THE PROBLEM - Although the overall supply of conventional aggregates in the United States is virtually inexhaustible, there are some areas of the country in which either (1) the quality of available aggregates is marginal for many applications, or (2) constraints exist which preclude efficient and economical development of necessary quantities of aggregates (such as urban development). In either instance, aggregates of suitable quality must be transported long distances at high cost of energy and dollars. In such areas, it is essential that specification and use of high quality aggregates be optimized, and that only the quality level required for desired performance in each application be specified.

In view of today's inflation, reduced material supplies, and potential curtailments on energy, examination of the consumption of materials and energy and efforts to optimize their use are needed and cost justified. Every application and construction practice must be examined, scrutinized, questioned, evaluated, and ultimately optimized if significant reduction of energy use and material waste is to be realized.

Optimizing means conserving scarce or expensive construction materials or energy by use of more plentiful materials when the performance level of the resulting application is not signficantly reduced. It means that material properties and their influence on application performance must be established, and that full consideration must be given to all factors in their proper perspective during the aggregate selection process. Efforts toward optimization have frequently been made in the past, but true optimization has seldom been achieved because of lack of valid information required for proper or complete analysis.

III. OBJECTIVES - The objective of the research is to develop criteria for establishing the required quality levels of aggregates for use in various applications constructed to serve in various environments and for various levels of performance. Aggregates to be included in the research effort should include (1) "high-quality" aggregates according

to existing specifications, (2) "borderline" aggregates (defined as aggregates having deficiencies which do not make them clearly unacceptable but which leave some uncertainty about possible adverse effects on application performance), and (3) "poor quality" aggregates according to existing specifications.

Information developed in the effort should indicate (1) the degree to which an aggregate meets, or fails to meet, a test requirement and (2) the performance of the end result application produced with the aggregate. In addition, the adequacy of test methods used for aggregate evaluation should be evaluated and only those tests that truly measure a property affecting performance should be promulgated.

IV. CURRENT ACTIVITIES

A. There are no known studies currently being conducted in this area. Extensive work has been performed by user agencies and researchers on specific aggregates for specific applications through the years, but emphasis has been limited to evaluation for conformance with existing specification. Little effort has been given to evaluation of the performance of applications constructed with "poor quality" aggregates.

B. Suggested key words: aggregate quality, optimization of aggregate use, aggregate evaluation.

V. URGENCY - The supply of economical, high quality aggregates in some areas of the country, including most urban and suburban areas, continues to decrease. As local supplies become unavailable, increased haul distance quickly increases the cost of high-quality aggregate and increases the consumption of energy. At the same time, high inflation and decreasing dollars available for construction compound the problem. Consequently, efforts to optimize use of all component materials used in construction, including aggregate, are urgently needed.

PROBLEM NO. 56

I. NAME OF PROBLEM - CRITERIA FOR THE USE OF SALVAGED AND RECYCLED AGGREGATE IN PAVEMENT STRUCTURES

II. THE PROBLEM - In certain areas of the country the supply of natural aggregates is limited, either through the depletion of economically available material or zoning restrictions on new quarry sites. This situation tends to exist in highly developed urban areas, where there often is the additional problem of proper disposal of wasted concrete. The combination of these two situations creates the incentive to incorporate the waste concrete as aggregate in new concrete, thus alleviating both problems. With increasing use of recycled concrete as aggregate in new concrete, the applicability of present aggregate tests to concrete salvaged from various structures and use and acceptance criteria for this material need to be established.

III. OBJECTIVES - It is known that recycled concrete has values which are higher than normally accepted for natural aggregates in such tests as absorption and L.A. Abrasion. Criteria need to be established as to what levels of test results are acceptable for recycled material, and also the applicability of certain test procedures. Criteria which need clarification include:

A. Gradation
B. Absorption (for both PCC and BCC)
C. Los Angeles Abrasion
D. Specific gravity
E. "D" cracking susceptibility
F. Alkali-aggregate reactivity
G. Freeze-thaw durability
H. Allowable contaminants.
   1. Gypsum
   2. Chlorides
   3. Bitumen
   4. Organics

IV. CURRENT ACTIVITIES

A. Suggested key words: recycling, recycled aggregates, recycled concrete, aggregate testing, aggregate acceptance.

B. Many states have become involved in the recycling of PCC and have therefore investigated some of these criteria. The FHWA has also been active in this area through its Demonstration Project 47, Recycling Portland Cement Concrete Pavements. Criteria such as gradation, absorption, and abrasion have been addressed by several states and the behavior of recylced material examined. For these criteria what is needed is establishment of generally acceptable levels. Other criteria listed in Section III are less well established in terms of the tests which are acceptable.

V. URGENCY - As recycling of PCC into aggregates for new concrete becomes more widespread, it becomes increasingly important to be able to screen materials to determine those which will provide acceptable performance in the proposed application. To this end, appropriate test methods need to be selected and acceptable test results established.

PROBLEM NO. 57

I. NAME OF PROBLEM - THE ADVERSE EFFECT OF CHLORIDES ON VARIOUS TYPES OF AGGREGATES

II. THE PROBLEM - Premature failure of portland cement concrete (pcc) pavement due to rapid deterioration is a serious problem that is intensified with the shortage of highway funds. The durability of pcc in a particular environment is dependent on materials, design, construction and maintenance. Substantial research has been conducted and is in progress in regard to the D-cracking mode of rapid

deterioration. Even though susceptible aggregates and some factors that affect the rate of deterioration have been identified, all failure mechanisms are not fully understood. The generally accepted failure mechanism of D-cracking is freezing and thawing.

Rapid failure of pcc may be due to freezing and thawing in conjunction with other factors such as chemical deterioration. Field reviews of pavements with identical materials, similar design and similar construction will often document the more rapid deterioration of roadways with greater deicing salt application. It would appear that the salt accelerates the deterioration through either physical or chemical reaction, or both. A more thorough understanding of the rapid failure mode will result in improved design and reduced maintenance of pcc pavements.

III. OBJECTIVES - Determine the effect of chlorides on aggregates that contribute to the rapid deterioration of pcc pavement by the following:

A. An investigation and summary of past and current efforts in this area.

B. Determination of the effects of freezing and thawing in water and freezing and thawing in chloride salt solutions as well as continuous soaking and wet/dry cycling in chloride salt solutions on various coarse aggregates.

C. Determination of the effects of these same conditions on concrete samples containing various coarse aggregates.

IV. CURRENT ACTIVITIES

A. There are no known studies currently going on in this area. This work would be an extension of work reported by J. E. Gillott on pages 177-192 Volume II of the Quarterly Journal of Engineering Geology, 1978.

B. Suggested key words: aggregates, D-cracking, portland cement concrete, freeze thaw distress, chloride, salt influenced distress.

V. URGENCY - D-cracking of concrete pavements continues to be a problem in obtaining necessary service life. Until the mechanisms involved in D-cracking are fully understood permanent prevention of the problem is difficult to achieve.

A2J03

PROBLEM NO. 58

I. NAME OF PROBLEM - LIME, FLY ASH AND LIME-FLY ASH APPLICATIONS IN PAVEMENT REHABILITATION AND MAINTENANCE

II. THE PROBLEM - The use of lime, fly ash and lime-fly ash for soil

modification and stabilization applications has proved highly successful in new construction situations. However, utilization of these additives in pavement rehabilitation and/or maintenance activities has received only limited attention from the research community. The use of recycled soil and soil-aggregate materials presents additional complexity for mixture design since additional variability has been introduced. The recycled materials will generally be more heterogeneous in nature than the original soils or aggregates. Furthermore, the recycled materials may have been treated with lime, portland cement, or bituminous agents during initial construction. While it is probable that lime, fly ash and lime-fly ash can be successfully utilized with recycled materials, this type of stabilization does not have adequate research or documented field evidence which can serve as a basis for mixture design and construction guidelines.

III. OBJECTIVES

A. Research and construction literature should be investigated to determine the extent of previous laboratory or field efforts which use lime and/or fly ash soil stabilization as a maintenance or rehabilitation strategy.

B. Well designed experimental research is needed to document the difference in soil-aggregate reactions with the lime and/or fly ash when recycled materials are used.

C. Current mixture design procedures for lime and lime-fly ash stabilized materials need to be tested using recycled materials to determine if significantly different laboratory procedures are needed.

D. Experimental field projects should be planned to verify the appropriateness of laboratory mixture design procedures studied in (c) as well as develop data that can be used for the structural design of rehabilitated pavement layers.

IV. CURRENT ACTIVITIES - Although previous work in this area is limited, fly ash has received the most attention since it involves the utilization of the waste-product. It appears that no current on-going research is being conducted which addresses the objectives listed above.

V. URGENCY - This research problem has substantial potential in the maintenance and rehabilitation of low-volume roads. Increased truck weights, increased truck tire pressures, and the shift of bulk commodity transport from railroads (caused by rail abandonment) to the highway system in many parts of the country has created maintenance requirements that must strengthen existing pavement systems in addition to rehabilitating the wearing surface. The structural improvement will use recycled materials. Lime and fly ash can be successfully used as stabilization agents to provide improved structural performance if the necessary laboratory and field research is conducted.

Since improved maintenance and rehabilitation procedures are urgently needed, especially for low-volume roads, the proposed research should be a high-priority item.

A2J04

PROBLEM NO. 59

I. NAME OF PROBLEM - MINIMIZING CRACKING IN STABILIZED (CEMENT TREATED) PAVEMENT

II. THE PROBLEM - It is generally accepted that soil cement would undergo cracking owing to drying shrinkage and environmental effects; the severity of cracking depending on the aggregate material characteristics, quality control and construction practice. Materials related factors of importance include fines content of the aggregate, cement content and tensile strength of the mixture. Importance of factors related to quality control during constructions are increasingly recognized by engineers; however, very little progress has been made in defining and delineating the significance of these factors. Moisture content and density during compaction (degree of saturation), during procedures and the effect of traffic on "young" uncured soil cement are but a few important items to be addressed in this study.

III. OBJECTIVES

A. Synthesize the existing knowledge on shrinkage and/or thermal cracking of stabilized layers.

B. Based on the existing knowledge propose a model and/or techniques by which stabilized soil with high crack potential can be detected.

C. With the ultimate aim of minimizing cracking develop specifications that may be used for design as well as during construction.

D. Develop a model and/or techniques by which reflection cracking from the stabilized layer can be minimized.

IV. CURRENT ACTIVITIES

A. Literature survey and personal contacts suggest that some research activity is underway in Europe. Results are encouraging in that cracking was almost eliminated by controlling the degree of saturation (Betz, Switzerland).

B. Suggested key words: stabilization, cracking, soil cement, reflection cracking, construction control.

V. URGENCY - Soil cement is extensively used as a base course material; however, the performance record has been somewhat mixed. Cracks reflecting from the stabilized layer seem to be a major problem.

Cost of research effort: $185,000

REFERENCES

1. Norling, L.T., "Minimizing Reflective Cracks in Soil-Cement Pavement - A Status Report of Laboratory Studies and Field Practices", HRR 442 pp. 22-23, 1973 TRB.

2. Smith, R.E., "A Laboratory Study of Factors Affecting the Shrinkage Characteristics of Cement Treated Bases", CALTRANS June 1974 EA No. 63393.

PROBLEM NO. 60

I. NAME OF PROBLEM - DEVELOPMENT OF CRITERIA FOR EVALUATING ADEQUACY OF ROLLER-COMPACTED CONCRETE CONSTRUCTION

II. THE PROBLEM - Roller-compacted concrete (RCC) is a zero-slump concrete, which has the consistency of damp gravel and is compacted by rubber-tire and vibratory rollers. It has characteristics of both conventional concrete and a cement-treated aggregate base (CTAB). At the present time, there is little standardization in laboratory and field quality control testing of RCC. For example, on most projects the acceptance criteria is based on a minimum percentage of the maximum compacted density. However, there is a debate as to how the maximum density is determined. Modifications to both the Vebe and moisture-density tests have been used. Also different methods are used for molding cylinder for compressive strength testing.

Standardized test methods are required to assist contractors, engineers, testing laboratories, and owners in evaluating the quality of a RCC project during construction.

III. OBJECTIVES

A. Develop universally accepted test procedures for molding cylinders and determining maximum density of RCC. Round-robin testing should be included for purpose of precision and accuracy.

B. Examine other parameters of RCC such as moisture content, water-cement ratio, mix uniformity, and air content. Determine the effect these parameters have on the performance.

IV. CURRENT ACTIVITIES - Suggested key words: roller-compacted concrete, quality control testing.

Due to the general interest in RCC from governmental agencies and private industry, some limited research is being done.

V. URGENCY - With the many RCC projects being planned or under construction, it is important standardized test procedures be available so that projects can be constructed and perform and intended.

General estimate of cost: $50,000.

PROBLEM NO. 61

I. NAME OF PROBLEM - USE OF PORTLAND CEMENT-STABILIZED ADMIX LINERS IN HAZARDOUS WASTE DISPOSAL

II. THE PROBLEM - Increasing emphasis is being placed on the use of liners to impede and control the effects of groundwater pollution from leachates that come out of the hazardous wastes in disposal facilities. The requirements for acceptable liners to be used for this purpose are: (1) low permeability, (2) long-term durability and compatibility with leachate, (3) ease of installation and (4) low cost.

Liner technology is relatively new and experience is limited on the performance of cement-stabilized materials as admix liners. There is need for research in this area.

III. OBJECTIVES

A. To determine the technical, practical and economic feasibility of soil-cement, and other cement stabilized materials (i.e., fly ash) for use as admix liners.

B. To develop quality criteria for the acceptability and use of cement-stabilized admix liners in hazardous waste disposal facilities.

IV. CURRENT ACTIVITIES - Current work in liner technology is quite active; however work in soil-cement liners is minimal.

V. URGENCY - In view of the increasing concerns over the groundwater pollution problems, there is urgency for this research.

REFERENCES

Soil cement is a compacted mixture of portland cement, water, and selected in-place soils. The result is a low strength portland cement concrete with greater stability than natural soil. The permeability of this mixture varies with the type of soil; a more granular soil produces a more permeable soil cement. A fine-grained soil produces a soil cement with a permeability coefficient of about 10^{-6} cm s^{-1} (Stewart, 1978). To date, there have been few studies performed to design a soil cement with very low permeabilities (less than 10^{-8} cm s^{-1}), as opposed to mixes designed for high compressive strength. To reduce permeability of soil cement, coatings such as epoxy asphalt and epoxy coal-tar have been used.

Any soil, except organic soil, with less than 50% silt and clay is suitable for soil cement. However, a well-graded soil with a maximum size of 0.75 inch and maximum silt and clay content of 35% is preferable (Bureau of Reclamation, 1963). A high clay content impairs the ability to form a homogeneous cemented material thus reducing the efficiency of producing an impermeable layer. Three criteria must be

considered for soil cement liners: cement content, moisture content, and the degree of compaction. The optimum moisture and cement contents are determined by laboratory testing. The optimum moisture is that which results in maximum density of the compacted soil cement. Laboratory samples should be tested in wet-dry and freeze-thaw cycle tests (ASTM D559 and ASTM D560) to determine the optimum cement content.

The aging and weathering characteristics of soil cements are good, especially those associated with wet-dry, freeze-thaw cycles. Some degradation has been noted when this substance is exposed to highly acidic environments (Stewart, 1978), but soil cements can resist moderate amounts of alkali, organic matter, and inorganic salts. One of the main deficiencies of soil cement as a liner material is its tendency to crack and shrink on drying.

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PROBLEM NO. 62

I. NAME OF PROBLEM - BIMODULAR PROPERTIES OF STABILIZED MATERIALS

II. THE PROBLEM - Conventionally the thickness design of stabilized soil layers has been based upon the tensile strength of the stabilized soil layer and/or the appearance of the first crack. The design literature does not allow one to consider the true development of cracking in the stabilized soil layer. Knowledge of the mode of such cracking could drastically alter the philosophy behind thickness design of layers.

It is believed by some that failure will not hinge on crack initiation as it does when a beam is tested in flexure. This is because different stress/strain conditions which develop in the pavement structure dictate the mode of crack propagation and hence the ultimate structural response.

It is necessary to fully understand the mode and process of fracture in stabilized layers in order to use these layers to their full potential.

III. OBJECTIVES

A. Model the crack propagation in laboratory specimens and determine analytically, numerically and empirically capability of the model to predict what happens in the pavement.

B. Examine the influence of material properties such as soil and stabilized type, molding moisture content, fabric, etc. on the ability of the material to sustain a load and propagate a crack under repeated loading.

C. Examine the influence of the above factors on the bimodular properties of the stabilized materials ($E_t = E_c$).

IV. CURRENT ACTIVITIES - Suggested key words: stabilization, cracking, flexure, dynamic loading, bimodular, soil cement.

V. URGENCY - This information is vital to the design and construction of cement stabilized pavements.

General estimate of costs: $220,000.

A2J06

PROBLEM NO. 63

I. NAME OF PROBLEM - EFFECTS OF ENVIRONMENTAL CONDITIONS ON PRODUCTS OF CHLORIDE STABILIZATION

II. THE PROBLEM - There is little data available to predict those environmental conditions that affect the interaction of chloride stabilizers and soils. It is suspected that environmental conditions do exist which favor or inhibit the reactions of chloride stabilizers.

III. OBJECTIVES

A. To determine those environmental influences which are impactive (favorably or non-favorably) on the interaction of chloride stabilizers and soil.

B. To develop test methods which forecast the presence or absence of the influencing factors found in objective A.

IV. CURRENT ACTIVITIES

A. Transportation research in progress areas 62, 63 and 64 have been scanned in preparing this statement.

B. Suggested key words: chloride tests, soil stabilization test, salt tests, chlorides and the environment.

C. No present research known to be in progress.

V. URGENCY - There exists a great need for the use of cost effective soil stabilizers to improve marginal materials for use in transportation facilities. Chlorides are currently being used for stabilization in limited geographical areas while other areas are not favorable to their use. This research should permit extended use of these stabilizers.

PROBLEM NO. 64

I. NAME OF PROBLEM - LABORATORY MIX DESIGN PROCEDURES FOR CHLORIDE STABILIZED SOILS

II. THE PROBLEM - No laboratory test methods have been developed for standardizing mix design procedures in chloride stabilized soils. These methods are needed to permit uniformity of data collection and analyses of the components and composites of the soil and chlorides to be blended.

III. OBJECTIVES - The objectives of this research are to develop test methods, procedures and data analysis techniques for use in evaluating chloride stabilization of soils. A further objective is the development of a mix design manual employing the test procedures and data analyses developed.

IV. CURRENT ACTIVITIES

A. Transportation research in progress areas 62, 63 and 64 have been scanned in preparing this statement.

B. Suggested key words: laboratory tests, chloride tests, salt tests, chloride mix design, chloride design manual, chloride stabilization, chloride test data analysis

C. No present research known to be in progress.

V. URGENCY - In the use of chlorides as stabilizer, current techniques are empirical and largely based on experience. As a result, it is almost impossible to transfer the design techniques in their current state of the art. The accomplishment of this research will provide a means of rapid technology transfer.

PROBLEM NO. 65

I. NAME OF PROBLEM - MECHANISMS INVOLVED IN STABILIZING SOILS WITH CHLORIDES

II. THE PROBLEM - Presently there is little substantiated understanding of the mechanisms by which chlorides react with soils. Available data does not provide an understanding of how the mechanisms function within the soil-chloride mixture. There does exist substantial evidence that chlorides do cause significant alternations in the properties of various soils, normally improving the engineering characteristics with respect to their load carrying capability.

III. OBJECTIVES - The objective is to determine the chemical and/or physical interaction which occurs between the chlorides and the soil being treated.

IV. CURRENT ACTIVITIES

A. Transportation research in progress areas 62, 63 and 64 have been scanned in preparing this statement.

B. Suggested key words: chlorides, soil stabilization, salt, calcium chloride, sodium chloride, magnesium chloride.

C. Chloride stabilization is currently being performed but little information is being generated on the theoretical aspects of the reaction mechanisms involved. The data available is being developed by chloride producers such as Dow Chemical Co. and the Salt Institute members or their contract research organizations.

V. URGENCY - Hundreds of miles of farm-to-market roads cannot be paved because of decreasing highway funds. It is felt that the load bearing characteristics and the serviceability of those roads can be improved through chloride stabilization.

PROBLEM NO. 66

I. NAME OF PROBLEM - METHODS OF STABILIZING WASTE PRODUCTS COMPOSED OF GYPSUM OR FOR USING GYPSUM AS A FILLER MATERIAL IN STABILIZING SOILS

II. THE PROBLEM - The Phosphate Industry is producing tremendous amounts of waste by-product Gypsum (Calcium Sulfate) which is becoming a major problem with respect to disposal. This hydrated material has thus far been virtually unusable when offered as a free building material. In many instances, its usage has been attempted unsuccessfully by City, County and State road-building agencies. Its low-cost and available quantity make it desirable as a building component if some economical method of stabilization can be found.

III. OBJECTIVES - The objective is to find some method to make waste gypsum a usable building component material in engineering applications.

IV. CURRENT ACTIVITIES

A. Several governmental agencies in Florida and several phosphate manufacturers are experimenting, both empirically and in theory, with Gypsum as a building material.

B. Suggested key words: Gypsum, soil stabilization, stabilizer, phosphate, sulfates, calcium sulfate, by-products, waste products.

C. Some incidental work is presently being performed by several phosphate producers and by a few county road departments in Florida. The Florida Department of Transportation has done a limited amount of investigation as well.

V. URGENCY - Millions of tons of this waste-product are generated annually and storage of same is fast becoming a problem. The cost of roadway building materials is rising rapidly as we use-up and/or cover-up natural deposits of desirable soils. Ability to use the large supply of waste type gypsum could relieve both problems.

A2K01

PROBLEM NO. 67

I. NAME OF PROBLEM - DEVELOPMENT OF TECHNIQUES AND APPARATUS FOR THE MEASUREMENTS OF LARGE STRAINS IN GEOTECHNICAL FABRICS - (GEOTEXTILES)

II. THE PROBLEM - The use of geotextiles for reinforcement of embankments constructed on soft foundations and as separation layers in temporary roadway construction is increasing. However, the engineering properties of geotextiles, design rules for their use, and construction specifications are not at present well developed. Consequently, laboratory model testing as well as full scale testing of geotextiles in embankments and roadways is required. Measurements of strains and deformations in fabrics will be an integral and important part of these tests. Currently there are no suitable strain

or deformation gages available specifically for geotextiles. Conventional SR-4 strain gages cannot measure strains beyond a few tenths of a percent, and large elongation SR-4 type gages are difficult to attach to fabric. Furthermore, for field use these latter gages are difficult to waterproof and to protect during installation.

III. OBJECTIVE - The objectives are to develop techniques and apparatus for large strain measurements of geotechnical fabrics under both field and laboratory conditions. Gages should be able to function not only for the short term in the laboratory but also under long term field conditions and under adverse environmental and climatic conditions. Gages should possess all of the desirable characteristics relating to accuracy, reliability, repeatability, etc. of any geotechnical field instrument.

IV. CURRENT ACTIVITIES - Some large elongation SR-4 type strain gages which have a maximum of $\pm$ 15% have been used on geotextiles in Holland and England, but not successfully in the U.S. as far as is known. When they are glued to the geotextiles the adhesive stiffens the fabric in the vicinity of the gage. A resistance type gage has been used experimentally at Purdue University, but it requires additional development work for use in the field. Another technique which has not been fully developed is the use of Bison inductance strain coils sewn or otherwise attached to the fabric in the horizontal mode. The physical size, relative inflexibility and possible rotation of these gages may present some interference in the stress distribution around the fabric.

V. URGENCY - This research is considered to be of very high priority since the use of geotextiles and fabric reinforcement offers the possibly of significant savings in construction of both highway and railroad embankments over soft soils.

PROBLEM NO. 68

I. NAME OF PROBLEM - IMPROVED LANDSLIDE MONITORING SYSTEM(S)

II. THE PROBLEM - To insure safety of the traveling public it is necessary to predict when a transportation facility in a landslide area becomes unsafe and must be closed. Predictions of safety based on rates and magnitudes of movement of the landslide have been used, but accurate and dependable measuring methods are not available.

The traditional method is to install inclinometer casing to determine lateral movements. This technique has limitations of relatively high cost and usually requires access to the landslide areas.

Sub-audible rock noise (SARN) measurement technology from the tunneling industry was used in California to warn of impending major movement. Photogrammetry is becoming a stronger possibility of a technique for monitoring. There is a need to further develop these and other technologies to obtain accurate dependable system.

III. OBJECTIVES - Develop low cost, accurate, dependable landslide monitoring systems and prepare detailed installation, operation and evaluation manuals. The systems must be capable of:

A. Measuring movements of up to two (2) feet with an accuracy of 1/4 inch.

B. Survival under field environment (frost, ice, salt, rains, snowplows, etc.).

C. Simple data gathering and evaluation techniques.

IV. CURRENT ACTIVITIES - Methodologies of landslide prediction based on movement are being developed by various states (New York, California, etc.) and some private organizations. Each has problems with the accuracy and dependability of the field instrumentation used. Also, obtaining records is very labor intensive and therefore costly. Few investigators contacted are completely satisfied with the present measurement systems. A symposium on landslide monitoring is proposed for 1987 which will focus on the state of the practice as well as state of the art techniques for monitoring.

V. URGENCY - The need for an adequate monitoring system (or systems) is increasing as the need for improving highway (transportation) safety is increasing, and near future construction involving highway widening may involve old landslide areas.

PROBLEM NO. 69

I. NAME OF PROBLEM - SIMPLE INSTRUMENTATION FOR TIEBACK MONITORING

II. THE PROBLEM - Tiebacks are used for lateral support for excavations both for temporary construction and permanent situations. Use of tiebacks for permanent lateral support is becoming more common, particularly since such applications are less costly than the traditional cantilever or gravity retaining wall. Proof loading of the tieback is accompanied by the measurement of force in and displacement of the tieback. Deformation and the rate of deformation of the tieback with time are used to evaluate tieback performance. Measurements for tieback testing are therefore very important in establishing the technical competence of the installation in both the short and long term.

Procedures and testing equipment exist in the industry but there are no reliable methods methods for simple monitoring. Field measurements are typically accomplished with load cells or extensometers. However, the use of such specialized instruments is, in fact, or perceived to be, costly and complex. This situation inhibits monitoring in many instances where monitoring may be needed. Also, a less costly design might have been adopted if simpler monitoring techniques were available.

III. OBJECTIVE - Identify and develop simple, low cost, reliable instrumentation to monitor load or deformation of tieback, particularly for long term application.

IV. CURRENT ACTIVITIES - FHWA has conducted a survey on procedures for monitoring applied load during permanent anchor testing. Its recommendations were circulated in an internal memorandum in January, 1986. This memorandum would be a starting place for future work.

V. URGENCY - High, in view of permanent tieback becoming more prevalent.

PROBLEM NO. 70

I. NAME OF PROBLEM - DYNAMIC STRESSES AND STRAINS AND FAILURE CONDITION OF SOILS DURING EARTHQUAKES

II. THE PROBLEM - Earthquake shaking has often caused soil failure in the past. During the 1964 Alaska earthquake, many landslides occurred. During the 1925 Santa Barbara, California earthquake, Shiffeld Dam failed. During the 1971 San Fernando, California earthquake, the slope of the lower San Fernando Dam failed.

Earth retaining walls, quay walls, bridge abutments have frequently been damaged by strong earthquake ground shaking because of excessive dynamic earth pressure generated by earthquake shaking on the wall.

Buried waterlines, sewerlines, gasoline and underground oil tanks have been damaged by soil consolidation, slumping, sliding and overstressing by seismic waves passing through the surrounding ground during earthquakes.

III. OBJECTIVES - To develop better instruments for measuring dynamic stress and strains of soils and to develop better methods of analyzing the dynamic stresses and strains and failure conditions of soil during earthquakes.

IV. CURRENT ACTIVITIES - Soils are complex particulate media whose physical properties under large strains and stresses during an earthquake are extremely complex.

The one very important practical problem is to evaluate the modulus and damping of soils as a function of the level of strains. The conventional geophysical methods produce only small amplitude shearing strains in the soil. Further research needs to be done to develop methods of inducing large strains that can be practically applied to dynamic analysis on soil behavior under earthquake shaking. Research should also be done on methods of determining in place soil damping as a function of shear strains induced by stress waves.

The stiffness and damping of cohesionless soils depend upon the density of the soil and the confining stress that acts on it. For cohesive soil, the time effects of load application have been a primary influence on soil stiffness. Laboratory testing techniques on determination of shear-strain-pore pressure relationship of soils have been advanced in recent years. More research is needed to evaluate the resultant reduction of soil stiffness and the changes in stiffness and damping during seismic loading.

In the evaluation of the seismic safety of embankment slope or fill slope, the determination of permanent deformations produced by

earthquake shaking is one of the primary requirements. Laboratory shaking table tests have provided valuable information on permanent deformation of embankment slopes. In recent years the development of centrifuge technology has overcome the need to scale soil properties. More full-scale prototype earth structures should be instrumented to observe their dynamic behavior during earthquake shaking. New or improved methods of in-place testing of soils both statistically and dynamically are also needed to be developed for large soil strains under earthquake loading.

V. RESEARCH PROCEDURES

A. Installation of arrays of strong motion instruments on prototype embankment in seismic area to record the earthquake motion in the embankment and the adjacent area.

B. Search for advanced dynamic stress and strain measurement device.

C. Comprehensive instrumentation, including the advanced static and dynamic soil stress and strain meters, vertical and horizontal deformation measuring devices, accelerometer and reference movements in the prototype embankment and the adjacent areas.

D. Conducting static and dynamic analysis of the performance and the dynamic behavior of the embankment and adjacent soil condition.

E. Comparison of analyzed results of the embankment behavior with those measured in the field.

V. URGENCY - The proposed study is considered highly important in the improvement of dynamic response analysis and seismic safety design of earth structures and engineering foundations.

A2K02

PROBLEM NO. 71

I. NAME OF PROBLEM - EARTH PRESSURES ON TIEDBACK WALLS

II. THE PROBLEM - The use of tiedback walls for permanent earth retaining structures in cuts has increased dramatically in the last few years. However, the design rules for tiedback walls are still based on the empirically developed relationships for braced cuts. The distribution of earth pressures on tiedback walls are likely to be considerably different from the earth pressures on braced walls because these walls have distinctly different deformation patterns. In addition, there frequently are considerable differences of opinion on the magnitude of earth pressures on tiedback walls. With increased usage of permanently tiedback walls, a rational earth pressure theory is necessary.

III. OBJECTIVES - Conduct research necessary to develop a rational earth pressure theory for tiedback walls. Specifically:

A. Develop an analytical model or select an existing analytical model that will model the deformation conditions within the soil and the stiffness of the different wall components. (To date analytical models have been used for parametric studies, but no attempt has been made to use them to design tiedback walls.)

B. Instrument and monitor full-scale walls.

C. Calibrate the analytical model so it will accurately predict the observed behavior. (To date researchers have not had access to adequate amounts of field data to enable the analytical model to be calibrated.)

D. Utilize the earth pressure theory to design temporary tiedback excavation support systems.

E. Instrument and monitor tiedback structures built in "D".

F. Refine analytical model developed in "C".

G. Use the analytical model to design permanently tiedback walls.

IV. CURRENT ACTIVITIES - Instrumentation is currently being done on many walls. The instrumentation is designed to insure that the wall is performing satisfactory. It is not designed to help develop a better understanding of tiedback wall behavior. During the last decade, finite element codes were developed for tiedback walls but these researchers did not have access to adequate amount of field observations to enable them to calibrate their model.

V. URGENCY - Very high, because of the increased usage of permanently tiedback walls for highway applications and the potential for cost savings resulting from more economical designs. The development of a rational earth pressure theory could be extended to other wall systems, i.e., soil nailing and element walls.

PROBLEM NO. 72

I. NAME OF PROBLEM - TOE PENETRATION OF TIEDBACK WALL

II. THE PROBLEM - Tiedback walls are used to support cuts for temporary and permanent earth retaining structures. The vast majority of these walls utilize solider beams. For temporary structures, experience rather than calculations has been used for determining the toe penetration, the length of the soldier beam below the bottom of the excavation. Normally, a five-foot toe penetration has performed satisfactorily unless the subgrade soils were weak. With the increased use of permanently tiedback structures, designers are using a variety of design rules rather than the experience developed on temporary walls to determine the depth of toe penetration required. Using these design rules has resulted in very long soldier beams toes. However, other wall systems, i.e., soil nailing and tiedback element walls, are performing satisfactorily without any significant

penetration below subgrade. A rational design procedure for soldier beam toes is required.

III. OBJECTIVES - Conduct research necessary to understand the behavior of the buried portion of a tiedback wall and develop an accurate rational method for determining the toe penetration. Specifically:

A. Instrument and monitor tiedback soldier beam walls to determine what portion of the vertical component of the tiedback loads are transmitted to the embedded portions of the soldier beam.

B. Instrument and monitor tiedback soldier beam walls to determine how the ground below subgrade and the embedded soldier beam resist the lateral earth pressures applied.

C. Develop an analytical model that will enable the soldier beam toes to be designed to adequately carry the imposed vertical loads and resist the lateral earth pressures applied.

IV. CURRENT ACTIVITIES - None known.

V. URGENCY - High, because of the increased usage of permanently tiedback walls.

PROBLEM NO. 73

I. NAME OF PROBLEM - DEVELOPMENT OF DESIGN RULES AND ECONOMICAL CONSIDERATIONS FOR SOIL NAILING

II. THE PROBLEM - A new in situ reinforcement technique called "soil nailing" has been developed in France. The system has been used successfully a few times for both tunnel construction and for retaining earth slopes. At present the nailed soil structures are simply built with only empirical design rules, and it is difficult to extrapolate to other sites and other soil conditions. A rational design procedure for soil nailing is required.

III. OBJECTIVES - Conduct research necessary for development of a rational design procedure for soil nailing. Specifically:

A. Theoretical and analytical studies, laboratory and field model tests and full scale instrumented field investigations of nailed soil structures are required.

B. Fundamental studies need to be carried out into the interaction and stress transfer mechanisms within the nailed soil mass.

C. For economical design optimization of bar properties and geometries must be carried out, and different materials such as cables vs. rigid bars could be considered.

D. Cost comparisons need to be made with untensioned nails vs. tensioned tiedback systems.

E. Research is needed on the effectiveness of complete grouting of the nail for corrosion protection.

This research would also be useful for tieback design and construction.

IV. CURRENT ACTIVITIES - Research is currently underway on soil nailing in France and Germany. Very little has been done in the United States, although it is one of the topics in FHWA Project 4M for FY 84-85.

V. URGENCY - High, because of the great potential in cost savings over pretensioned tiebacks.

PROBLEM NO. 74

I. NAME OF PROBLEM - SOIL REINFORCEMENT INTERACTION BEHAVIOR

II. THE PROBLEM - The rapid increase in the use of geotextiles and related materials in the design and construction of transportation facilities is well known. However, in many of these applications, particularly in reinforced retaining walls and embankments, the soil reinforcement interaction mechanisms is not well understood. This may make economical but safe designs difficult to achieve in practice

III. OBJECTIVES - Conduct research into both the short term and long term behavior of geotextiles and related materials in realistic soil reinforcing systems. This involves studies of soil reinforcement friction, stress-strain behavior and the creep response of geotextiles and geogrids.

IV. CURRENT ACTIVITIES - Some research in underway on these topics at a number of universities in the U.S. (Oregon State, Purdue, Drexel, to name a few).

V. URGENCY - Very high priority. The continued development of the use of geotextiles is impeded by this lack of information.

PROBLEM NO. 75

I. NAME OF PROBLEM - DEVELOPMENT OF A RATIONAL DESIGN PROCEDURE FOR REINFORCED EMBANKMENTS ON SOFT SOILS

II. THE PROBLEM - The use of geotextiles and geogrids for reinforcement of soft foundation embankment soils will undoubtedly proliferate in the foreseeable future due to the obvious economics possible by acceleration of fill placement rate and a firmer working table. The engineering properties of the reinforcement optimum performance at a given site have not yet been established since the soil-geosynthetic interaction has not been characterized analytically. Testing techniques are generally textile industry related and not necessarily applicable to the geotechnical situation.

III. OBJECTIVES

A. Develop an analytic procedure consistent with empirical experience to characterize the interaction of the geosynthetic and soil in the reinforcement mode.

B. Develop specifications using the analytical characterization which will assure optimum performance.

C. Develop testing techniques which analyze the material properties so that the evaluations are applicable to geotextile and geogrid applications.

IV. CURRENT ACTIVITIES - Reinforcement of fill construction has been successfully utilized at a number of sites on an experimental basis. The simple model of using the grab tensile strength of the reinforcement as a resistance force in conventional slip circle failure analyses is not unacceptable.

V. URGENCY - This research is considered to be high priority since the use of geosynthetic reinforcement offers the possibility of significant savings for construction over soft soils.

PROBLEM NO. 76

I. NAME OF PROBLEM - EFFECTS OF UNDERGROUND CONSTRUCTION TECHNIQUES ON AREA SUBSIDENCE

II. THE PROBLEM - Construction specifications normally permit the construction contractor a great deal of latitude in the methods selected for excavation support and dewatering systems, holding him fully responsible for the correction of any detrimental effects of area subsidence. Many contractors lack the necessary expertise to evaluate the detrimental effects of normal construction procedures as there is normally no practical experience to use as a guide in any new location involved. The shifting of the burden to the contractor was possible in the past only because underground construction was a highly specialized art, and engineers did not have the theoretical tools or sophisticated devices needed for proper evaluation of the problems involved. Today, with the vast background of technical experience available, as well as special investigative and monitoring procedures developed, the engineer is in a position to better serve the owner and the community in taking full responsibility for the control of underground construction.

III. OBJECTIVES

A. Assemble a bibliography on all available methods of underground construction and excavation support systems. Summarize available knowledge as to the applicability of each system to various soil stratifications, including rock tunnels and rock excavation.

B. Establish a checklist of potential field hazards associated with

each system of underground support including the effects associated with various applicable methods of dewater.

C. Review the applicability of available Soil and Rock Mechanics theory to the evaluation of area subsidence related to the various methods of underground construction, excavation support and dewatering systems. Assemble a bibliography on available theory and empirical design approaches.

IV. CURRENT ACTIVITIES - Investigation of the effects of pile driving, dewatering, rock blasting, tunnelling equipment and procedures, soldier beams and lagging, interlocking steel sheeting, shotcrete and any other systems, including methods of anchoring and bracing on area subsidence. Investigation, testing and monitoring procedures should be included in the review.

V. URGENCY - Area subsidence can have extensive adverse effects on existing as well as newly installed structures. Damage induced often result in costly claims and reconstruction which can be avoided if available knowledge were employed in developing the initial designs and instrumentation controls to avoid undesirable area subsidence and its irreversible effects. The practice of shifting the responsibility to the contractor is no longer realistic, as the burden will nevertheless fall on the engineer to provide all necessary information to permit proper evaluation of construction conditions. The contractor, with only a limited time to evaluate and bid on construction work, is forced to be very conservative in his pricing unless the engineer can fully describe the safe methods of construction to be used. The engineer should be in a position to safeguard the owner and minimize construction contingencies by leaving as little as possible to change and not encumber the contractor with avoidable risks. In so doing any increase in investigation and design costs will be more than compensated by the reduction in contingent costs of construction uncertainties and claims.

A2K03

PROBLEM NO. 77

I. NAME OF PROBLEM - PILE LOAD TEST DATA BASE

II. THE PROBLEM - The present state-of-the-practice in the design of pile foundations for highway bridges is such that high factors of safety are applied because of the lack of confidence in methods of analysis, input variables, and predicted performance. There is a need for developing a larger data base of high quality pile load tests to failure on properly instrumented and monitored piles of all types and in various soils deposits. Correlation studies of predicted and measured performance will be used to reduce the uncertainty involved in selecting the appropriate input parameters and methods of analysis.

III. OBJECTIVES - To develop a high quality data base of pile load tests and an improved design procedure for pile foundations.

IV. CURRENT ACTIVITIES

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

B. Suggested key words: piles, load tests, bearing capacity, settlement.

C. The Federal Highway Administration (FHWA) has conducted numerous load tests on well-instrumented piles and pile groups to initiate a master data base. A computer program (PILGP1) was developed to analyze and predict pile load transfer and load-deformation behavior of single piles and pile groups. The Mississippi State Highway Department recently completed a correlation study of laboratory, field, and pile load test data acquired on a large number of pile load tests conducted over a period of several years. The data generated from this study and other research projects will be combined with the FHWA data to produce a master data base.

V. URGENCY - The lack of an accurate design method for piles usually results in overdesign (too many piles or piles that are too big or too long) and occasionally in underdesign (excessive settlement or bearing capacity failure). Because piles are the most commonly used foundation element and represent a significant cost element in the overall bridge project, an improved design method would result in significant cost savings. A properly instrumented and carefully conducted pile load test study can be performed for approximately $40,000 - $50,000 depending on the size of the pile and soil deposit being investigated. The unit cost of these tests can be reduced signification if more than one test is conducted at the same time.

PROBLEM NO. 78

I. NAME OF PROBLEM - DESIGN PROCEDURES FOR PRECAST GRAVITY RETAINING WALLS

II. THE PROBLEM - The method of earth pressure analysis to be used (Coulomb or Rankine) makes a substantial difference in the end result; i.e., the ratio of B/H. Proponents of each method argue the merits and limitations for both methods; however, no research has been conducted to address this issue. Although the Coulomb method is more commonly used in highway design applications, the procedures, which depend on the backwall geometry and foundation conditions are not well understood.

III. OBJECTIVES - To develop an improved design procedure for precast gravity retaining walls with special emphasis on the most appropriate method of earth pressure analysis.

IV. CURRENT ACTIVITIES

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

B. Suggested key words: retaining walls, earth pressure, Coulomb, Rankine.

C. No government or university sponsored research is currently addressing this issue. Manufacturers and developers of proprietary retaining walls systems are using their own methods which may or not be entirely valid. Very little validation testing has been done to verify the design procedures.

V. URGENCY - In recent years reinforced soil structures have emerged as a cost-effective alternative to expensive, conventional retaining wall systems. The proprietary Reinforced Earth method of earth retention and reinforcement and numerous other alternate retaining wall systems have reduced construction costs by using earth fill instead of concrete, reducing installation time, reducing site preparation, and increasing tolerance to differential settlements. Some of the newer systems show great potential; however, many technical questions remain unanswered and design procedures are conservative. Although the questions on proper earth pressure design remain unanswered, many of these alternate retaining wall systems are being built each year, and some problems have occurred which can be traced to the earth pressure design method. It is urgent that research be initiated to address this issue.

Cost Estimate $150,000 - $200,000

PROBLEM NO. 79

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

II. THE PROBLEM - A considerable number of full scale load tests have been conducted on single piles, but very few full scale load tests have been conducted on groups of piles. The design of pile groups is based on the extrapolation of single pile behavior to predict group performance; however, insufficient correlation efforts have been made to adequately infer the correct relationship between a single pile and a group of piles. The gain or loss of "group efficiency" is affected by the type of soil and other factors such as pile geometry and driving conditions. The effect of group action on both bearing capacity and settlement must be considered. Most of the piles in the group should be instrumented to measure load transfer at various depths of the piles, and ultimate values of bearing capacity and settlement should be obtained whenever load testing to failure is possible and affordable. If testing to failure is not appropriate, measurement of load transfer and settlement under working loads on actual bridge foundations should be made and correlated with results from load tests on single piles. Both sands and clay soils should be investigated.

III. OBJECTIVES - To develop an improved design procedure for pile groups that relates single load test behavior with soil and pile parameters, group efficiency factors, and overall group performance.

IV. CURRENT ACTIVITIES

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

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

C. The Federal Highway Administration (FHWA) conducted a full scale load test to failure on a group of nine steel pipe piles (11 inch diameter and 43 feet long) in a clay foundation soil. A computer program (PILGP1) was developed to predict pile load transfer and overall group action/performance. A load test to failure was also conducted by FHWA on a group of eight timber piles in sand and a group of five pipe piles in sand. Current FHWA research involves load transfer measurements on actual bridge foundation piles and correlation of data with PILGP1 predictions. Small scale model studies and centrifuge testing are also underway. Many more tests are needed to refine and verify the PILGP1 method.

V. URGENCY - The most common type of bridge foundation is piles; and, not surprisingly, piles are a very expensive item in the overall cost of bridge construction. The lack of rational design methods for pile groups results in either overdesign (too many piles) or underdesign (excessive settlement or bearing capacity failure). The Surface Transportation Assistance Act of 1982 provides for increased funding to reconstruct and rehabilitate the large number of deficient bridges in the United States. The development of improved pile group design methods will result in significant cost savings in future bridge construction.

The cost of this research will vary according to the type of soil, the size and number of piles in the group, and whether or not a failure condition is induced by the test loads. A pile group of 5-10 piles under an actual bridge pier can be instrumented and monitored for approximately $100,000. A full-scale pile group built and load tested to failure for research purposes only (not later incorporated in an actual bridge foundation) will cost approximately $100,000.

PROBLEM NO. 80

I. NAME OF PROBLEM - PERFORMANCE EVALUATION OF HIGHWAY BRIDGES SUPPORTED BY SPREAD FOOTINGS

II. THE PROBLEM - The use of spread footings to support highway bridge piers varies widely between the various highway agencies in the United States. A few states use spread footings to support most of their bridges, however, most use pile foundations to support the majority of their bridges. Some states make very little use of spread footings.

Although spread footings have been used quite successfully for many years in a few states, their acceptance has not been quick or widespread among the majority of states because there is a lack of well documented performance studies. Much of the necessary information is available in the files of many highway departments.

The remaining information can be gathered by inspecting existing bridges for damage and correlation performance with soils and other key parameters. Elevation surveys should also be performed to determine the amount of total and differential settlement that has occurred over the life of the structure. Cost comparisons between spread footings and piles should also be conducted on each case history example whenever sufficient cost data is available in the project records.

It would also be very valuable to instrument spread footings for new bridges to develop comprehensive case history examples for evaluating the advantages of using spread footings in lieu of piles. Settlement monitoring should begin as soon as footing construction is completed and continue through the major phases of bridge construction and finish after an appropriate post-construction monitoring period. Contact pressure cells should be placed on the soil surface just beneath the footing, and load cells could also be used to measure the amount of load-settlement-time relationships is necessary to performance an accurate evaluation of spread footing reliability.

III. OBJECTIVES - To conduct a systematic performance evaluation of highway bridges supported on spread footings to determine their safety, reliability, and cost effectiveness as an alternative to pile foundations.

IV. CURRENT ACTIVITIES

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

B. Suggested key words: spread footings, bridge abutments, settlement, bearing capacity.

C. The Federal Highway Administration (FHWA) recently completed a performance evaluation of highway bridge abutments supported on compacted fill. It was concluded that spread footings performed very well in all cases and represented a cost-effective alternative to piles when good foundation soils are available. FHWA is currently performing additional studies on the safety, reliability, and cost effectiveness of spread footings to support bridge piers. More case history studies are needed to expand and broaden the existing data bank of performance values.

V. URGENCY - There are many situations where spread footings could be used instead of expensive pile foundations, but they are not used because of lack of confidence and documented performance behavior of bridge piers supported by spread footings. Information on the reliability and cost-effectiveness of spread footings must be gathered and made available to those bridge designers that currently do not utilize spread footings because of a lack of confidence. Recent cost analyses have shown spread footings to be 50-65 percent cheaper than piles when used in situations where good quality soil materials are available.

Cost estimate: $75,000 - $100,000

PROBLEM NO. 81

I. NAME OF PROBLEM - EVALUATION OF BITUMINOUS AND OTHER COATINGS TO REDUCE PILE DRAG

II. THE PROBLEM - Pile drag can be compensated for in a rational pile design in several ways. Bituminous coatings have proved effective in reducing pile drag, however not enough research has been undertaken to establish reliable design parameters. Research is needed to evaluate the various types and thicknesses of bituminous and other types of coatings under varying installation and soil conditions and more importantly, to follow up with design data which can be employed by the engineer. Different coatings should be tested on different pile types for varying soil conditions. The piles must be thoroughly instrumented and monitored during pile driving and the period of post construction settlement when the piles are subjected to the drag forces.

III. OBJECTIVES - The research should culminate in a useful (to the design engineer) comparison and evaluation of the coatings and other variables in the experiment. The effectiveness of each coating should be stated in terms that can be translated by the designer into design parameters and specifications.

IV. CURRENT ACTIVITIES

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

B. Suggested key words: pile drag, bituminous coatings, negative skin friction, pile design.

C. Recent research results on the use of bituminous coatings from studies in Massachusetts, Hawaii, Oregon, and Kentucky have demonstrated that bitumen coatings reduce downdrag by about 90 percent. The cost is only about 15 percent greater than the cost of uncoated piles. The Oregon research showed the value of pile uplift tests to measure the improvement of drag resistance by coatings.

V. URGENCY - This research is badly needed to give the Engineer a reliable tool so that effective and economic pile designs which are subject to drag conditions may be progressed. A 90 percent reduction in pile loads can be achieved for a 15 percent increase in pile costs.

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

PROBLEM NO. 82

I. NAME OF PROBLEM - CONSTRUCTION VERIFICATION OF BEARING VALUES

II. THE PROBLEM - Verification of excavations in engineered fill and/or in situ soils and shales, for compliance with predetermined design bearing values is a routine assignment in construction monitoring.

The adequacy of the bearing area materials to provide the design values is generally based on visual inspection and "good professional judgment," with little other documentations. Simple field test devices are fabricated for use in local materials, but over a widely spread geographic area.

The literature suggests in situ penetration and shear testing as an aid to judgment in approving footing areas.

III. OBJECTIVES - To develop economical uniform, portable field test equipment and procedures for evaluating the suitability of compacted fills and excavations in soils and shales, to support the loads assumed in design of footings.

IV. CURRENT ACTIVITIES - An article appeared in the June 1979 issue of the ASTM Geotechnical Testing Journal, relative to this need.

V. URGENCY - Soil and shale bearing footing areas are being approved daily, often with little or no documentation. Development of the mentioned equipment and procedures would give considerable "peace of mind" to field construction engineers and inspectors as well as designers.

PROBLEM NO. 83

I. NAME OF PROBLEM - THE BEARING CAPACITY OF COMPACTED EARTH BRIDGE APPROACH EMBANKMENTS

II. THE PROBLEM - The height of the usual bridge approach fills ranges from 18 feet to 35 feet. The material used for such embankments, typically comes from local sources. Local materials may be glacial tills, fresh water, or marine deposits. While the in situ shear strength characteristics of such materials are well known, the performance and suitability of these as a load-bearing structure in their remoulded and compacted state, should be further investigated.

In the past, the bearing capacity of these compacted fills was estimated rather than computed or evaluated on the basis of parameters, or small or full-scale tests results. As a rule, such estimates were believed to be very conservative - consequently, the bridge designer shied away from placing spread footings within the fill and instead, utilized pile support or other deep foundations for the abutments.

Evidently, the latter design, in many cases, might not have been the most economical solution.

III. OBJECTIVES

A. To develop methods for the evaluation of the suitability of compacted fills, to carry bridge abutment loads constructed of (a) granular, (b) heterogeneous, and (c) various cohesive materials.

B. To study the stress distribution under spread footings, constructed with above approach fills.

C. To determine the best geometry of approach fills for the suitability of supporting abutment loads on spread footings.

IV. CURRENT ACTIVITIES

A. Transportation research in progress areas 62 and 65 have been scanned in preparing this statement, but no references were identified.

B. Suggested key words: foundation, spread footings, compacted embankments, bearing capacity, settlement.

C. Current related research activities include: (1) an FHWA contract on tolerable movement criteria for highway bridges by West Virginia University, (2) an FHWA staff study on correlation of shallow foundation movements with superstructure distress manifestations, (3) a laboratory study of bearing capacity of foundations on a sloped embankment has been completed at the University of Ottawa, Canada, for the Ontario Ministry of Transportation and Communications, and an associated field trial is now underway.

Further studies are proposed by FHWA on the Behavior and Efficiency of Spread Footings.

V. URGENCY - The economics possible offer great economic benefits, particularly as timber piles become scarce and shells for CIP piles may become short in supply.

PROBLEM NO. 84

I. NAME OF PROBLEM - NEW DESIGN AND CONSTRUCTION GUIDELINES FOR TIMBER PILE FOUNDATIONS

II. THE PROBLEM - The expenditures for pile foundations represent a very significant percentage of the cost of highway structures, particularly for small bridges. The cost for producing the most used types of piles such as steel and concrete are increasing in proportion to such factors as energy production costs as well as other inflationary factors. Transporting costs for piles are a major part of price increases.

Timber piles are frequently overlooked by the designer in favor of steel or concrete types. This stems largely from what is felt to be traditional low load capacities prescribed by current specifications and an accompanying concern for durability in various types of environments.

The current specification values for timber pile capacities are believed to be largely unsubstantiated. Treatment for durability is also not believed to be as difficult a problem to solve as in the past.

The application of modern pile capacity determination procedures to timber piles would result in an upgrading or more accurate definition of capacity over traditional values. This would then reflect a greater design reliability and possible substantial savings

when compared to the lower range of capacity for steel and concrete piles.

This study would also have to address itself to economical methods for insuring longevity of timber piles. This phase would not be limited to marine environments but also to areas of fluctuating groundwater. Current and new methods of treating piles for this purpose could be reviewed and evaluated.

Attempts to study rapid pore pressure dissipation adjacent to timber piles might also be worthy of examination. This aspect of the program could be optional. However, a modest static load test program for timber piles in various types of soil would be mandatory in this study. It would also be advisable to perform and evaluate dynamic load testing on timber piles.

III. OBJECTIVES - To develop technical guidelines for the design and construction of timber pile foundations. In addition, the following optional objectives can be included:

A. The optimum pile moisture content for hard driving conditions should be determined.

B. The effect of pile density on driving could be investigated.

C. The pile analyzer should be correlated to results of load tests in various soil conditions.

D. The drivability of debarked versus machine-peeled piles should be determined.

E. Dynamic formulas e.g., wave equation and the Engineering News Record Formula, should be compared to load test data.

F. Case studies of timber pile jobs throughout the country could be summarized including load capacity, pile hammer, etc.

G. Different hammers could be analyzed, up to and including 40,000 foot-pound diesels, to determine the best hammer for given load and soil conditions.

IV. CURRENT ACTIVITIES

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

B. Suggested key words: timber piles, pile load tests, allowable stresses, pile deterioration.

C. The Federal Highway Administration (FHWA) recently completed a study of allowable stresses in piles. The University of Colorado, supported by the American Wood Preservers Institute and the Forest Products Laboratory, is presently conducting research on the compressive strength of timber piling. Research on timber piling at the University of Colorado will address the effect of confining

(soil) pressure on the crushing strength parallel to grain of pressure-treated timber piling, e.g., Southern yellow pine and Douglas fir. Also, time effects will be studied to determine at what percentage of "allowable" compressive stress creep goes to zero.

V. URGENCY - The potential economy for using timber piles where appropriate could be a direct and quickly achieved benefit with new reliable design and construction criteria.

Cost estimate: $175,000

A2K04

PROBLEM NO. 85

I. NAME OF PROBLEM - REPRESENTATION OF LIVE LOADS ON 2-DIMENSIONAL BURIED STRUCTURE ANALYSIS MODEL

II. THE PROBLEM - Several recent research reports dealing with flexible buried long-span structures have pointed to large discrepancies between measured live load responses and those calculated by currently available 2-dimensional techniques. These techniques are generally based on an adaptation of the Boussinesq elastic relationships for a semi-infinite elastic medium. They do not account for rigid flexible inclusions, such as a culvert, within the medium. More recently 2-dimensional finite element methodology has employed a semi-finite live load. While this technique more rigorously distributes live load in the plane of the analysis, it still depends upon the same approximations in the third dimension.

In addition, no 2-dimensional solution exists for the prediction of buried structure responses due to moving live load across a skewed alignment. This problem has been ignored for small diameter culverts under adequate fill. However, for long-span structures under shallow cover with heavy live loads, it may need to be considered.

III. OBJECTIVE

A. Develop accurate live load representations for implementation in currently available, 2-dimensional analysis methods for both stiffened and unstiffened top arcs.

B. Assess the need for impact factors to account for the effects of moving loads.

C. Develop a 2-dimensional design method, if possible, for dealing with live loads on skewed alignments.

IV. CURRENT ACTIVITIES

A. Suggested key words: buried structures, culverts, soil-structure interaction, live loads, load distribution, corrugated metal plate, structural plate.

B. Related research: Recent research on live loads on long-span buried structures has been conducted in both the U.S. and Canada. Much of this work was done on relieving slabs designed to distribute wheel loads over the top arc. It will be useful background for the proposed research.

V. URGENCY - A rational method for determining the applied live load at any given cross-section for various corrugations, top arc stiffeners, skew alignments, soil types and cover heights would add significantly to the design technology for shallow cover long-span structures. Next to structure geometry and soil unit weight, live load is the most important design parameter, yet it is the least defined in current technology. Since long-span buried structures are playing a major role in rehabilitation of the nation's highways, significant public dollar savings may be realized by developing accurate live load representative.

PROBLEM NO. 86

I. NAME OF PROBLEM - STRUCTURAL REQUIREMENTS FOR PROFILE WALL PLASTIC PIPE

II. THE PROBLEM - Current AASHTO and ASTM materials specifications and the proposed AASHTO Bridge Committee Design Procedure for profile wall (corrugated, ribbed, etc.) plastic pipe require a minimum ring stiffness (based on flexible pipe theory such as the Iowa deflection formula) as the only structural requirement beyond material standards for these types of pipes. Recent evaluation of the performance of maintenance crew installed corrugated polyethylene pipe culverts in Ohio indicated that localized structural distress and/or failure modes for this type of pipe is more closely related to corrugation or profile stability as defined as resistance to localized longitudal flexibility of the corrugation and/or pipe.

Pipe stiffness (circumferential or ring stiffness) of the pipe is defined and can be measured using standardized (ASTM D 2412) lab tests. However, no measurable parameters exists for determining profile or corrugation stability or longitudinal flexibility and resistance to localized bending moments. Acceptable limits for these parameters are not known nor are appropriate laboratory tests available and standardized.

III. OBJECTIVE

A. Determine acceptable profile or corrugation design parameters to sufficiently provide longitudinal loading stability.

B. Conduct laboratory tests of profile wall and corrugated pipe samples to define parameters to reflect longitudinal flexibility, resistance to bending moment, and corrugation stability.

C. Conduct field and laboratory tests and computer simulations of installed profile wall and corrugated plastic pipe with varying backfill conditions to determine acceptable limits of the parameters indicated in A and B above.

D. Recommend revisions to the materials and design specifications for profile and corrugated wall plastic pipe types based on A, B, and C above.

IV. CURRENT ACTIVITIES

A. Highway research in progress:

1. Individual corporate profile and corrugation development.
2. No federal highway or state DOT work known.
3. Proposed research for computer simulation using CANDE sponsored by the Corrugated Plastic Tubing Association.

B. Suggested key words: ring stiffness, flexibility, flexibility factor, bending moment, soil structure interaction, corrugation, profile wall, corrugated polyethylene pipe.

V. URGENCY - As part of the current national trend to repair the country's deteriorating infrastructure, many states have greatly increased their programs of small culvert replacement. Corrugated polyethylene pipe has shown promise as an easily handled durable product for maintenance culvert replacements. However, structural requirements for this material should reflect the actual distress and/or failure modes encountered in this type of installation.

PROBLEM NO. 87

I. NAME OF PROBLEM - MEASUREMENT OF EARTH PRESSURES ACTING ON EXISTING LATERAL RETAINING STRUCTURES

II. THE PROBLEM - A number of the major U.S. government agencies are embarking on programs to rehabilitate old structures. As a first step, it is necessary to know the level of lateral stresses acting on the structures, and what stresses may be added as a result of the rehabilitation process. Since the structures in many cases have been in place for long periods of time, the existing earth pressures will reflect the effects of initial placement, structural deflection, creep, subgrade movement, surcharging, and vibrations among others. Stress concentrations may also have developed in areas where there are structural shape transitions, and arching may play a role if the backfill is located in a constrained environment. Little is known about the nature of long term loadings on structures. Added to this is the problem of the stresses that might be induced by the unusual construction processes that are often used in rehabilitation efforts. All of this suggests that we need to be able to measure and predict the long term earth pressures acting on existing structures as well as those induced by various construction activities.

III. OBJECTIVE - The objective would be two-fold. First, we have to develop reliable methods to measure the existing lateral stresses on older structures, and those that might be induced by nearby construction processes. This probably will utilize some of the existing technology for in situ testing of soils in a modified form.

Second, as a result of the measurements we should work to develop analytical methods which can be used to predict the loadings without recourse to measurements, or with only a minimal use of them. The research will require equipment innovations with testing in controlled laboratory environments, followed by a series of field tests involving actual projects. Analytical work will also be needed after the phenomena are explored through the field work.

IV. CURRENT ACTIVITIES

A. Transportation research in progress: no specific research projects are known to be underway. However, several major projects which are under consideration are facing the issue. For example, the Westside Highway Project in New York will involve building structures adjacent to the Holland and Amtrak tunnels. The Muni-turnaround in San Francisco will have excavation and construction above the BART tunnels.

B. Other research: The Corps of Engineers is considering the problem for a research thrust because of the expected rehabilitation of numerous navigation structures.

V. URGENCY - This problem is important since our major agencies project that in the near future, the majority of their budgets will be directed towards the cause of rehabilitation, not new construction. Much of the geotechnology we have developed addresses new structures, not existing ones. Measurement of lateral stresses on existing structures is an area which will allow us to capitalize on the coming emphasis of our funding agencies.

A2K06

PROBLEM NO. 88

I. NAME OF PROBLEM - COST EFFECTIVENESS OF USING FREE DRAINING LAYERS IN THE PAVEMENT SYSTEM

II. THE PROBLEM - A major factor contributing to the rapid development of pavement distress is excessive moisture in the pavement structural section. In recent years numerous states have utilized free draining base course layers and subdrainage systems to remove water from the structural pavement section. Although the addition of free draining layers and subdrainage systems to pavement during rehabilitation and new construction increase the total cost, there is considerable feeling that this cost is far outweighed by the increase in performance life of the pavement.

The major problem that exists in this area is that of providing quantitative data which can be used to evaluate the cost effectiveness of using drainage layers in pavement systems and provide a more exact evaluation of the benefits of various types of pavement drainage layers.

III. OBJECTIVES - The general objective of the project is to develop a

quantitative base to describe the effectiveness of using free draining pavement layers. The specific objectives of the study are:

A. Define the various types of free draining layers used in pavement systems.

B. Evaluate the total cost of construction of free draining pavement layers to include material costs.

C. Compare the performance of pavements on free draining layers with those on poor draining layers.

D. Quantitatively compare the cost vs. performance properties of pavements with free draining layers with those pavements without free draining layers.

IV. CURRENT ACTIVITIES - Although the benefits of pavements subdrainage are well accepted, little has been done to quantitatively evaluate those benefits. Some of the current activities include:

A. Studies of subdrainage effectiveness on rigid pavement faulting by California DOT.

B. Studies of open graded base course gradation requirements by Pennsylvania, New Jersey, Illinois, and other DOT offices.

C. Studies of open graded base course performance in France by the Central Laboratories of the Ponts et Chaussees.

D. Numerous FHWA studies on the influence of subdrainage, pumping, and aggregate gradation on pavement performance.

E. The continued interest by highway agencies in water related problems as indicated in SHRP.

V. URGENCY - The influence of water in pavement systems has been widely documented. Various subdrainage systems are being utilized in pavement rehabilitation and construction which need to be evaluated in reference to their cost and benefit. Although there is a qualitative feeling about the practical benefits of good subdrainage systems, an urgent need exists to quantitatively evaluate these systems. It is felt that this study will provide greater insight for the design of cost effective pavement drainage layers and to establish the value of drainage layers in pavement systems.

PROBLEM NO. 89

I. NAME OF PROBLEM - DEVELOPMENT OF GENERIC CRITERIA AND TEST METHODS FOR GEOCOMPOSITE DRAINS

II. THE PROBLEM - Over the past few years, eight or more prefabricated drainage products (a core material wrapped with geotextile) have come on the market. These products were a response to the need for less

expensive and easier installed drainage systems for various applications in transportation facilities. These applications include: pavement edge drains, foundation and retaining wall drains and subsurface wick drains. While some of these products have performed well in certain field applications and have subsequently been specified in a few states, no generic criteria for performance or material characteristics exist. Additionally, standardized test procedures to measure these characteristics are not available.

III. OBJECTIVES - The overall objective of the project is to develop specification criteria, by application, for geocomposite drains. The specific objectives are:

A. Define the various applications for geocomposite drains and the significant product characteristics that effect performance in each application.

B. Develop standardized test methods to measure significant performance or materials properties.

C. Determine minimum/maximum performance or material property criteria for each significant characteristic.

IV. CURRENT ACTIVITIES - Some of the current activities include:

A. Developmental product testing by various private corporations.

B. Laboratory testing by the University of Illinois and Drexel University under contract to private industry.

C. Full scale field evaluations by some states to include: Illinois, Pennsylvania, and New York.

V. URGENCY - The economic installation and successful performance of at least one of these products in pavement base drain applications has indicated a significant potential savings approval of a number of acceptable products, even more savings could be realized. It can be assumed that, as drainage system costs decrease, the use of effective drainage items will increase - thus increasing the performance lives of pavements, retaining walls, etc.

PROBLEM NO. 90

I. NAME OF PROBLEM - EDGE DRAIN TRENCH COMPACTION

II. THE PROBLEM - Installation of longitudinal edge drains next to new or old pavements is becoming increasingly popular as the detrimental effects of subsurface water upon pavement systems is becoming more generally recognized. Installation generally calls for the excavation of a trench adjacent to the pavement. No general specifications or construction procedures are available to ensure adequate trench backfill compaction. Field experience indicates that, at least in some cases, construction compaction was minimal or ineffective. Lack of compaction of the trench backfill leads to:

A. Settlement of the trench backfill.

B. Lack of edge support for the pavement structure. The settlement presents a maintenance problem. The loss of edge support may result in a substantial loss of pavement fatigue life due to resulting higher strain under loading.

III. OBJECTIVES - The objectives of this research are:

A. Evaluate current construction practices in this area.

B. Propose and evaluate appropriate construction procedures to achieve high levels of trench backfill compaction.

C. Evaluate loss of pavement edge support due to trenching operations with both good and poor compaction procedures.

IV. CURRENT ACTIVITIES - Past work has been performed on large utility trenches. No research activity into the area of narrow edge drain trenches is known to the writer.

V. URGENCY - Pavement edge drains are being used to a much greater extent now than in the past. The engineering profession must assure itself that the installation of these drains to remove unwanted subsurface water does not result in magnified pavement strains which will, in turn, lead to shortened fatigue life.

PROBLEM NO. 91

I. NAME OF PROBLEM - DETRIMENTAL EFFECTS OF RECYCLED P.C. CONCRETE AS SUBBASE MATERIAL ON SUBSURFACE DRAINAGE SYSTEMS

II. THE PROBLEM - In the next several years, restoration, rehabilitation and reconstruction of our highways will be our major program effort. To accomplish this program, recycling, milling and crushing of old portland cement concrete has proven to be an economical approach to provide granular materials for subbase and porous media backfill. However, it has been observed that porous media and underdrain pipes become encrusted with a cementations material believed to leach out of the processed portland cement concrete. This leached material has plugged the installed subsurface drainage such that the free moisture becomes trapped in the pavement section causing early surface distress.

III. OBJECTIVES - The general objective is to continue the economical use of the recycled portland cement concrete in pavements. An economical pavement requires good long-term subsurface drainage characteristics. Therefore, a method needs to be developed to reduce the cementatious effect of the leachate from the recycled portland cement concrete.

IV. CURRENT ACTIVITIES - At present, some States are investigating the reasons that underdrain systems have failed and have recognized the above problem to exist.

V. URGENCY - There is a considerable benefit to be gained by keeping needed subsurface drains functioning throughout the life of a pavement. With the use of recycled (waste) materials being economical, any detrimental effects on other entities of the pavement system should be corrected to obtain the most cost-effective installations.

A2L02

PROBLEM NO. 92

I. NAME OF PROBLEM - SOIL-GEOFABRIC PULL-OUT INTERACTION

II. THE PROBLEM - Pull-out tests on geofabric reinforcements in soil traditionally use testing procedures which were developed originally for quasi-inextensible reinforcements in granular soils. They provide basically peak and residual pull-out resistances as obtained from displacement controlled pull-out tests. However, the growing use of a variety of geofabrics in fine grain soils raise pertinent fundamental issues related to:

- effect of reinforcement extensibility on design value of pull-out load,
- effect of reinforcement creep on load transfer and admissible load,
- soil-reinforcement interaction in fine grain soils,
- testing procedure to evaluate creep pull-out load in fine grain soils,
- sample preparation and normalized testing procedures to evaluate geofabric performance and pull-out resistance in fine grain soils,
- interpretation procedures and load transfer models to assess extensibility effect on pull-out load-displacement curve,
- long term in-soil performance of geofabrics,
- anchoring effect vs. lateral friction in soil-geogrid interaction testing and interpretation.

III. OBJECTIVE - To improve design methodology and specifically methods to obtain relevant soil-geofabric interaction parameters for the design of geofabric/geogrids reinforced soil structures.

IV. CURRENT ACTIVITIES - None

V. URGENCY - The increasing use of geofabrics related reinforcing materials in the construction of highway embankments and retaining walls necessitates elaboration of appropriate and standardized design methodology to provide relevant design parameters. The expected

research findings will therefore be of immediate practical use and could be implemented through appropriate guidelines for design of geofabric/geogrid reinforced embankments with different types of reinforcement and embankment materials.

Estimated required research period five (5) years.
Estimated costs $400,000

PROBLEM NO. 93

I. NAME OF PROBLEM - IN SITU MEASUREMENT OF SOIL PROPERTIES

II. THE PROBLEM - Most subsurface site investigations for the foundations of transportation facilities utilize disturbed auger sampling, the Standard Penetration Test (SPT) or, in some cases, Shelby tube sampling. The SPT is the only in situ technique, and it provides very limited information, especially in cohesive soil deposits. This lack of information has lead to increasing interest in the use of such in situ test instruments as the Dutch cone penetrometer, vane shear test, the pressuremeter including the self-boring pressuremeter and the dilatometer. Because these devices give only indirect measures of the soil properties required for foundation design, correlations are tentative and highly empirical.

III. OBJECTIVE - To develop better in situ estimates of the design parameters required for stability and settlement analyses of both foundations and earth slopes. This research should involve both natural and treated deposits.

IV. CURRENT ACTIVITIES - Not too much now directly related to transportation, except Penn DOT project with J.H. Schmertmann on Dilatometer. More basic work going on now at MIT, Clarkson, Univ. of California, Berkeley, UBC, LSU, Univ. of Florida, Georgia Tech, and Purdue.

V. URGENCY - Use of design parameters determined from usual site investigation procedures are likely to result in conservative and unnecessarily expensive design. Improvement of techniques to obtain these parameters in situ can result in more economical designs of foundations for transportation facilities.

PROBLEM NO. 94

I. NAME OF PROBLEM - EVALUATION OF SOILS AFTER TREATMENT BY GROUND IMPROVEMENT TECHNIQUES

II. THE PROBLEM - Most of our correlations for soil properties from in situ techniques such as the SPT, CPT, PMT, etc. have been determined on either laboratory tests on undisturbed samples or in a few cases full scale field performance. When these devices are used to evaluate sites which have been treated by soil improvement techniques, the old correlations are necessarily used. There is some evidence that these correlations may be inappropriate for treated ground, apparently

because of modifications to the soil structure caused by the treatment. There is need for research to either verify that our present correlations are reasonably correct or to develop new correlations.

III. OBJECTIVE - To verify and/or develop new correlations for important soil properties as determined by various in situ techniques in ground which has been treated. These devices can either be in common in situ tests or geophysical tests such as cross-hole dynamic tests.

IV. CURRENT ACTIVITIES - There has been some limited research in this area, particularly by J.H. Schmertmann, W.H. Baker, and J.K. Mitchell.

V. URGENCY - Urgent because of the potentially unconservative nature or uneconomical use of existing correlations.

PROBLEM NO. 95

1. NAME OF PROBLEM - IN SITU TESTING IN TRANSPORTATION GEOTECHNOLOGY KNOWLEDGE BASED EXPERT SYSTEM DEVELOPMENT

II. THE PROBLEM - Transportation networks are undoubtedly some of the most massive and wide spread man-made structures. They involve thousands of miles of subgrade and base/subbase soils making up highways, airstrips, canals, waterfront structures, etc. It is necessary to provide fast, reliable and economical information concerning the technical properties of the former prior to design, and the latter after construction. A variety of in situ testing/evaluation techniques (SPT, CPT, VST, PMT, DMT) are commonly preferred to conventional boring/sampling and laboratory testing, since they are usually less cumbersome and time consuming, and more economical and reliable. However, there does not exist uniformity in their goal-specific use, and thorough evaluation of test results.

A review of the available data reveals that Cone Penetration Test (CPT) and Dilatometer Test (DMT) are the most valuable candidates for extensive use of the transportation industry from the viewpoint of practicality, economy and versatility. Vast amounts of local and mostly semi-empirical correlations concerning soil classification, soil strength/stability and compressibility do exist, but have not yet been comprehensively analyzed, cross correlation with theory, conventional testing methods and/or each other.

III. OBJECTIVES

A. Conduct a national/international data base search from reliable agencies concerning CPT and DMT results obtained in well-documented natural deposits and in laboratory calibration chambers with pre-defined soil properties and boundary conditions.

B. Develop a state-of-the-art calibration chamber.

1. Run a nation-wide field testing program covering a wide variety of sediments from regions of different geologic origin.

2. Conduct two (or three) sets of calibration chamber sets on representative samples from these sites.

C. Develop a knowledge-based expert system which will cross-correlate and manage the data, and will self-update with additional input information in the future.

IV. CURRENT ACTIVITIES

A. A number of independent research projects concerned with experimental and theoretical aspects of wide variety of in situ testing methods are active in the U.S. (UC, Texas A&M, LSU, UF, Purdue, MIT, UBC) and Europe (Oxford Univ., NGI, ENEL, Groenoble Univ.) Calibration chamber testing has been more extensively pursued in Europe (U.K., France, Italy, Norway), and to a lesser degree in the U.S. (UF, VPI). Knowledge based expert system development, although widely used in other fields, has only recently been introduced into soils related work.

B. Suggested key words: in situ tests, CPT, DMT, soil strength, compressibility, stability, classification, expert system analysis.

V. URGENCY - Reduction or total elimination of disturbed/undisturbed soil sampling and many strength/deformation tests, utilized in answering geotechnically oriented problems of the transportation industry, will result in great savings. To achieve this goal a good number of DOT's are turning to in situ tested methods. It would thus appear that a better understanding of the geotechnical parameters provided by two of the most promising candidates (i.e., CPT and DMT) of these methods, together with a "smart" data correlating and managing expert system is timely.

Estimated project duration: 3 years
Estimated project cost: $350,000

PROBLEM NO. 96

I. NAME OF PROBLEM - PREDICTION OF AXIAL CAPACITY OF FRICTION PILES BY IN SITU TECHNIQUES

II. THE PROBLEM - Present trend of U.S. DOT's is to emphasize in situ testing and more particularly CRT, as demonstrated by previous or pending purchase of fully equipped CPT vehicles and related equipment by several DOT's, and more particularly, Florida, California and Louisiana DOT's.

DOT's and FHWA are aware of the need to also improve analytical capabilities with regard to the ability to predict pile capacity and behavior with more confidence. FHWA funded large pile test programs at the Univesity of Houston in over-consolidated clays and in San Francisco in medium dense sand. As regards to the latter, ten experts were invited to predict the load capacity, load distribution and load-settlement behavior of a single axially loaded control pile and

an axially loaded group of fifty stiffly capped piles of the same design as the control pile. As demonstrated by the results of these predictions (presented at the June 17-18, 1986 Pile Group Prediction Symposium), none of the predictions adequately predicted the observed behavior. It is, in fact, interesting (if not frightening) to see that the spread among predictions was at times as large as 3 to 1 and some of the predictions over-predicted the ultimate capacity by a factor of two or more.

III. OBJECTIVES

A. Demonstrate the use and capabilites of a battery of in situ tools which can be deployed with a CPT vehicle.

1. Frictioncone and piezocone (stratigraphy and engineering properties).

2. X-probe (pile shear transfer parameters)
   X-probe is a properietory instrumented model pile.

3. Marchetti Dilatometer (in situ state of stress).

4. PAF76 (in situ strength and deformation parameters).

5. High quality sampling (26 and 66 mm samples for confirmation of stratigraphy and cross-correlation with conventional laboratory testing).

The latter two tools are optional but were listed since they can be deployed by a specially equipped CPT vehicle.

B. Develop a data bank for DOT's use in designing friction piles. The data bank will be placed on a micro computer for cross-correlation and will be an evolving relationship which "self-improves" with the continuous gathering of data.

C. Develop improved and designer oriented:

1. stratigraphy identification

2. classification of soils

3. soil parameters determination in situ

4. hydraulic conductivity

5. pile capacity methods.

As regards to the latter, the present trend, as also realized by FHWA and state DOT's, is to move away from limit equilibrium methods in favor of load-deformation methods which recognize the deformation characteristics of pile foundations.

IV. CURRENT ACTIVITIES

A. There has been a number of recent projects (mentioned above) on "Pile Capacity Prediction." However, the extent of involvement with in situ testing techniques and development of knowledge-based expert systems have been minimal, if not non-existent.

B. Suggested key words: in situ test, CPT, DMT, PMT, X-probe, pile capacity, load-deformation, expert system analysis.

V. URGENCY - Although the ability of the geotechnial community to characterize a site is improving with the use of in situ tools such as the CPT, and our ability to implement complex analytical methods has made great strides with the use of computers, pile capacity prediction methods, particularly for friction piles, are lagging far behind. This state of affairs is recognized by both state and federal highway design teams which would make this topic a top priority "Research Needs."

Estimated project duration: 3 years
Estimated project cost: $400,000

PROBLEM NO. 97

I. NAME OF PROBLEM - DEVELOPMENT OF ANALYTICAL MODELS TO ADEQUATELY ACCOUNT FOR INTERFACE CHARACTERISTICS OF SOILS AND GEOSYNTHETICS

II. THE PROBLEM - Geosynthetics have been used on an increasing number of projects as an effective means of stablization. Too often these materials are thought of as cure-alls for a number of problems. Very little effort has been directed towards evaluating the specific effect of the interaction between soil and geosynthetic. Lab modelling of field problems indicate that there are numerous parameters which affect interface properties. It is, therefore, extremely difficult to generalize these properties in a simple analytical model which is useful and yet reliable.

III. OBJECTIVES - The objective of this research is to quantify the actual interface characteristics of geosynthetics in contact with real soil. This would be accomplished by proper modelling of the geosynthetic/soil system and measuring system stress-deformation-volume change characteristics during loading as well as actual stress-deformation chaacteristics of the geosynthetic material. Upon completion of this phase, development of a realistic analytical model which accounts for these characteritics would be initiated.

IV. CURRENT ACTIVITIES

A. Manufacturers typically address and report basic geosynthetic properties in their literature. When results are reported they are for specific normal stresses, small scale models and "convenient" soil. A more fundamental picture needs to be developed.

B. Suggested key words geosynthetic, geotextile, geogrid, modelling, laboratory simulation, analytical modelling.

V. URGENCY - The use of geosynthetic material for stability has been steadily increasing in recent years. New products are constantly being developed, including some very high strength composites. Very little is known about their interaction. Expensive full-scale test sections are often undertaken to try and fine tune design decisions. This procedure could be made more efficient with good fundamental research as indicated.

PROBLEM NO. 98

I. NAME OF PROBLEM - DEVELOPMENT OF A RAPID DEPLOYMENT SCHEME FOR THE SELF-BORING PRESSUREMETER

II. THE PROBLEM - In situ soil tests have been gaining in popularity in the recent past. The advantages are numerous. One test, the self-boring pressuremeter test, has long been recognized as having the greatest potential in evaluting with confidence a very wide range of engineering properties. Its disadvantage has historically been a painfully slow test to conduct due to the self-boring requirement. New deployment concepts of jetting and full displacement have been conceived and subject to limited development. These methods need to be further investigated to evalute the sacrifice in test quality that results.

III. OBJECTIVE - The objective of this research is to develop a companion lab and field testing program to evaluate the effects of property evaluation due to deployment technique. The lab program would be conducted at a scale modelling could be utilized and actual in situ response quantified. Equipment development would proceed based on the lab and field trials.

IV. CURRENT ACTIVITIES

A. Engineering practice has often required the use of the self-boring pressuremeter. Due to time constraints, rapid deployment schemes were attempted with mixed success. Little fundamental work has been directed to this area but results have been very encouraging.

B. Suggested key words: pressuremeter, self-boring pressuremeter, test equipment, deployment, modelling simulation.

V. URGENCY - A fundamental study of deployment techniques has not been initiated. Specific projects have required self-boring pressuremeter utility and certain constraints have required alternate deployment schemes of jetting and/or full-displacement be attempted. Results indicate that significant time and cost savings are possible with potentially little effect on the derived engineering parameters.

PROBLEM NO. 99

I. NAME OF PROBLEM - INTERPRETATION OF IN SITU SOIL AND ROCK TESTS FOR ENGINEERING DESIGN PARAMETERS

II. THE PROBLEM - There currently exists a number of in situ soil and rock tests which are being used to evaluate engineering properties. The numerous advantages of these tests are often offset by the fact that existing test interpretation techniques are based more on empirical correlation than upon theory. In many cases it is extremely difficult to assess the actual stress strain response of soil and thus not possible to include these characteristics in the interpretation scheme.

III. OBJECTIVES - The objective is to develop interpretation schemes for dilatometer and pressuremeter tests which are based upon the actual stress-strain history of the soil before insertion, during insertion, and during the actual testing. Specifically, a main thrust of the research would be directed towards establishing the actual stress and deformation field associated with these tests in various soils. This would extend some of the European work which historically has concentrated on softer soils.

IV. CURRENT ACTIVITIES

A. Work in this area started strong with research undertaken in Europe. Very little fundamental work has been initiated in the U.S. The work in Europe has changed course over the years and the U.S. practice has been drifting toward empirical utility.

B. Suggested key words: in situ testing, soil properties, pressuremeter, dilatometer.

V. URGENCY - In situ testing has been gaining acceptance among practicing engineers in the U.S. The dilatometer and pressuremeter are extremely popular in widespread usage. Many of the questions concerning test applicability and test interpretation are answered by relying on experience and conservation. Knowledge of actual behavior will lead to more confident use, a more realistic assessment of engineering properties, and ultimately more economic design.

A2L03

PROBLEM NO. 100

I. NAME OF PROBLEM - CHARACTERIZATION OF WASTE SULFATES FOR USE IN HIGHWAY CONSTRUCTION

II. THE PROBLEM - Waste sulfates are by-products containing significant quantities of calcium sulfate or calcium sulfite. They result from desulfurization of flue gases in power plants, neutralization of acid mine drainage, fluidized bed combustion or chemical industry (phosphoric acid, hydrofluoric acid) effluent discharges. Large quantities are produced annually and have been stockpiled over the years. Utilization in highway construction has been limited.

Past research (see references) has shown that waste sulfates, usually stabilized with lime/fly ash, or cement (to a lesser extent) can be used in base courses. Potential also exists for their utilization in admix liners, grout mixtures, synthetic aggregate and bulk fills. Although stabilized waste sulfate mixtures appear to produce adequate strength when properly designed, their durability characteristics (freeze-thaw, resistance, expansion, shrinkage, etc.) have not been well-established. Their leachate characteristics in the stabilized or unstabilized form and their environmental impact are not well-known. Questions remain on the effectiveness of cement stabilization with waste sulfates. The microscopic engineering properties (chemical, physiochemical) and their effect on performance have not been well-documented.

Research is needed to fill in the gap.

III. OBJECTIVES

A. To characterize the physical, chemical, physiochemical, and behavioral properties of the various waste sulfate materials.

B. To study the feasibility of stabilizing the various waste sulfates with pozzolanic, cement and bituminous binders with specific emphasis on long-term durability characteristics.

C. To develop guidelines for material evaluation, mix-design and construction procedures in view of the special characteristics of waste sulfates.

IV. CURRENT ACTIVITIES - FHWA has supported some research during the 1970's. Some related work was sponsored by Florida Institute of Phosphate Research. West Virginia University's Civil Engineering Department recently completed two studies on HF by-product sulfate. Texas A&M researchers have been working on a road base project with phosphogypsum.

V. URGENCY - The proposed research has moderate urgency.

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A2L04

PROBLEM NO. 101

I. NAME OF PROBLEM - LEGAL ASPECTS OF ROADWAY INSULATION USAGE

II. THE PROBLEM - Field observations have demonstrated that buried subgrade insulation layers may, under certain atmospheric freezing conditions, result in the formation of surface frost or ice deposits at times when adjacent normally constructed roadway sections remain ice free. This condition of differential surface ice can create a hazardous situation for motorists because of the unexpectedly low skid resistance. The condition is similar to that of ice formation on bridge decks, where it reportedly occurs with a much higher frequency than above insulation layers. The original supplier of extruded polystyrene roadway subgrade insulation previously refused to supply insulation for roadway burial in the USA unless the user agency agreed to indemnify them from lawsuits through the mechanism of a "Hold Harmless" Agreement. This situation nearly eliminated the consideration of insulation products for the control of frost heave in the USA between 1974 and 1984. However, road insulation usage remained common in Canada, under a different legal system and the absence of an indemnification requirement. At this time, nothing has

been written to guide the road designer in reaching rational and defensible decision on when and how to use buried insulation layers for frost heave control and freeze protection for buried utility and drainage systems.

III. OBJECTIVES - The study objective is to provide practicing engineers with factual information on the probable and potential legal consequences of surface ice formation which can result from installation of near-surface insulation layers beneath roadways and airfields. This will include information on prediction of the probable frequency of ice formation, and on possible methods of improving skid resistance through surfacing modification.

Legal aspects addressed should include consideration of the following alternatives:

A. Minimizing the frequency of icing by increasing the depth of cover over insulation.

B. Applying surface friction improvement modifications such as "Verglimit" or "Plus Ride" pavements.

C. Justifying the decision to insulate based on economy.

D. Applying roadway insulation only in non-braking areas or only to short lengths of roadway.

E. Refusing to insulate hazardous frost heave areas, i.e., choosing the "Do Nothing" alternative.

IV. CURRENT ACTIVITIES - No activity in the legal analysis area has come to our attention. Prior work exists on predicting the occurrence of differential surface ice over insulated pavements. The skid resistance of icy surfaces over various pavement types and textures has received only minimal study. Research on "Plus-Ride" rubber-modified asphalt pavements and "Verglimit" pavements for increasing icy road friction levels, demonstrates some benefits of this material.

V. URGENCY - The use of buried roadway insulation has started to increase in the USA, following a long period where the only supplier refused to sell insulation board as a result of legal concerns over the liability for road icing. New manufacturers have recently commenced production of competing products adequately resistant to deformation and water absorption, and a fresh look at all aspects of subsurface insulation will benefit designers and road users.

PROBLEM NO. 102

I. NAME OF PROBLEM - CHANGES IN SOIL STIFFNESS AND STRENGTH INDUCED BY FROST ACTION

II. THE PROBLEM - Moisture changes and other effects induced by freeze-thaw cycles significantly alter the strength and stiffness

properties of soil, and thereby affect the performance of the pavement. Current pavement design methods do not adequately account for reduced subgrade support conditions caused by these frost induced changes. Reduction factors are estimated on the basis of judgment and limited field performance studies rather than test procedures. Recently developed mechanistic pavement design methods which are based on calculated stresses and strains and make use of cumulative damage principles require an accurate assessment of the seasonal variation in strength and stiffness. The use of a resilient modulus test appears to be the best procedure for characterizing the response of subgrade and base materials under freeze-thaw conditions; however, other parameters should also be examined. The development of laboratory test procedures will need be verified by comparing predicted theoretical pavement response to measured deflections in the field.

III. OBJECTIVES - The general objective of this research is to determine the methods for characterizing the effects of frost action on the strength and stiffness of subgrade soils and granular unbound base course materials. The specific objectives are:

A. Evaluate pavement response and performance models currently in use or being developed to determine which strength or stiffness parameters of soil and unbound base courses affected by freeze-thaw serve as the most useful and important input parameters to the preferred models.

B. Determine laboratory and field procedures for evaluating the selected strength and stiffness parameters.

C. Develop predictive models of the selected strength and stiffness parameters in terms of readily measured soil properties.

D. Validate the strength and stiffness models by means of controlled laboratory and field tests.

E. Couple the strength and stiffness models with pavement response and performance models for use in design and evaluation of pavements affected by frost action.

F. By observations of actual pavements in service, validate the performance model to verify the determined relationship between frost-dependent material parameters and development of pavement distress such as cracking and rutting.

IV. CURRENT ACTIVITIES

A. Frost research in progress:

1. The development of laboratory techniques and procedures for characterizing the stress-strain response of subgrade soils in the frozen, thawing, and thawed states is underway at the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL).

2. The development of laboratory techniques and procedures for index tests for determining an order ranking of frost susceptibility of subgrade soils is underway or completed at several research agencies such as FHWA, CRREL, Purdue University, Massachusetts DPW, Pennsylvania DOT, New Hampshire DOT and several foreign countries.

3. Mathematical modeling projects are currently underway at CRREL. The oil and gas industries also are engaged in modelling frost action affecting pipelines.

4. Full-scale field testing of frost heave and thaw weakening are currently underway at several sites in Pennsylvania, Massachusetts, and New York. Frost heave of buried pipelines is being tested in Alaska and Alberta.

5. By current field and laboratory investigation in Alaska, relationships are being defined between fines content in subgrades and granular bases, extent of thaw weakening shown by spring deflections, and evidence of pavement distress by cracking and rutting.

B. Suggested key words: frost action, freeze-thaw, thaw weakening, resilient modulus, pavement damage accumulator, materials characterization, soil strength, soil stiffness, and pavement response.

V. URGENCY - There is no fundamental way, currently available, to accurately account for the significant reduction in strength and stiffness due to frost action on pavement systems. There is a critical need for a broad data base of actual values of resilient modulus and other suitable parameters of a wide variety of subgrade soils and base course materials, measured throughout the year including periods of freezing, thawing and recovery. These actual field measurements are necessary to verify analytical and laboratory predictive techniques which are in turn urgently needed to improve pavement design in seasonal frost areas.

PROBLEM NO. 103

I. NAME OF PROBLEM - SYSTEMATIC PROCEDURES FOR APPLYING SEASONAL LOAD LIMITS ON FLEXIBLE PAVEMENTS IN FROST AREAS

II. THE PROBLEM - The load carrying capacity of a flexible pavement varies with season because of the influence of environmental factors such as frost, moisture and temperature. The primary phenomenon is the loss of subgrade support or thaw-weakening during the spring thaw period. Many states have recognized this problem and have invoked temporary load restrictions on pavements during periods that they consider critical. A recent review of literature indicated that 42 states and Canadian provinces experience seasonal freezing of pavements. Of these, 20 impose springtime load restrictions by a variety of methods. Many of these methods are based on engineering judgment and,

therefore, are subjective. Too, often, restrictions are applied only after the damage is apparent. In other cases, load limits are placed when not needed. A need for an objective approach to establish load limitations and to assess penalties for overloads exists. Field measurements of the pavement system strength levels should provide the data used to establish the level of load limits and also the duration thereof. Non-destructive deflection measuring devices such as the static Benkelman beam and plate bearing tests, and dynamic loading devices such as the Dynaflect, the Falling Weight (FWD), and the Road-Rater are good indicators of pavement strength changes and could well be used to establish objective data bases.

III. OBJECTIVES - The general objective of this research is to establish recommended procedures for applying seasonal load limitations on flexible pavements that can be widely accepted and implemented. The specific objectives are:

A. To develop a method of determining the maximum allowable load on a flexible pavement during critical periods based on objective measurements which are indicators of in-place strength.

B. To develop a system for establishing when load limits should be applied to and removed from each road segment based on indicators of in-place strength. The development of such a system should include a review and recommendations on appropriate in situ instrumentation which directly measures or correlates with in-place strength.

C. To develop a rational method for predicting damage caused to pavements during critical periods, by loads in excess of those determined in objective A.

D. To recommend an implementation procedure which includes a method of controlling or enforcing the load limitations, an overweight permit policy, and an equitable method of assessing overload penalties based on incurred damages determined by objective C.

E. To modify currently available guidelines for use by city and county highway personnel in posting temporary load limits in the absence of extensive data.

IV. CURRENT ACTIVITIES - State transportation agencies in Alaska, Idaho, Minnesota, Pennsylvania and Washington have published reports on deflection based load limitation schemes. Six states have implemented load limitation systems based on some type of deflection measurement. At this time, no research is underway relating to this problem statement; however, a recently completed study funded by the FHWA will help to focus a request for proposals.

V. URGENCY - It is paramount to obtain the maximum useful lives from our existing pavements. The rational application of spring-time load limits based on objective pavement measurements would substantially increase service life since most load related distress occurs during

this portion of the year. General adoption and implementation of rational load restriction procedures in seasonal frost areas should be made as soon as possible to slow pavement deterioration rates. Conversely, restrictions placed on trucking when not necessary, ultimately result in excessive costs and delays to the general public.

A2M01

PROBLEM NO. 104

I. NAME OF PROBLEM - TRACK IMPACT LOADING FROM WHEEL TREAD DEFECTS

II. THE PROBLEM - Track impact loading from wheel tread defects poses the greatest obstacle to more economical concrete tie design. It is believed that the impact loads which can cause distress in concrete ties have for years been causing accelerated degradation on wood tie track. No one has ever documented the costs associated with operation of permissible wheel tread defects in North American railroads.

In 1947, the AAR conducted a series of tests measuring the effect of slid-flat wheels on a 70-ton car on track structure. the report was excellent, but the instrumentation was crude by the standards of today. With the modern rail shear strain gauge circuit which can directly measure high frequency track loading, it is time that impact loading from wheels with currently permissible shells, slid-flats, built-up treads, and "out-of-round" conditions on empty, 70-ton, 100-ton, and 125-ton cars be fully documented over the speed range 5 to 80 mph. Without tightening the standards on wheel renewals, there could be heavy track maintenance penalities associated with operation of heavier cars and 60 to 80 mph trains.

III. OBJECTIVES - Data should be collected such that AAR Interchange Rule No. 41, Section A, Cause for Wheel Renewal, can be amended by including wheel loading exceedence limits as direct cause for wheel renewal. The following is proposed for consideration:

Wheel loads exceeding the following limits shall provide cause for wheel renewal, effective on given dates.

Total Load	Incremental Load	Effective
75 kips	42 kips	January 1, 1987
65 kips	32 kips	January 1, 1989
55 kips	22 kips	January 1, 1991

The incremental load limit would form a vital part of the rule as it would be used to condemn wheels on empty and partially loaded cars.

To document effects of "bad" wheels, it is suggested that a train full of non-condemnable wheel tread defects be run on the FAST track, and that the accelerated rates of rail spalling, concrete tie cracking, wood tie plate cutting, loosening of rail fastening systems, gauge widening degradation of ballast, roadbed settlement rates, and increases in fuel consumption be measured. The possible (or probable) false economies associated with operation of "bad" wheels could be established, and apportioned through extrapolation to operating railroads.

IV. CURRENT ACTIVITIES - Amtrak has successfully used results from a wheel loading measurement system to clean up wheels on their passenger fleet. Wheel loading from freight cars is being evaluated. The Florida East Coast Railway now has three wheel loading detection stations, and they are using data to renew wheels. CN are now collecting data from a wheel loading detection station on wood tie track to determine incidence of "bad" wheels, and are considering purchasing a second system for use on concrete tie track. CN Reseach in August 1985 ran a work train having 14 wheelsets with non-condemnable tread defects at speeds from two to 75 mph over a wheel loading measurement station on concrete tie track. There have been some appalling results from all of the measurement stations, and future reports will undoubtedly document this grim story.

V. URGENCY - It does not make sense to talk about operating 125-ton cars and freight trains to 70 and 80 mph without addressing current AAR stndards governing renewal of wheels with tread defects. In North American, over a billion dollars a year revolves directly around what occurs at the wheel/rail interface, and the costs associated with currently "permissible" impact loadings have not been determined or apportioned. It is high time they were.

PROBLEM NO. 105

I. NAME OF PROBLEM - MULTIPLE VS. SINGLE TRACK OPERATIONS

II. THE PROBLEM - None stated.

III. OBJECTIVE - To study and further evaluate the performance and economic benefits.

IV. CURRENT ACTIVITIES - There is an increasing trend to reduce trackage utilizing modern technology to handle the traffic.

V. URGENCY - To determine how all the factors influenced affect the inherent savings.

PROBLEM NO. 106

I. NAME OF PROBLEM - TRACK GEOMETRY VEHICLES - PRESENT AND FUTURE!

II. THE PROBLEM -None stated.

III. OBJECTIVES - To evaluate the current results of vehicles being used and assess their potential.

IV. CURRENT ACTIVITIES - A number of Class I Railroads are using track geometry measuring vehicles. Most have their own systems.

V. URGENCY - To consolidate the information available, define the inherent values obtained (i.e., inspection, comparison, correction, current and future maintenance/construction planning, regulatory compliance, etc.).

PROBLEM NO. 107

I. NAME OF PROBLEM - APPLICATION OF RAIL LUBRICANTS - FIXED WAYSIDE UNITS VS. LOCOMOTIVE UNITS

II. THE PROBLEM - None stated.

III. OBJECTIVES - Study the merits of each method and determine where and when each would be more beneficial.

IV. CURRENT ACTIVITIES - None known.

IV. URGENCY - Current studies indicate that beyond a doubt rail lubrication is justified, both as a fuel economy and to extend rail service life. The issue is a matter of the most practical and economical method to apply the lubricant.

PROBLEM NO. 108

I. NAME OF PROBLEM - STANDARD VS. HEAT TREATED VS. ALLOY RAIL

II. THE PROBLEM - None stated.

III. OBJECTIVES - Based on economics involved, develop a matrix to assist in determining the laying location of each type of rail to obtain the maximum service life.

IV. CURRENT ACTIVITIES - None known.

V. URGENCY - With the change in motive power tractive effort and truck configuration, car size, capacity and labor costs to install, remove rail, it is incumbent that the most effective and economical type of rail be laid at the various locations which will result in the maximum service life.

PROBLEM NO. 109

I. NAME OF PROBLEM - EVALUATE CONCEPTS TO UPGRADE EXISITNG TRACK TO ACCOMMODATE INCREASED AXLE LOADS OR INCREASED SPEED

II. THE PROBLEM - Increased axle loads have a non-linear and still not fully understood effect on track costs. While the problems of 66,000 lb. axle loads have generally been overcome, still heavier axle loads are future possibilities and may be necessary for rail competitiveness.

III. OBJECTIVES - Tabulate and evaluate all known concepts for possible upgrading of track to meet heavier axle loads. Determine track designs needed for 100,000 lb. axle loads at normal track speeds.

IV. CURRENT ACTIVITIES

A. FAST track.

B. AAR TDD studies.

V. URGENCY - All railroads are actively engaged in their individual methods. Overall advice on evaluation of all technqiues would be of help.

PROBLEM NO. 110

I. NAME OF PROBLEM - INVESTIGATE THE TRADE-OFF BETWEEN INCREASING AXLE LOADINGS AND TRACK COSTS

II. THE PROBLEM - In the U.S.A. rail axle loadings have been increasing over the past two decades due to large volume cars being designed and built. The question is now whether to go beyond the 66,000 lb. axle load. Many of the effects on track costs of doing this need more study to be able to quantify the additional track costs.

III. OBJECTIVES - Determine the true dollar value of increased axle loadings after deducting additional track costs per net ton.

IV. CURRENT ACTIVITIES - Some past activities such as analysis of economics of the 125 ton coal hopper cars. Some activity in studies of wheel loadings on rail

V. URGENCY - The study is needed for decisions which might otherwise have to be made with less certainty.

PROBLEM NO. 111

I. NAME OF PROBLEM - "FOOTING" OR "PAVING" TO SUPPORT RUBBER TIRED LIFTING EQUIPMENT

II. THE PROBLEM - Do existing methods of designing paving (using load repetitions, coverage, and equivalents) apply to supporting heavy wheel loads that cover larger areas and remain in one location oscillating for several minutes between movements?

III. OBJECTIVES - Determine the thickness of foundation including structural section and underlying soil and rock to be included in the economical design for support in common classifications of materials. Include medium dense sand, medium dense silt, medium stiff silty clay, and soft clay.

IV. CURRENT ACTIVITIES

A. Suggested key words: depth in investigation required, depth of design required.

B. Observations of existing facilities, good records of sections and subgrade materials, spacing of joints and cracks vs. widths and thickness, load tests with pressure cells, piezometers, etc.

V. URGENCY - Normal development as demand for rubber tired equipment changes.

A2M02

PROBLEM NO. 112

I. NAME OF PROBLEM - RAILROAD ELECTRIFICATION FIXED PLANT INSTALLATION COSTS

II. THE PROBLEM - Major cost discrepancies exist for railroad electrification fixed plant installation between the United States and other countries. While labor costs or rates of exchange vary widely from country to country the differences cannot be attributed solely to these factors. A detailed comparison of design requirements, installation methods and specifications would help identify areas of differing requirements and support rationale.

III. OBJECTIVES - The objective is to identify and document areas of railroad electrification cost differences including wayside substations, catenaries, signalling and communication systems. Analysis would be conducted to determine if the variance is due to design requirements, manufacturing procedures, installation practices, work rules, operating philosophy, etc.

IV. CURRENT ACTIVITIES

A. The FRA maintains an active data file of worldwide railroad electrification projects. An updated annual report is published each year.

B. The TRB Committee A2M02 has an active subcommittee dealing with electrification cost differences.

C. The TRB Committee A2M02 has formal presentations related to comparison cost issues at its semiannual meetings.

D. Suggested key words: railroad electrification, cost comparisons, electrification costs, overhead catenary power supply distribution, and alternative system capacities and styles.

V. URGENCY - The results of the research are an important factor in railroad electrification cost benefits analyses. It appears that a number of recent electrification system installation cost estimates could have been reduced by the incorporation of improved design techniques and/or more precise cost data. A number of alternative factors have been identified which might result in reduced installation costs--these include simplification and changes in the areas of structural design, clearances, substations and signal and communication system modifications. Such reductions in cost might result in a sufficient improvement in investment return to justify electrification implementation.