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TRANSPORTATION RESEARCH CIRCULAR

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RESEARCH PROBLEM STATEMENTS

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GENERAL NOTE

This circular supercedes Circular 227 dated April 1981. Additional statements emanating from Group 2 Committees are contained in Circular Number 260 dated July 1983 and Circular Number 261 dated July 1983.

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 forty-three 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.

PRIORITY RATINGS

In assembling these problem statements the Standing Committee on Research Needs has attempted to develop a best consensus of the top priority research needs. Each contributing committee was asked to rate its problem statements by its own method. All statements were then screened at the Group Section level for overlap and duplication. Some sections then chose two top priority statements from the collective efforts of its committees. All problem statements were then submitted to the Standing Committee for final review and processing. As a result of this review and based on the committee and section recommendations the problem statements have been rated in priority categories by section and by 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 of priorities.

RESEARCH PROBLEM STATEMENTS

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A. GENERAL DESIGN - Samuel V. Fox, Chairman

A2A01 Photogrammetry and Aerial Surveys - Tommie F. Howell, Chairman

PROBLEM NO. 1

I. NAME OF PROBLEM - AIRBORNE PHOTOGRAMMETRIC CONTROL SURVEYS

II. THE PROBLEM - Ground control for use in photogrammetric mapping is a time consuming and expensive process. While the use of Analytical Aerotriangulation has substantially reduced the amount of ground survey points there remains a real need to develop methodology to accomplish this task from an airborne platform.

Due to the increasing demands for photogrammetric geographic data bases for use in regional transportation planning, design, construction and other transportation applications considerable emphasis should be given to reduce the manpower and time required to perform this essential task.

III. OBJECTIVES

A. Review existing procedures to determine if these can be significantly enhanced.

B. Determine if existing procedures can be combined to improve overall throughput.

C. Conduct research to develop a procedure to compute the relative coordinate values of the aerial camera geometry, as each picture is exposed, to be transformed into project coordinates as the mapping phase is initiated.

IV. CURRENT ACTIVITIES - Considerable work has been accomplished in the area of satellite surveys, inertial surveys and analytical aerotriangulation.

V. URGENCY - Millions of dollars in both equipment and manpower is currently being expended to perform these tasks using current methods. Also, the time lost to the engineers and planners awaiting this information results in a significant overall increase in the total cost of the project. There is an immediate need to improve existing procedures to accomplish this task and minimize or eliminate the requirement for on-the-ground surveys.

PROBLEM NO. 2

I. NAME OF PROBLEM -AUTOMATION OF ROAD PAVEMENT EVALUATION

II. THE PROBLEM - Millions of miles of road need to be evaluated each year on a worldwide basis. An automated pavement evaluation system is needed to better accomplish this task. For many years pavement rating methods have been handled manually, usually by one person viewing the pavement from a moving vehicle, mentally assessing the pavement condition and formulating a numerical rating representative of the pavement condition. In recent years there has been a growing interest in automating the pavement rating process. Some efforts have been directed to the use of standardized surface distress rating forms. The Ministry of Transportation and Communications in Canada, for instance, has identified and described most pavement distress conditions, such as potholes and alligator cracking, which contribute to deteriorating pavement conditions. The California Department of Transportation uses a surface distress evaluation form together with ride quality and skid resistance equipment as input data for selecting specific rehabilitation strategies. A number of mechanical devices have been developed for measuring various pavement conditions such as ride quality, skid resistance, changes in profile, and deflection characteristics. Some research is underway to place these mechanical devices in a single unit so that all of these measurements may be made from one vehicle. But, to date, this has not been done in a way that allows pavement to be rated in a single operation and that relates the numerical ranking to the underlying conditions. Mechanical devices when properly calibrated have good repetative qualities but manual rankings obtained by visual observations and mental assessment are difficult to repeat even when done by the same person who did the previous rating.

There is a need to devise a method for combining the measurable components of pavement condition including the visual into a single system so that through the use of mathematical models and statistical sampling methods a repeatable rating can be provided. Ride meters and skid resistance readings could be incorporated with visual surface pavement distress evaluation to provide a road condition index and possibly a recommended rehabilitation strategy. Provisions also could be included to quantify changes over time and provide a rate of change index.

III. OBJECTIVES

A. Develop a system for automating the evaluation of highway conditions. Both semiautomated direct visual techniques and automated image pattern recognition techniques should be investigated.

B. Develop techniques for analyzing change in highway conditions.

C. Demonstrate the use of the system and the validity of the highway condition index and change index based on data from selections of highways.

IV. CURRENT ACTIVITIES

A. Suggested key words: pavement evaluation, pavement rating, automated pavement evaluation, automated defect detection, surface distress.

B. There is considerable research in pavement maintenance and evaluation methods especially in the development of single instrument devices for a specific purpose. No reference to research using automated pattern recognition techniques or methods which could integrate readings of various evaluation equipment could be located.

V. URGENCY - The need for improved pavement evaluation methods is immediate. Newly developed methods of automated evaluation would be implemented by FHWA, state DOT's, county road departments and other agencies worldwide.

A. Estimated cost: $150,000 to $200,000.

PROBLEM NO. 3

I. NAME OF PROBLEM - COMPUTER ASSISTED TERRESTRIAL PHOTOGRAMMETRY USED IN HIGHWAY OPERATIONS AND MAINTENANCE EVALUATIONS

II. THE PROBLEM - The allocation of highway funds for system operations and maintenance requires some system of fund prioritizing for allocation. The process of prioritizing requires various information. The gathering of this information is usually accomplished using costly time consuming field surveys. Many times these surveys are inadequate. This is due to the complexity of problem surveyed, a labor intensive process, traffic hazard and subjective analysis, lack of repeatability and inadequate historical recordation of conditions. There is a need to reduce costs, reduce personnel effort, speed up process and systemize the data gathering process so that realistic data can be displayed in various ways which allow alternative processes to be displayed.

III. OBJECTIVES

A. Review field surveys presently being done for operation and maintenance activities.

B. Quantify those surveys that could be accomplished by use of either very low level aerial and/or terrestrial photogrammetry.

C. Determine those uses that are operational and those that need research.

IV. CURRENT ACTIVITIES - Terrestrial photogrammetry has been successfully used in architecture, airframe quality assurance, some pavement evaluation, roadside hazard studies, very large scale topographic mapping of landslides, cut bank erosion, bridge studies, tunnel deformation and traffic studies. No research is known that uses these photogrammetric techniques in a computer assisted environment.

V. URGENCY - Recent increases in gas tax will provide revenues and, due to the deteriorated state of transport facilities, it becomes urgent that techniques be developed to assure that expenditures are made in a most prudent manner and that the remedial work be accomplished where the most urgent need exists.

A2A02 - Geometric Design -
Geoffrey M. Nairn, Jr., Chairman

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 criterial 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 multilane 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 theoretical assumptions. The research results should be applicable to suburban areas where the greatest number of driveways are being built.

IV. CURRENT ACTIVITIES

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

B. 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 - ADDITIONAL THROUGH LANES AT INTERSECTIONS

II. THE PROBLEM - A highway usually has much higher traffic capacity between intersections than it does at either signalized or unsignalized intersections at grade. To utilize the highway capacity between these intersections, urban or rural, additional lanes can be provided to facilitate through movements and provide sufficient lanes for left or right turn movements. There is a need for a determination of length of the additional lane, both in advance of and beyond the intersection, to permit safe and efficient flow of through traffic. This determination must be recognized as a separate problem and not the same as an auxiliary lane as derived in the highway capacity manual. The most uncertain part of the design is what length of lane is required beyond the intersection to provide a satisfactory traffic merge when the added lane is ended.

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

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

B. The required length of extra through lane (including taper requirements) needed in advance of the intersection with or without a designated left turn lane.

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

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

IV. CURRENT ACTIVITIES

A. Suggested key words: geometric design, intersection design, added lanes, capacity, safety traffic merge, truck and RV factors.

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

V. URGENCY - This project warrants an immediate and high priority because existing highways and street systems can be provided with increased capacity at relatively minor costs if the designer is assured that the design is safe and efficient.

A2A04 - Safety Appurtenances -
Hayes E. Ross, Jr., Chairman

PROBLEM NO. 6

I. NAME OF PROBLEM - DEVELOPMENT OF LOW MAINTENANCE SAFETY APPURTENANCES

II. THE PROBLEM - Many safety appurtenances, including breakaway signs, roadside barriers and crash cushions, require frequent attention to insure proper performance. Limited maintenance budgets and the level of technical training and expertise required of maintenance personnel continue to create problems with appurtenance maintenance.

III. OBJECTIVES

A. Review and define the extent and nature of the problem.

B. Identify specific appurtenances that are maintenance intensive, the nature of the problems and recommended solutions, including retrofit measures for existing appurtenances and self-restoring capabilities for future designs.

C. Recommend a course of action that will result in reduced maintenance of existing appurtenances and future designs.

IV. CURRENT ACTIVITIES

A. Suggested key words: maintenance, safety appurtenance, barrier, signs, crash cushion.

B. Research is underway at the Southwest Research Institute to develop self-restoring longitudinal barriers and at TTI to develop a self-restoring crash cushion for narrow objects.

V. URGENCY - There is an urgent need to reduce maintenance costs and to improve safety performance of highway appurtenances. Both can be achieved by development and use of low maintenance appurtenances. This problem was rated a high priority item in a 1982 summer workshop sponsored by A2A04 entitled, "Operational and Maintenance Problems with Safety Appurtenances."

PROBLEM NO. 7

I. NAME OF PROBLEM - USE OF LIFE CYCLE COSTS IN SELECTION OF SAFETY APPURTENANCES

II. THE PROBLEM - Subjective and indiscriminate methods are often used to select appurtenances. Initial cost in many cases is the overriding factor. This has resulted in unnecessarily large life cycle costs and the use of appurtenances that do not offer the best safety performance.

III. OBJECTIVES

A. Develop a comprehensive set of guidelines from which transportation agencies can objectively select safety appurtenances.

B. Develop user aided techniques that will assist transportation agencies in the use of the guidelines, including charts, nomographs and computer programs for microcomputer application.

C. Develop a training program and course on use of the guidelines and user aids.

IV. CURRENT ACTIVITIES

A. Suggested key words: cost effectiveness, safety appurtenances, selection, life cycle, costs.

B. The 1977 AASHTO Barrier Guide, several FHWA studies on guardrail, sign supports, etc., and an NCHRP study on bridge railing have addressed this problem. However, the procedures and recommendations are fragmented and should be consolidated in a unified form.

V. URGENCY - This problem was rated a high priority item in a 1982 summer workshop sponsored by A2A04 entitled, "Operational and Maintenance Problems with Safety Appurtenances."

PROBLEM NO. 8

I. NAME OF PROBLEM - PROTECTION OF MAINTENANCE AND WORK ZONE PERSONNEL

II. THE PROBLEM - Serious injuries and fatalities of maintenance and work zone personnel are on the increase. The problem is especially acute on high speed, high volume freeways for repairs of relatively short duration.

III. OBJECTIVES

A. Review and define the nature and extent of the problem.

B. Subject to the findings of the review positive protective devices should be developed and tested to satisfy recognized performance standards. Furthermore, the devices should have the following characteristics:

1. Offer a minimum disruption of traffic and should occupy a reduced width to prevent blocking of traffic.

2. Should be readily and safely deployable to permit placement on a day-to-day basis.

3. Have a comparatively low cost of construction, deployment and storage.

IV. CURRENT ACTIVITIES

A. Suggested key words: safety, work zones, accidents, barriers, maintenance.

B. Texas Transportation Institute is currently performing HPR Study 262 for the State of Texas. It has addressed the above problem to a degree but is limited in scope.

V. URGENCY - The need for repair and rehabilitation of roadways and freeways has become a major problem. There is urgent need for protection of the workers who will be making these repairs. This problem was rated a high priority item in a 1982 summer workshop sponsored by A2A04 entitled "Operational and Maintenance Problems with Safety Appurtenances."

A2A07 - Utilities -
Ronald L. Williams, Chairman

PROBLEM NO. 9

I. NAME OF PROBLEM - UTILITY ATTACHMENTS TO HIGHWAY BRIDGE STRUCTURES

II. THE PROBLEM - There is a great disparity, from state to state, with regard to how and what utility is allowed to utilize a bridge structure to cross a physical obstruction.

Utility lines must cross streams, highways, railroads and other physical obstructions during their normal practice of connecting source or supply to treatment or usage. Construction of these crossings usually involve disturbance to the stream or traffic flow and always involve considerable expense to the utility owner.

III. OBJECTIVES

A. Survey present installation practices on all types of highway bridges (freeway, limited access, primary secondary roads and city streets).

B. Survey to quantify experience as to the effects of existing utility attachments to bridges:

1. Pipeline electrolysis.

2. Installation of hanger anchors.

3. Use of utility sleeves (conduit).

C. Correlate data obtained from viewpoints of highway agencies and utilities.

D. Make recommendations concerning design parameters attachment to highway bridge structures that could be utilized by the various bridge authorities.

IV. CURRENT ACTIVITIES - Some governmental agencies prohibit pipelines carrying certain hazardous materials on bridge structures. Some agencies prohibit utility access through bridge abutments or anchor attachment to the bridge structure.

V. URGENCY - It is estimated that this study could be completed in 24 months at a cost of $100,000.

With the current emphasis and concern over spiraling costs, this project could result in the savings of millions of dollars each year.

B. PAVEMENT MANAGEMENT - W. Ronald Hudson, Chairman

A2B01 - Pavement Management Systems -
George B. Way, Chairman

PROBLEM No. 10

I. NAME OF PROBLEM - DATA COLLECTION NEEDS FOR PAVEMENT REHABILITATION AND PAVEMENT MANAGEMENT

II. THE PROBLEM - In the technical presentations of the 1980 FCP Review Conference it was continuously repeated in the pavement sessions that "we have inadequate data to verify this result or that model, etc." In most instances the data needed is time-history data of pavement performance. Active support is needed for setting up realistic sampling, data collection and data processing efforts for collection of such performance history data.

The same basic type of data is also needed for the entire pavement management process. The data is required at three levels of data intensity and breadth or data quantity.

A. Network Level. Relatively sparse annual sampling of a few variables such as 1) serviceability or roughness, 2) pavement distress or cracking, 3) skid resistance, and 4) perhaps deflection or simple structural evaluation and maintenance costs.

B. Project Level. More detailed data on each project placed under construction or rehabilitation. More detailed samples of condition and structure as related to redesign and construction.

C. Research Verification. An intense study of a few existing pavement sections in detail with time-history of performance, maintenance, costs, environment, etc.

III. OBJECTIVES - To outline pavement data needs and provide guidelines at three levels on a nationwide basis to begin codified development of an adequate data base for pavement management and improvements.

IV. CURRENT ACTIVITIES - At present no one is providing a coordinated nationwide data base. The FHWA planning activity, HPMS, is taking some data but none on a standard, stable basis of long term predictive value.

V. URGENCY - Very urgent to begin now.

This data base should be national in scope in order to minimize cost to any single state. For example, only 20 sections per state would yield a total of 1,000 in the nationwide data base, enough data to verify most pavement models. Consideration should be given to encouraging development of these data activities and continuing support for them. A project is probably needed to establish guidelines for these activities and for outlying potential funding and realistic operational approaches to the problem.

PROBLEM NO. 11

I. NAME OF PROBLEM - JOINT MULTISTATE PAVEMENT MANAGEMENT PROJECTS

II. THE PROBLEM - There is a need to promote multistate research projects in pavement rehabilitation and pavement management. There is an economy of scale and benefits to be gained by having four or five states in a related region to jointly fund Pavement Management System development. The results would provide an overall plan and a set of computer programs for PMS, including a process of life cycle costs analysis, which could easily be adapted to individual state DOT's, thus saving the duplication of reinventing the "wheel" or "method" in each state individually.

III. OBJECTIVES - To support the various states in getting together and forming a multistate study with a central research team. The specific objective is to assist four or five states with development of a PMS with a common related format upon which each state can build its own PMS.

IV. CURRENT ACTIVITIES - At present many states are involved in Pavement Management Studies but few have moved rapidly. Most states need outside input but are reticent to hire a consultant directly.

V. URGENCY - There is considerable benefit to be gained in the resulting information exchange and in reducing the time required to implement a Pavement Management System in any individual state.

Support for this concept should be provided by AASHTO, NCHRP and FHWA. This project is urgent in order to speed up the implementation of Pavement Management.

PROBLEM NO. 12

I. NAME OF PROBLEM - LONG TERM FIELD OBSERVATIONS OF PAVEMENT PERFORMANCE TO EVALUATE LOAD-ENVIRONMENTAL EFFECTS

II. THE PROBLEM - The purpose of this effort is to cooperatively develop within the highway community cost effective, practical alternatives which will produce an adequate long term data base providing improved understanding of pavement performance and its related cost implications. Particular aspects of issues are listed below.

Currently pavement design, rehabilitation and maintenance decisions as well as highway cost allocation decisions related to pavements are based on the results of the AASHO Road Test and such additional information as can be obtained from existing theoretical models and analysis of various short term small data bases which currently exist. Neither the AASHO Road Test nor these data bases adequately treat the questions of:

a. the long term effects of climate and environment on pavement performance;
b. the effects of age on pavement performance;
c. the interaction of environment and load and their effects; and
d. the interaction of loads and age and their resulting effects and the more complicated interactions of load-environment, age and subgrade soil or geologic type on pavement performance.

These questions remain in the forefront of congressional and public concerns about highway funding, and the answers can only be obtained with real time long term observations.

An ongoing monitoring effort in FHWA is concerned with three aspects of this problem:

a. collection, analysis and evaluation of pilot case study data currently being obtained by several sample states;
b. investigation and recommendations on monitoring as related to pavement management systems at the state, network and project level; and
c. the evaluation and development of alternatives to establish the feasibility of implementing a nationwide long term pavement data base to address the critical problems outlined above.

III. OBJECTIVES - A program is needed to observe thirty to forty pavement sections per state and for forty to fifty states to generate data for 1,000 to 2,000 test sections with relatively simple long time frame observations. The objective of this project is to provide technical support to these activities and to recommend one or more alternatives for economical long term monitoring addressing the objectives outlined above. Specifically, recommendations are needed on sampling plans, sampling frames, minimum data taking requirements, calibration and coordination among the various agency data takers and related practical problems associated with these issues.

IV. CURRENT ACTIVITIES - The benefits of this project are immense. During the 23 years since the end of the AASHO Road Test, no progress has been made on evaluating the problem of environmental effects and environment-load interactions. The project proposed here is one of the few methods capable of economically gathering the data required.

V. URGENCY - It is essential to get started immediately if we are to collect long term data.

A. Level of Funding: $500,000.

PROBLEM NO. 13

I. NAME OF PROBLEM - ROLE OF REFLECTION CRACK ATTENUATORS

II. THE PROBLEM - Cracking of pavements is recognized as a major form of distress. If this distress is corrected by an overlay generally some type of crack attenuating material is used as an interlayer. At present overlay design methods do not indicate which material should be used for a given project. Since this problem is not addressed directly by the overlay design method it is difficult to justify the use of any of these materials.

III. OBJECTIVES - Develop a procedure wherein cracking attenuating materials could receive some credit in the overlay design method.

IV. CURRENT ACTIVITIES

A. Suggested key words: reflection cracking, pavement design.

B. Considerable research has been conducted concerning reflection cracking.

C. There are many overlay design methods; however, none of them directly address this problem.

V. URGENCY - Cracking plays a major role in the deterioration of pavements. Overlay design methods that directly address reflection crack attenuation would significantly reduce the rate of pavement deterioration. Resolution of this problem represents a highly important development representing millions of dollars of savings.

A. Anticipated costs of the study would be $300,000.

PROBLEM NO. 14

I. NAME OF PROBLEM - DETERMINE THE EFFECT OF CRACK SEALING ON OVERLAY LIFE

II. THE PROBLEM - Considerable time and money is spent by maintenance to seal cracks in preparation of an overlay. Does this sealing add life to the overlay and, if so, how much?

III. OBJECTIVES - Review existing experience and recorded data base of maintenance activities and overlay performance. From these derive the effect of crack sealing.

IV. CURRENT ACTIVITIES

A. Suggested key words: Crack sealing, maintenance, overlay performance.

B. Past research in this area is virtually nil.

C. Many states record information but very little is done with it.

V. URGENCY - Resolution of this problem could either mean less maintenance is needed or more is needed. For pavement management purposes the problem is of great importance as the impact in dollars in the U.S. could total as much as $25 million per year.

A. Anticipated study costs would be $150,000.

A2B02 - Rigid Pavements -
Richard A. McComb, Chairman

PROBLEM NO. 15

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

II. THE PROBLEM - Joints are considered as a weak part of rigid pavements. Much of the pavement distress initiates from a joint. The effect of various types of joints on the design and performance of rigid pavements has 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 computer models based on the finite element methods were developed for the analysis of jointed slabs. To evaluate the effect of joints on pavement design and performance on a rational basis a review of the previous studies in light of these new models is needed.

III. OBJECTIVES

A. Evaluate the existing computer models and compare the computed stresses and deflections with the experimental measurements.

B. Modify the models, if needed, so that the stresses and deflections in jointed slabs can be determined under various field conditions.

C. Establish design criteria for slabs and joints and predict their performance based on the computed stresses and deflections.

IV. CURRENT ACTIVITIES

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

B. A large volume of experimental data are available in 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 computer models based on Winkler, Boussinesq and layered foundations are also available.

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 the design and performance of rigid pavements. This problem is highly important not only for the design of new pavements but also for the maintenance or rehabilitation of existing pavements. The ability to 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. 16

I. NAME OF PROBLEM - EFFECTS OF AND PREVENTIVE MEASURES FOR 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, etc., differential subgrade movements and erosion of foundation material due to pumping action. Since most, if not all, current design procedures assume uniform foundation support for thickness designs 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 rigid pavement performance and to develop methods for either preventing the occurrence of nonuniform support and/or consideration of the effects of nonuniform support in determination of the thickness of rigid pavement which will yield the desired performance.

IV. CURRENT ACTIVITIES

A. Suggested key words: rigid pavements, distress, foundation support, warping, curling, pumping.

B. 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 which 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. 17

I. NAME OF PROBLEM - 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 that lesser quality aggregates be used. 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 design of a composite rigid pavement.

III. OBJECTIVES - The realization of the inherent properties of econocrete is fully utilized in a composite design with the two layers intimately bonded. Composite design procdures have been proposed which take account of the physical properties of the component layers of the pavement system as well as appropriate traffic design data. Attention has been given to provide sufficient interface bond between the two layers. Several composite pavements have been installed and field tests and laboratory data are available. Based on these sources of field data and theoretical concepts a rational design procedure may (a) be provided by a correlation study of field performance and theoretical concepts, (b) be based on the model derived, and (c) verify its dependability in a controlled full scale test installation--preferably in a laboratory study.

IV. CURRENT ACTIVITIES - 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 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 work is desirable--coupled with appropriate field and laboratory tests.

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 energy advantages.

A2B03 - Flexible Pavements -
R. G. Hicks, Chairman

PROBLEM NO. 18

I. NAME OF PROBLEM - THICKNESS DESIGN COEFFICIENTS FOR ENERGY EFFICIENT PAVING MATERIALS

II. THE PROBLEM - Thickness design coefficients give the structural number of a pavement which links the design to expected performance. These were developed based on materials used at the AASHO Test Road. Subsequently, coefficients for other materials have been used in structural number calculations by various agencies.

Recently, there has been an uncertain supply of petroleum based products essential in transportation and depletion of readily accessible high quality aggregate sources. Many agencies have salvaged old asphalt and concrete pavements while others have utilized marginal and waste materials. It is essential that applicable thickness design coefficients be found for these materials.

Since it is unlikely these materials will fit narrow specifications applicable thickness design coefficients should be found through a consistently applied procedure of laboratory or full scale testing.

III. OBJECTIVES - Develop a laboratory evaluation procedure which will provide adequate guidance on applicable thickness design coefficients for salvaged, marginal and waste paving materials.

A suggested test series is to run repeated load permanent deformation tests on 4 by 8 inch cylinders of various materials, then cutting the cylinders in half and testing for unconfined compressive strength and modulus using 4 by 4 inch cylinders as per ASTM-D-1074. Beam fatigue tests should be run to develop plots of strain level versus loads to failure.

IV. CURRENT ACTIVITIES - Many agencies are proceeding with mechanistic methods of pavement design which require materials to be characterized through specific methods of test.

V. URGENCY - Uncertain supplies of petroleum products are creating a growing demand for recycled paving materials. Environmental restrictions have increased use of marginal and waste materials. There is increasing pressure to approve higher permissible axle and gross vehicle weights. Therefore, pavement designers urgently need guidance on applicable thickness design coefficients for these energy efficient materials.

PROBLEM NO. 19

I. NAME OF PROBLEM - FLEXIBLE PAVEMENT STRUCTURAL DESIGN REQUIREMENTS FOR LOW VOLUME ROADS

II. THE PROBLEM - There are no flexible pavement design procedures that have been specifically tailored for low volume roads. Those in use today were developed for higher volume highways and are intended to determine the design required to provide satisfactory service for a specific period of time with only minor structural maintenance. These procedures are being extended to low volume roads which constitute the majority of the total highway mileage but are funded at a lower level than most highway systems. Concern has been expressed that current procedures tend to overdesign pavements for low volume roads relative to the overall needs and available funds. Because of the low traffic volumes many believe that lower levels of service can be tolerated and, accordingly, more structural maintenance can be performed during the pavement service life on low volume roads than on higher trafficked highways, which will permit stretching the available dollars to more miles of roads to better meet the overall needs. Support for this belief is expressed by the practice of many local agencies in utilizing stage construction in the design of new roads and tending to postpone indefinitely the construction of the second stage.

III. OBJECTIVES - The objectives of this study are to determine satisfactory levels of service for low volume roads that are consistent with the needs and available funds, and to establish criteria that can be used to either modify existing methods or develop new flexible pavement structural design methods specifically tailored to the needs of low volume roads.

IV. CURRENT ACTIVITIES

A. Suggested key words: flexible pavement, structural design, low volume roads, surface distress, structural maintenance, pavement service level, performance, terminal Serviceability Index.

B. A variety of research activities are ongoing in the area of flexible pavement design but are not specifically addressing the needs of low volume roads relative to the structural aspect. Those pertaining to low volume roads are mostly directed toward geometric design and safety standards.

V. URGENCY - The problem is of high priority among local agencies and the results will be of immediate value in the refinement of flexible pavement design procedure to respond to the specific needs of low volume roads.

PROBLEM NO. 20

I. NAME OF PROBLEM - EFFECTS OF ENVIRONMENT AND TRAFFIC ON PAVEMENTS

II. THE PROBLEM - The AASHO Road Test conducted in 1958-60 was an accelerated test and no comprehensive study could be made of the long term environmental effects on pavement behavior. Loop One, in which most of the structural designs of the controlled traffic test loops were incorporated, is in place today without ever having carried traffic. Also in place as a part of Interstate 80 are many of the survivor test pavements from the original traffic tests which have now carried mixed traffic. Other sections of our interstate system, such as parts of the New Jersey Turnpike, various parkways and expressways throughout the country, serve only automobile traffic with no heavy axle loads. Opportunities exist to explore the effects in the four environmental zones (wet-freeze, dry-freeze, wet-no freeze and dry-no freeze) of automobile and mixed traffic interacting with the environment.

III. OBJECTIVES - The goal of this study is to

develop logical regional factors for flexible pavement design. A corollary output will be damage function (equivalency factors) for an equitable cost allocation system to finance our nation's roads.

IV. CURRENT ACTIVITIES - A recently awarded FHWA research contract is entitled "Load Versus Environmental Effects for Zero-Maintenance." Another FHWA planning study will formulate a cost allocation system.

V. URGENCY - This research is urgently needed to develop a cost allocation procedure. As a result the highways and roads should also exhibit improved performance and become more desirable public facilities.

A2B04 - Pavement Rehabilitation -
Gordon W. Beecroft, Chairman

PROBLEM NO. 21

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 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 experimental and limited use applications of new materials in pavement rehabilitation.

IV. CURRENT ACTIVITIES

A. Suggested key words: pavement materials, rehabilitation, recycling, fabrics.

B. 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 on new materials used in pavement rehabilitation. However, the required engineering properties of these new materials and their performance are not well defined.

V. URGENCY - This study is considered of value and importance because of the widespread interest in new materials and the increased emphasis on pavement rehabilitation.

A. Level of Funding: $100,000.

PROBLEM NO. 22

I. NAME OF PROBLEM - EVALUATION OF EXISTING PAVEMENT SURFACES PRIOR TO RESTORATION

II. THE PROBLEM - Restoration of pavements to serviceable conditions is being accomplished by other than the more traditional methods of the past which have included primarily the asphalt concrete overlay. These methods now may include but are not limited to some combination of material removal; removal and replacement; various forms of recycling; the use of fabrics, membranes, inner layers; use of tied shoulders, underdrains, pressure grouting; or other simple treatment applications. Techniques for evaluating existing pavement surfaces prior to a major restoration or rehabilitation treatment are not well defined. These evaluation and treatment techniques should address the impact on traffic and incorporate TSM planning techniques.

III. OBJECTIVES - The objective is to develop techniques for evaluation of existing pavement surfaces prior to the restoration of that surface. Specific objectives might include a synthesis and evaluation of existing techniques and the development of some experimental and limited use applications of new materials now available.

IV. CURRENT ACTIVITIES

A. Suggested key words: pavement evaluation, pavement surface, testing, pavement restoration.

B. Available funding and material shortages have placed more emphasis on restoration and reconditioning of existing pavements rather than the traditional methods of rehabilitation which have been in the form of overlays. State-of-the-art R&D is probably underway in the NCHRP, FHWA administrative contract and through R&D projects in the state sponsored and administered HPR programs. The details of these current activities are beyond the scope of this statement. It is a very contemporary topic and a much needed informational element relative to current major expenditures for pavement rehabilitation.

V. URGENCY - This study is considered of value and importance because of the widespread interest in restoration and maintenance of existing pavements at low levels of funding.

A. Level of Funding: $200,000.

PROBLEM NO. 23

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 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 under heavy traffic conditions. 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 succeed and what types do not. The ongoing long term 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. Suggested key words: concrete pavement, rehabilitation, heavy traffic, concrete pavement design, life cycle cost, concrete pavement evaluation.

B. 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 HPR 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.

C. Efforts currently underway in the long term monitoring 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 criteria 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.

A. Level of Funding: $200,000.

A2B05 - Strength and Deformation Characteristices of Pavement Sections -

Amir N. Hanna, Chairman

PROBLEM NO. 24

I. NAME OF PROBLEM - ASSESSMENT OF MATERIAL TEST PROCEDURES AND THEIR IMPLICATIONS ON PERFORMANCE PREDICTION

II. THE PROBLEM - Performance prediction models for pavements must include measured characteristics of the layer materials if reasonable accuracy is to be attained. Although numerous very approximate performance prediction models (such as the AASHO model that predicts reductions in serviceability) have been developed through use of multiple regression techniques on measured field data only mechanistic models with detailed material characterizations or empirical models including significant material properties offer much hope for predictive accuracy. Unfortunately, the engineering properties to represent the materials needed as input to these models are attained only through rather sophisticated and costly laboratory or field tests.

Elastic theory (elastic layer or finite element) is used as structural model for most nonempirical performance models. For the structural model the modulus of elasticity and poisson's ratio are required for each material in the pavement structure. These properties change with stress state and/or seasonally with temperature or moisture, so a series of tests are required for each to define them in terms of their stress and/or environmental dependencies. The performance models use responses calculated by the structural models plus other material characterizations (to represent say permanent deformation or fatigue cracking potential of the materials) and other inputs to represent traffic and/or the environment. Because of the numerous material inputs required and the time and cost for obtaining them a serious attempt at predicting the performance of a single pavement structure consisting of specific materials placed in particular states is not practical in terms of cost and time expended.

When faced with a model so complex or costly as to be impractical engineers almost always simplify the model or its input in ways that they do not believe seriously reduce their accuracy. That is the approach proposed for reducing the materials testing effort needed for pavement performance predictions. The accuracy of various material inputs required by performance models depends on the sensitivity of the model to specific material inputs; i.e., how large an error in the predicted performance results from errors in measurement of specific material properties. The problem is to establish the sensitivity of contemporary performance models to specific engineering properties used to represent the materials and to clearly identify those that may be approximated with acceptable loss of accuracy and those that must be carefully measured. This can be accomplished through a combination of literatuve review of numerous sensitivity analyses conducted in the past and additional sensitivity analyses with contemporary models.

III. OBJECTIVES - Clearly identify the relative

importance of accurate characterization of the various material properties used in contemporary pavement performance models. The primary criterion should be the accuracy of the pavement performance predictions.

IV. CURRENT ACTIVITIES - There have been in the past a number of sensitivity analyses for specific models and similar limited studies may be presently underway for specific research purposes. However, there is no known current activity aimed at and organized specifically to develop a comprehensive understanding of the importance of specific test results to predictive accuracy and to result in recommendations for elimination or simplification of tests.

V. URGENCY - One of the most serious problems in managing the nation's highway and airfield pavements is our limited capability for predicting performance and consequently maintenance and rehabilitation needs. The project proposed is urgently needed to advance our capabilities for performance predictions toward practical applications.

PROBLEM NO. 25

I. NAME OF PROBLEM - DEVELOPMENT OF LABORATORY TEST METHODS THAT CONSIDER ENVIRONMENTAL FACTORS

II. THE PROBLEM - Pavement materials are presently evaluated using a wide range of laboratory tests including CBR, Marshall stability, unconfined compression, static triaxial and more recently fatigue and rutting tests. The fatigue and rutting test offers an important advance in evaluating the behavior of highway materials under simulated field conditions of repetitive loading and stress state. At the present time, however, in performing these tests little consideration is given to environmental factors which are known to have important and sometimes dominating effects on the performance of both stabilized and unstabilized materials.

Aging of materials due to ultraviolet light, oxidation and other physical and chemical changes with time result in reduced levels of performance. Moisture causes a general deterioration of all stabilized materials and loss of strength of unstabilized materials. Moisture can also cause stripping in some asphalt concrete mixes and swelling in expansive soils. Temperature and moisture gradients cause thermal stresses in stabilized layers which can significantly decrease fatigue life. Finally, freeze-thaw and wet-dry cycles have been known for a long time to cause significant deterioration of stabilized materials.

In recent years a number of mechanistically based pavement design theories have been developed which, when tempered with experience, can be used to design pavements on a rational basis. Improved laboratory testing techniques such as fatigue and permanent deformation (rutting) tests are also now available. Both the mechanistic design methods and state-of-the-art laboratory tests have contributed considerably to our understanding of pavement behavior. Unfortunately, the incorporation of environmental effects into both laboratory tests and design procedures for the most part has lagged behind in development. Environmental factors are hence a "missing link" in establishing pavement behavior.

III. OBJECTIVES - The objective is to develop test procedures to consider environmental factors in evaluating stabilized materials for fatigue, rutting, stripping and general durability. The tests should be practical to perform and, where possible, should be incorporated into existing test methods. Special problems such as low temperature response are not included.

IV. CURRENT ACTIVITIES

A. Suggested key words: aging, environment, environmental effects, material testing, moisture, moisture gradient, pavement deisgn, rutting, stabilization, stripping, temperature, temperature gradient.

B. Lottman has recently developed test techniques for studying stripping due to moisture in asphalt concrete. The Georgia Institute of Technology in cooperation with the Georgia Department of Transportation is currently working on the effects of moisture on fatigue and rutting for asphalt concrete mixes having selected additives. Research work on stripping is also being carried out at the University of Texas and by the Virginia Highway and Transportation Research Council.

V. URGENCY - The rising cost of petroleum has lead to the development of numerous new materials and additives to improve properties of existing materials. An urgent need presently exists to be able to rationally evaluate stabilized materials under realistic environmental conditions simulating those encountered in the field.

A. Estimated Cost: $300,000.

A2B06 - Monitoring, Evaluation and Data Storage - William A. Phang, Chairman

PROBLEM NO. 26

I. NAME OF PROBLEM - CONSISTENCY OF HIGHWAY PERFORMANCE MONITORING SYSTEM (HPMS) DATA ACROSS STATES

II. THE PROBLEM - The use of the Highway Performance Monitoring System (HPMS) by the Federal Highway Administration (FHWA) represents a major step in the collection, storage and analysis of pavement related data because it provides a uniform framework for addressing the same data items across all states. While the same data items are maintained for each test section in each state there appears to be variability across states for the methods used to determine actual data values for some of the reported items. For example, some states may use objective measurements (e.g., Maysmeter roughness) to calculate PSR (Present Serviceability Rating) while other states may rely on visual surveys to deter-

mine PSR. With these different procedures it is likely that a data value for a given measurement in one state has a different meaning than the same data value for that same measurement in a different state. This lack of compatibility could result in misleading conclusions if the data were used to assess highway conditions on a national basis or if it were used to allocate funding among the states.

III. OBJECTIVES - The objective of the research is to examine the techniques/methods/procedures used by the states to determine the data values reported into the HPMS and evaluate the compatibility of these values across states. Specific objectives include a review of states' existing procedures, identification of any incompatibilities which prevent reliable comparison of data values across states and a presentation of recommendations for resolving any incompatibilities so that the HPMS data can be used for analysis of highway data at a national level.

IV. CURRENT ACTIVITIES

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

B. Highway Research in Progress: It appears that this document is no longer produced. However, an on-line search of the HRIS data base was conducted for active projects in the area of pavement management and no projects dealing with HPMS were located.

C. There are a number of ongoing projects associated with the development of pavement management systems for individual states. Other work is active in the areas of evaluating pavement performance and/or investigating the relationship between pavement performance and distress. The HPMS data is being summarized and used in assessing the condition of the nation's highways.

V. URGENCY - The fact that the HPMS data is already being used for analysis when there is a possibility that compatibility problems exist in the data (and that incorrect conclusions could result) suggests that this is an important area for investigation.

PROBLEM NO. 27

I. NAME OF PROBLEM - DEVELOPMENT OF DATA REDUCTION PROCEDURES FOR PAVEMENT PROFILE MEASUREMENTS

II. THE PROBLEM - Although a method has been developed to bring an exact copy of pavement surface profile to the computer for analysis the significant task remains to develop data processing methods for the reduction of the large volume of data into meaningful management information for the transportation engineer. This task is even more difficult because the computer programmer who will develop the methods to be used must first determine from the transportation engineer what information is required and how to process the pavement profile data to produce this information.

III. OBJECTIVES

A. To determine the needs of the transportation engineer that can be met by the appropriate data processing of pavement profile measurements that have been made and stored in magnetic tape for further data processing.

B. To determine what pavement profile data processing programs have already been developed by existing users of pavement profile measuring equipment.

C. Develop the requirements of a library of pavement profile data reduction programs that will meet the needs of the transportation engineer in the management of the pavement system including the cost benefits associated with the proposed programs.

IV. CURRENT ACTIVITIES

A. Suggested key words: data reduction procedures, pavement roughness, data processing methods, bituminous fill computation, pavement profile measurement, power spectrum analysis, computer program, Mays meter, GMR profilometer, BPR roughometer, pavement management system, rolling straightedge and serviceability index (SI).

B. Several states, including Kentucky, Michigan, Pennsylvania, Texas and West Virginia, have developed computer programs for the reduction of road profile data to assist in the management of their highway pavement system.

Even with this start a significant amount of work remains to be done to bridge the gap between being able to measure pavement profile and being able to use the information contained in those measurements.

Programs that have been developed include:

(1) the computer simulation of other measuring devices such as BPR Roughometer, Mays Road Meter and the Rolling Straightedge;
(2) Mays Road Meter correlation program;
(3) Bituminous Fill Computation;
(4) Serviceability Index (SI);
(5) Power Specturm Analysis; and
(6) other selected methods for analyzing the amplitude - wave length content of the measured pavement surface profile.

V. URGENCY - The GMR Profilometer has been available to the highway community for fifteen years. It is presently used in five states as an effective tool in their pavement management system. However, one reason it is not used more extensively by more states is absence of a cost effective library of pavement profile data analysis and reduction computer programs to assist the transportation

engineer in his pavement management task.

A2B07 - Surface Properties - Vehicle Interaction - A. Scott Parrish, Chairman

PROBLEM NO. 28

I. NAME OF PROBLEM - DYNAMICS OF PAVEMENT-TRUCK INTERACTION

II. THE PROBLEM - Research in pavement-vehicle interactions has concentrated on passenger cars, to the neglect of any other vehicle types. Some of the accumulated knowledge may be applied directly to truck traffic, but in some areas such assumptions may lead to serious errors.

III. OBJECTIVES - This study will determine the dynamic interactions between pavements and vehicles, particularly with all types of trucks, and the degree these interactions are significantly different from passenger cars. The investigation shall include the following aspects:

A. Highway Safety: Does pavement friction, as measured by the standard method (ASTM E274), provide the same degree of safety to all vehicles and tire types? How do curves, grades and cross slopes affect the safe handling of trucks? Do road roughness and rutting affect safety adversely?

B. Ride Quality and Comfort: Ride quality of trucks cannot be expected to be as good as passenger cars because truck design must meet different operating conditions. But can pavement be designed and maintained to minimize the contribution to reduce truck ride quality?

C. Dynamic Loads on the Pavement: The weight of trucks is up to 50 times greater than of small passenger cars and truck tires have pressures about three times greater. The dynamic effects of these loads and tire pressures are amplified by high centers of gravity and by some suspension types. How can these effects be reduced, or else, how can users' fees be made proportional to the damage?

D. Effect on Vehicle Operating Cost: What are the effects of deteriorating road conditions on direct and indirect vehicle operating costs?

The effort to answer these and other related questions will be extensive both in time and cost. Some bits of the required information is probably available. A practical approach to resolve this problem might be to conduct a Phase 1 study for preparing a detailed work plan for Phase 2. This work plan would define the questions to be researched and outline the study approach and methodology.

Much of the work in Phase 2 can be done by analysis of real data and by deduction from related experiences. Some simulation as well as full scale and laboratory testing will be required. The objective shall be to establish equivalency or conversion factors between different types of vehicles. This would permit state highway departments to predict pavement performance (in terms of safety, rate of deterioration and effect on users) from traffic counts, vehicle type distribution and environmental data.

IV. CURRENT ACTIVITIES

A. Suggested key words: pavement-vehicle interaction, trucks.

B. Most research in this area is concentrated on passenger cars. Virtually no work has considered the effects of trucks.

V. URGENCY - This research is urgently needed. In planning pavement rehabilitation state highway departments need to consider the effects of all vehicle types and find compromise solutions.

PROBLEM NO. 29

I. NAME OF PROBLEM - SAFE TIRE/PAVEMENT INTERACTION AND FRICTION MEASUREMENT

II. THE PROBLEM - The measurement of pavement friction has been standardized with the ASTM E274 procedure using the ASTM E501 ribbed tire. It is realized by most engineers that this measurement does not necessarily fully describe the tire/pavement interaction related to safe stopping and maneuvering of vehicles for wet and dry pavement conditions.

Current research has indicated relationships between pavement texture (macro and micro) and friction numbers measured both by the ASTM E501 ribbed tire and the ASTM E524 blank tire, and these relationships have had a further relationship to wet weather accidents. It is therefore desirable to determine and document the relationship between some measure of safety and friction and texture measurement of the pavement surface.

III. OBJECTIVES - In order to perform this study data would need to be gathered from high wet weather accident sites. Additionally, full scale vehicle tests on test pavement surfaces should be conducted to verify safe stopping and maneuvering characteristics.

IV. CURRENT ACTIVITIES

A. Suggested key words: texture, micro, macro, friction.

B. The Pennsylvania State University has conducted a study that demonstrates the relationship between surface texture and friction as measured with both the ribbed and blank tire. Other states have realized that testing friction of open graded mixes with a ribbed tire is not a true measure of the effectiveness of the surface.

V. URGENCY - It is realized that the driver, roadway geometrics and vehicle condition can play an important role in wet weather accidents, but if the pavement surface can be controlled so that it is not a factor this would eliminate a factor for which a state

can be held liable.

PROBLEM NO. 30

I. NAME OF PROBLEM - ROUGHNESS EFFECTS ON PAVEMENT FRICTION

II. THE PROBLEM - The stopping friction experienced by a vehicle on a pavement is influenced by the dynamic motions of the vehicle. Principally, pavement roughness which tends to disturb the vertical dynamic motion of the vehicle causing unweighting of the wheel loads will create a less than optimum friction characteristic, thus, longer stopping distance. Another effect of pavement irregularities, in the form of dishing, is to contain water on the surface which can also provide friction coefficient variations by increasing the depth of water, eventually to the hydroplaning depth.

III. OBJECTIVES - This study will determine the extent of the effects on both wet and dry coefficients of friction by the road profile and the roughness characteristics of the pavement as they affect the vehicle dynamics.

IV. CURRENT ACTIVITIES

A. Suggested key words: pavement friction, roughness.

B. The Pennsylvania State University is conducting a related study using their circular test track with pavement surfaces with built in roughness.

V. URGENCY - This research is needed to further the understanding of the interaction between vehicles and pavements.

PROBLEM NO. 31

I. NAME OF PROBLEM - SUCCESSFUL SURFACE COURSE DESIGNS

II. THE PROBLEM - Fifty years of skid resistance research have produced a wealth of information about the causes of wet pavement slipperiness and remedies for it. A like amount of progress is, however, not evident in the field, primarily because of the continuing increase of the exposure of pavements to traffic and of the intervals between replacement or renewal. On the other hand, surface courses are not always of optimum design, even if allowance is made for fiscal and other restraints.

III. OBJECTIVES - It is proposed that a compendum of clearly successful surface course designs be prepared. It would list wearing courses, overlays and surface treatment with every pertinent detail. This would include, among other things:

(a) traffic exposure (with due recognition of the traffic unit, channelization, studded tire use, etc. throughout the documented history of the pavement);
(b) climate and weather details;
(c) performance data (skid resistance, roughness, PSI, etc. again over the years);
(d) pavement geometry (curves, cross slopes, etc.);
(e) mix design, production and installation details with measurements made before, during and after construction (including intentional and unintentional deviations from specifications);
(f) materials descriptions (in the case of aggregates all available details; description by general terms such as "dolomite," or identification by source are meaningless unless petrographic data are given); and
(g) any other details that might have a bearing on performance.

There are probably relatively few pavements for which all pertinent details can be documented so that their "recipes" could be followed by others who have access to identical materials and must deal with identical conditions. The objective of the compendium would be served as a "cookbook." Therefore, pavements that have features and materials that are of purely local character would be excluded.

IV. CURRENT ACCTIVITIES

A. Suggested key words: mix design, wet pavement, skid resistance, wearing courses.

B. Many studies have been done on pavement mix performance but none has ever tried to collect a compendium of successful surface courses that have been fully documented.

V. URGENCY - The results of this study could provide a basis for the design and construction of new pavements and overlays that have adequate skid resistance and that can be expected to perform exceptionally well throughout their design life.

PROBLEM NO. 32

I. NAME OF PROBLEM - LONGITUDINAL PAVER CONTROL AND RIDEABILITY

II. THE PROBLEM - The travelling public generally judges a pavement based on a "seat of the pants" opinion rideability. Longitudinal electronic (hydraulic) controls for pavement construction and rehabilitation equipment were developed in order to improve the resultant rideability of the pavements. Unfortunately, it has been demonstrated that this has not necessarily led to improved rideability. This may have been due to malfunction, misplacement or misoperation of the equipment. It has also been noted that the longitudinal sensor has had different lengths and configurations.

Generally, the contractor and inspection personnel know nothing about the operation of such equipment except that there is a delayed realization when it has not been working properly to produce a desirable ride. Therefore, the determination of the best configuration and operation of such equipment should

be standardized and documented.

III. OBJECTIVES - This study should survey all current longitudinal controls and by theoretical analysis and the construction of test sections determine best configuration placement and operation of the controls. It may be possible to incorporate some indicator which tells the operator and inspector that the system is operational.

Additional factors in achieving good rideability in addition to the operation of the longitudinal control should be documented.

IV. CURRENT ACTIVITIES

A. Suggested key words: rideability, paver controls, longitudinal control, roughness.

B. Many studies have been conducted on how to control roughness, but none has considered all the various types and configurations of controls that are available.

V. URGENCY - This study is needed to improve the quality of paver controls and the resultant rideability of the pavements.

PROBLEM NO. 33

I. NAME OF PROBLEM - CALIBRATION OF PAVEMENT FRICTION TEST TRAILERS

II. THE PROBLEM - The Regional Pavement Friction Test Trailer Calibration Centers, operated at Transportation Research Center (TRC) of Ohio and Texas Transportation Institute (TTI) at the Texas A&M University, have provided calibration services for the states and other agencies using Pavement Friction Test (PFT) rigs to evaluate the skid number of travelled surfaces for federal safety requirements. The cost for this calibration has previously been covered by the Federal Highway Administration. Now, each state is expected to pay nine or ten thousand dollars plus travel costs to visit a calibration center. This cost causes some states to defer calibration, when it is needed more often.

III. OBJECTIVES - Most users of this equipment have some form of platform type calibrator. NBS developed a calibration system for the air bearing platform two axis calibrators commonly used by many owners of this equipment. This system is now in the possession of TTI who will perform calibration of individual units on this NBS primary standard traceable system for a nominal fee of less than $1,000. In addition, under the auspices of AASHTO, NBS has acquired two air bearing platform calibrators which are to be maintained in good calibration as secondary standards and are expected to travel from state to state to provide comparative correlation type calibration of the state's own calibrator system and pavement friction testers. This study is needed to verify the validity of such comparative calibration procedures to assure that this method will provide satisfactory and dependable calibration.

IV. CURRENT ACTIVITIES

A. Suggested key words: friction test, static calibration, calibrator.

B. The AMRL has just begun static calibration of friction testers as part of their laboratory evaluations.

V. URGENCY - This study is needed to verify the validity of such comparative calibration procedures to assure that this method will provide satisfactory and dependable calibration for their friction testers.

C. STRUCTURES - John M. Hanson, Chairman

A2C01 - General Structures -
Clellon L. Loveall, Chairman

PROBLEM NO. 34

I. NAME OF PROBLEM - BONDED CONNECTIONS ON BRIDGES

II. THE PROBLEM - Fatigue failures are occurring on steel highway bridges at locations where elements such as cover plates, lateral bracing and stiffeners are connected by welds to primary bridge girders. This fact demonstrates the need for alternate connection details or alternate connection techniques.

III. OBJECTIVES - The overall objective is to assess the feasibility of bonded structural connections for bridges. The primary issues regarding the use of adhesives are:

(a) realistic mechanical properties and constitutive models for the adhesive materials in a variety of environmental conditions;
(b) adhesion strength theories and changes in adhesion strength with time;
(c) durability of bonded connections in a bridge environment;
(d) design methodology for bonded connections; and
(e) bonding specifications.

IV. CURRENT ACTIVITIES

A. Suggested key words: adhesives, bonded connections.

B. Related research activities are being done in the areas of sealing materials, resin anchoring systems, epoxy coverings for rebars, and paint systems. Research projects on adhesives for bridges are in progress at the University of Maryland and at Case Western Reserve University. In Great Britain the University of Bath and the University of Dundee have active research on applications of adhesives to bridges.

V. URGENCY - The research may provide designers with connection details for secondary attachments on bridges which will improve the fatigue life of our bridges. The information generated could be useful in our current bridge rebuilding program.

PROBLEM NO. 35

I. NAME OF PROBLEM - FIBER COMPOSITES FOR BRIDGE CONSTRUCTION

II. THE PROBLEM - The cost of bridge construction is steadily increasing and ways must be sought to economize. One of the ways is to develop new structural materials that will result in less expensive structures, including life cycle costs.

Over the past 25 years the field of fiber composites has developed and rapidly expanded. One of the early materials was fiberglass, which was used for car bodies and smaller items. More recently metal matrix fiber composites have been developed for use in the space and military programs. Fiber composites are now used for a very wide range of applications, including aircraft propellers and structural members, sailboat masts, automotive drive shafts and springs and a variety of sports equipment. The Corps of Engineers is developing a heavy duty military bridge of fiber composites. Of significant importance (to the cited research topic) is the fact that several one and two story high "electrically invisible" buildings have been constructed exclusively of fiber composites.

It is recognized that the cost of fiber composites is rather high, but the cost is being reduced by technological advances. It is envisioned that fiber composites may be used for major load carrying members, entire bridges and a variety of other bridge hardware such as guard rails and luminaire supports. Structural members of substantially lower weight could lead to synergistic reductions in the total weight of the superstructure and substructure size.

III. OBJECTIVES - To critically evaluate the technical and economic feasibility of using fiber composite materials for bridge construction. The scope of work would deal with fiber-plastic and metal matrix fiber composits and would include:

(a) state-of-the-art survey;
(b) design studies for fiber composite structural members; and
(c) economic analyses related to the cost of individual members as well as total initial construction cost and projected life cycle costs.

IV. CURRENT ACTIVITIES

A. Suggested key words: plastics, reinforced plastics, fiber composites, metal matrix composites.

B. No known directly relatable research in progress.

V. URGENCY - The results of this study could lead to substantial reductions in the cost of bridge construction for certain types of structures or applications.

A. Required Funding: $90,000. If the results of this study are favorable follow-on research would be needed to fabricate and test fiber composite structural members and assemblies under various loading and environmental conditions.

A2C03 - Concrete Bridges
Robert C. Cassano, Chairman

PROBLEM NO. 36

I. NAME OF PROBLEM - EFFECTS OF SALT PENETRATION INTO HIGH STRENGTH PRESTRESSED CONCRETE MEMBERS

II. THE PROBLEM - Prestressed concrete bridges have been in service in the United States since 1950. Some prestressed concrete members of these bridges such as adjacent box beams with bituminous surface courses are exposed to direct salt contamination. Questions have been raised by engineers as to whether high strength concrete needs the same corrosion protection as other concrete. There is considerable difference of opinion. Some of the old beams were constructed without air entrainment, some with 2 to 4 percent air, and for the last decade with 4 to 8 percent air.

III. OBJECTIVES - Salt penetration through high strength concrete of the prestressed concrete member should be measured in order to develop a method to predict contaminant intensity and depth of penetration. This information can be used to determine to what extent costly protective systems or concrete covers are necessary to protect the top layer mild reinforcement steel in prestressed concrete bridge members or which perhaps could be deleted.

Research should determine whether the corrosive effects upon the reinforcement steel in high strength concrete warrants the expense of protective systems currently employed or proposed, and the cost effectiveness.

This proposed research complements the "Minimization of Design Standards" trend which is being implemented by various highway or transportation departments and could provide information to support or reject the need to use the various prestressed beam salt protective systems or methods.

IV. URGENCY - Since permit and legal loads are ever increasing and overstressing our bridges it is important to insure that all members maintain their load carrying capacity. Therefore, the effects of corrosive elements upon the reinforcement steel in prestressed concrete members should be known, so that the structural safety of these members can be maintained and the load carrying capacity of older bridges can be adjusted to reflect the remaining capacity which may have been severely damaged by the deleterious effects of the long term salting.

PROBLEM NO. 37

I. NAME OF PROBLEM - CONNECTION DETAILS FOR SHORT SPAN PRECAST BRIDGES

II. THE PROBLEM - State, county and other local transportation agencies are finding that use of standard precast concrete beams is an expedient means of reconstructing short span bridges on low volume roads. A recent study entitled "Connections for Modular Precast Concrete Bridges" by the Federal Highway

Administration has shown that most of the problems with integral deck bridges are related to the longitudinal connections between the precast members. The effect of heavy vehicles, as well as the time dependent transverse thermal effects, induce forces in these connections that are difficult to analyze and to evaluate by current technology.

III. OBJECTIVES - To develop design criteria and recommend details for connections that are easy to fabricate and which will also insure good long range serviceability of these bridges.

IV. CURRENT ACTIVITIES

A. Suggested key words: design, short span, precast, flexure, shear, torsion, load distribution, connections.

B. A current Federal Highway Administration study provides background information on the performance of these bridges. In addition, a proposed NCHRP program is planned that is intended to study load distribution in these bridges and to develop design criteria suitable for incorporation in the AASHTO specifications.

C. Research projects in progress in this area are unknown.

V. URGENCY - Completion of this research should allow transportation agencies to increase use of readily available precast sections for rehabilitation and replacement of short and medium span bridges.

PROBLEM NO. 38

I. NAME OF PROBLEM - SEGMENTAL PRESTRESSED CONCRETE MULTIPLE STEM GIRDER BRIDGES

II. THE PROBLEM - Because of resulting economy precast segmental bridge construction has gradually gained acceptance in the United States over the past decade. Other features of segmental construction include speed of construction, least traffic interruption and least disturbance to the environment. Also, precasting offers advantages of on-line production, better quality control and higher strength concrete. Currently, FHWA is sponsoring an investigation on "Feasibility of Standard Sections for Segmental Prestressed Concrete Box Girder Bridges."

However, open sections are easier to cast than box girders. Casting of integral deck multiple stem units is feasible. Full width, full span units were used for the superstructure of Lake Pontchartrain Bridge in Louisiana. These heavy units were barged into position. For general application, girders should be manufactured in segments. With multiple stem sections the form can be adjusted for different width bridges.

III. OBJECTIVES - To determine feasibility of standard sections for segmental prestressed concrete multiple stem girder bridges.

IV. CURRECT ACTIVITIES

A. Suggested key words: bridges, prestressed concrete, segmental construction.

B. None to the proposer's knowledge.

V. URGENCY - The cost of new bridge construction and bridge replacement keeps rising. Statistics show that considerable new bridge construction and major reconstruction is ongoing. Therefore, long term economy resulting from segmental prestressed concrete multiple stem girder bridges can be substantial. The research findings can be implemented through national standards recommended by the AASHTO Committee on Bridges and Structures.

PROBLEM NO. 39

I. NAME OF PROBLEM - OPTIMIZED SECTIONS FOR PRESTRESSED CONCRETE BRIDGE GIRDERS

II. THE PROBLEM - In a recent investigation sponsored by FHWA, standard AASHTO-PCI bridge girders were compared with other cross sections for optimum costs. As a result bulb-T cross sections were recommended for use as national standards for spans in excess of 80 ft. To fully utilize benefits of the completed project other design aspects require more in-depth investigation. Aspects include shear strength, especially where girders are continuous for live load, initial and long term midspan deflections and lateral stability of long members during transportation and erection.

III. OBJECTIVES - To investigate shear strength and deflections of proposed optimized sections for long span bridge girders. To determine girder length beyond which lateral stability should be considered during transportation and erection.

IV. CURRENT ACTIVITIES

A. Suggested key words: bridges, deflections, prestressed concrete, shear, stability, structural analysis.

B. The investigation recommending optimized sections was completed in 1981. No follow-up work has been initiated.

V. URGENCY - Dissemination of the research findings of the completed investigation is currently underway. To further optimize the efforts of bridge engineers shear strength, deflection and lateral stability of recommended sections should be investigated. The research findings can then be implemented through national standards recommended by the AASHTO Committee on Bridges and Structures and the Federal Highway Administration.

PROBLEM NO. 40

I. NAME OF PROBLEM - LIVE LOAD DISTRIBUTION FACTORS FOR CONCRETE BRIDGES

II. THE PROBLEM - Despite all the refinements in design of concrete structures the basic

distribution factors for live load remain unchanged. Skew, diaphragm spacing, slab depth, etc., are not taken into account in the distribution formulas.

III. OBJECTIVES - To conduct an investigation of existing codes and research work on concrete slab and beam distribution to develop a comprehensive live load distribution table. This should eventually include all types of bridges with the results being placed in AASHTO and/or equivalent design specifications.

IV. CURRENT ACTIVITIES

A. Professor Scordelis of the University of California, Berkeley, California and others have made scale models of box girders and tested them for bending, load distribution, etc.

B. AASHTO is studying these factors and appears to be letting them continue as is.

C. Research of literature on live load distribution with respect to diaphragms, skews, etc., revealed mainly the works of Professor Scordelis.

V. URGENCY - Now that the load factor design is being used in design of concrete bridges, etc., it is of extreme importance to obtain the correct live load distributions.

PROBLEM NO. 41

I. NAME OF PROBLEM - RESTRAINTS IN CONCRETE BRIDGES WHICH AFFECT THEIR STRUCTURAL INTEGRITY

II. THE PROBLEM - Because wider and longer structures of continuous spans are now being built cracking of restrained concrete decks and support members is becoming quite common. Restraints such as conduits in the deck, frozen bearings, continuous railings and/or sidewalks, guard rail connections across expansion joints, etc., prevent movement of concrete superstructures. Coupled with the corrosive environment that exists from salt chlorides major repairs are needed in recently built structures.

III. OBJECTIVES - To determine the effect of these restraints acting together and then set guidelines in structural design which will eliminate these restraints.

IV. CURRENT ACTIVITIES

A. Highway research was scanned and nothing was found on structural restraints.

B. No activity on this probjem has been found by proposer.

V. URGENCY - The inability of structural designers to recognize these restraints and properly weigh their contribution to stresses is evident by the lack of past activity in this area. Guidelines should be developed for inclusion in AASHTO through their Committee on Bridges and Structures.

PROBLEM NO. 42

I. NAME OF PROBLEM - EXPANSION AND CONTRACTION STRESSES IN CONCRETE BRIDGE SUBSTRUCTURE UNITS/END SPANS

II. THE PROBLEM - Abutments or piers that are submerged in fills have a substantial difference in temperature between the top slab and the supporting system. This differential causes cracking between the support beams and the slab as well as in the slab itself on abutment widths of 25 feet or more.

III. OBJECTIVES - To develop design criteria or guidelines that take into account differential movement of concrete slabs over concrete beams.

IV. CURRENT ACTIVITIES

A. Highway research records were scanned on substructure units and nothing was found as to expansion or contraction stresses.

B. No activity on this problem has been found by proposer.

V. URGENCY - The wide U-type concrete end spans have shown cracking in the slab and its connections immediately after construction and prior to being opened to traffic. Additional cracking becomes evident in following years.

PROBLEM NO. 43

I. NAME OF PROBLEM - BREAKING OF PRETENSIONING STRANDS DURING STRAND CUTTING AND MULTIPLE BEAM REMOVAL

II. THE PROBLEM - During the process of removing multiple pretensioned beams from a 330 foot casting bed occasionally some of the bottom horizontal strands break in the process of cutting the strands between the beams. The procedure of cutting the strands (by torch) begins at the top draped strands and proceeds simultaneously downward at each location betweem beams and at the bed ends. The following conditions appear to contribute to the strands breaking:

(a) time of year (outside temperature);
(b) form removal before cure is completed;
(c) distance between beams on casting bed; and
(d) length of time of beam cure to gain required concrete strength prior to cutting strands.

III. OBJECTIVES - To determine a procedure which will allow the strands to be cut without having some of the bottom strands break and place a sudden vibration type of shock loading into the beams.

IV. CURRENT ACTIVITIES

A. "PPB Breakage" research of literature on this type of strand breakage has not yielded any significant studies or reports.

B. MNDOT had load tested, on July 10, 1978, a beam with 12 broken strands and found the beam acceptable.

V. URGENCY - The number of strands breaking on the fabricators bed has varied from four to twenty-two and has resulted in movements of two to seven inches on the beds. Determination of final properties of these pretensioned beams is not possible. Therefore, a procedure to eliminate this problem is extremely urgent for MNDOT.

A2C05 - Dynamics and Field Testing of Bridges - James W. Baldwin, Jr., Chairman

PROBLEM NO. 44

I. NAME OF PROBLEM - INCORPORATION OF FIELD TESTING IN THE BRIDGE RATING PROCESS

II. THE PROBLEM - During the past decade there has been a great deal of emphasis on the development of inspection and rating processes for old bridges. In general, the processes which have evolved are based on the types of analyses used in the design of new bridges. This approach is complicated by imponderables which include but are not limited to:

(a) accurate assessment of the material properties such as yield strength and fracture toughness;
(b) determination of the effective section properties remaining after environmental degradation of the members;
(c) existence of fatigue cracks; and
(d) actual distribution of stresses in structures with multiple load paths.

In the absence of factual data it is necessary to make conservative estimates for each of these imponderables, and the net result is a compounded safety factor which may be more conservative than necessary. An excessive safety factor in design may result in a slightly higher cost, but in the evaluation of an old structure it may mean the condemnation and removal from service of a structure that is in fact quite safe.

In many cases limited field tests could firmly establish bounds of acceptability on some of these imponderables, thereby providing the basis for a much more realistic evaluation of the structure. Thus, there is an acute need for research to develop standard field testing techniques for use in the bridge rating process.

III. OBJECTIVES

A. To identify specific cases where field testing would be beneficial to the rating process.

B. To develop standard types of tests to be performed.

C. To suggest guidelines for interpretation of the test results.

D. To demonstrate these techniques under field conditions.

IV. CURRENT ACTIVITIES - This problem statement was developed as a consensus of the committee on field testing of bridges. Many of the committee members are actively engaged in field testing and there are numerous reports on field testing techniques. One committee member from Canada has conducted several field tests on bridges which remain in service. However, no one was aware of ongoing efforts to standardize field tests as a part of the bridge rating process in this country.

V. URGENCY - Even during the writing of this statement hard decisions are being made in nearly every state concerning the selection of bridges to be repaired or replaced. These decisions are particularly hard because in general there are insufficient funds to make all the replacements which might be desirable. Thus there is a great urgency for any technique which will help distinguish between those bridges which must be modified or be replaced immediately and those which can be depended upon for several more years of satisfactory service.

A2C06 - Culverts and Hydraulic Structures - Richard A. Parmelee, Chairman

PROBLEM NO. 45

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. 46

I. NAME OF PROBLEM - DESIGN LIVE LOADS FOR CULVERTS

II. THE PROBLEM - Currect 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.

D - Bituminous - Jon A. Epps, Chairman

A2D02 - Characteristics of Nonbituminous Components of Bituminous Paving Mixtures - Prithvi S. Kandhal, Chairman

PROBLEM NO. 47

I. NAME OF PROBLEM - AGGREGATE-ASPHALT COMPATIBILITY

II. THE PROBLEM - The lack of compatibility of some aggregates with asphalts, often shown by early aging and by stripping tendencies, has received considerable attention. A variety of antistripping agents have been found useful in improving compatibility. However, when the coarse and fine aggregates are of different compositions and especially when baghouse dust, a material with as yet little understood chemical and physical properties, is added to the mixture new compatibility problems are being recognized.

III. OBJECTIVES

A. Identify representative combinations of asphalts, aggregate and baghouse dust filler which will have poor durability as indicated by laboratory tests.

B. Correlate test performance of the mixtures with the chemical and physical properties of the components to permit extrapolation of the findings to components not included in the tests.

C. Determine what economically feasible measures can be taken to minimize the compatibility problems identified.

IV. CURRENT ACTIVITIES - Study of baghouse fines in bituminous paving mixtures has been done by various agencies in the recent past.

V. URGENCY - Better identification of incompatible combinations and successful determination of preventive measures will lead to long lasting bituminous pavements and will encourage maximum use of all available aggregates. The results of this research will have immediate application and will produce large savings in maintenance funds in a short time.

PROBLEM NO. 48

I. NAME OF PROBLEM - REALISTIC LIMITS ON AGGREGATE DUST IN BITUMINOUS MIXTURES

II. THE PROBLEM - The dust accompanying and coating coarse and fine aggregate particles is detrimental to the adhesion of the asphalt especially in dryer drum plants and when emulsions are used, as well as when the aggregate is used in cold patch and for surface treatments. The total amount of material smaller than 75 micrometers may not be a sufficient criterion in every case. The sand equivalent test provides more information but has not had sufficient acceptance to have a consensus on specification limits.

III. OBJECTIVES

A. Determine the amount and composition of

aggregate dust, both coating and accompanying coarse and fine aggregates, from sources representing a wide range of compositions, as well as dust contents.

B. Evaluate the durability of bituminous mixtures containing these aggregates, including asphalt stripping tests on the aggregate in its as-received condition.

C. Collect field observations of the performance of pavements containing these aggregates.

D. Correlate amount and composition of the dust with laboratory and field performance.

IV. CURRENT ACTIVITIES - None known.

V. URGENCY - This research will provide a basis for establishing more realistic limits on aggregate dust which will lead to longer lasting pavements thereby saving maintenance funds and conserving aggregate resources.

PROBLEM NO. 49

I. NAME OF PROBLEM - EFFECT OF FINE AGGREGATE PARTICLE SHAPE ON RUTTING CHARACTERISTICS

II. THE PROBLEM - It has been reported that in at least two states unstable mixes and pavement rutting have been attributed to the unfavorable shape of fine aggregate in the bituminous concrete. Although there are several ways to characterize the shape of fine aggregate particles there is a need to relate the particle shape to the stability and rutting characteristics of paving mixes.

III. OBJECTIVES

A. Survey the most promising methods for evaluating the shape (angularity and sphericity) of fine aggregate particles, such as has been done by ASTM C09.03.05 for concrete aggregate, and identify the most promising method.

B. For fine aggregate representing a wide range of shape and composition correlate the stability of laboratory mixes with particle shape. Consideration should be given to using a single filler, a limited number of coarse aggregates each of a different shape and to using only clean, washed coarse and fine aggregates.

C. Collect field observations of the performance of various bituminous surface courses containing the fine aggregate studied and correlate with the laboratory performance.

IV. CURRENT ACTIVITIES - None know.

V. URGENCY - This research is needed to alleviate the rutting problem occurring in some states and, thus, a significant savings of maintenance funds.

PROBLEM NO. 50

I. NAME OF PROBLEM - CORRECTION OF INDICATED ASPHALT CONTENT BASED ON EXTRACTED AGGREGATE GRADATION

II. THE PROBLEM - A common problem of the testing engineer is the evaluation of a "wild" value resulting from a test of a sample of paving mixture for asphalt content. Such values are often accepted for asphalt content. Such values are often accepted on a judgement basis, but a formal procedure is needed to justify acceptance. The problem is intensified in the case of paving mixtures containing large (plus one inch) particles of aggregate since it may be impractical to attain a correct proportional distribution of asphalt and aggregate in a sample of usual size.

III. OBJECTIVES

A. To develop a mathematical and graphical method of evaluating results of tests for asphalt content of paving mixtures.

B. To determine the relative accuracy of the method developed under A above in evaluating results of tests of paving mixtures containing large (1"-2") aggregate particles.

IV. CURRENT ACTIVITIES - This method of estimating the actual asphalt content of the batch by correcting the asphalt content of the sample on the basis of gradation is used by the British, formerly by a graphical method (British Standards Institution, "British Standard 594, Specification for Rolled Asphalt /Hot Process/, 1961) and also by a table of correction factors (Hardman, R., "A System for the Judgement of Compliance with Specifications for Rolled Asphalt to BS594," Road Research Laboratory Report LR276, 1969). West Virginia has used a similar graphical method (West Virginia Department of Highways Standard Specifications Roads and Bridges, Adopted 1982, Table 303.5). It is known, from research and unpublished data, that the linear relationship between percent asphalt and percent fine aggregate is not constant over a range of surface, binder and base asphalt paving mixtures. However, there is some evidence (Krieger, F. L., "Final Report - A Study in the General Field of Quality Control Engineering" for the State Road Department of Florida, pp. 2-21 to 2-46, 1965) that there is a curvilinear relationship between the percentage of fine aggregate in the batch and the value of the slope parameter "b" over the range of paving mixtures. If this is the case the overall relationship may affect the relationship of proportion of fine aggregate to asphalt in the sample so that the relationship may not be truly linear. As far as known the possibility has not been adequately investigated by prior research.

V. URGENCY - This research is needed to give the testing engineer another tool towards the immediate implementation of an effective means of quality control with respect to the asphalt content of paving mixtures.

E - Concrete, Robert E. Philleo, Chairman

A2E01 - Performance of Concrete - Charles F. Scholer, Chairman

PROBLEM NO. 51

I. NAME OF PROBLEM - VALIDATION OF REQUIREMENTS FOR FROST RESISTANT CONCRETE

II. THE PROBLEM - It has been assumed with confidence in most quarters for some years that portland cement concrete produced in accordance with the current standards of good practice will be immune to the action of freezing and thawing regardless of whether or not such action is accelerated by the use or nonuse of any of the normally used chemical deicing agents. This concept has been questioned. People are asking whether there is something important, chemically, about any of the normal deicing agents, especially urea. People are questioning whether the criteria for adequacy of the air void system in air entrained concrete are applicable to all kinds of hydraulic cement concrete, particularly those which contain large amounts of materials such as pozzolan (especially fly ash) and slag. Research is therefore needed to review the data upon which the current standards of good practice have been based and to review and confirm or disapprove the assumption that there is no significant role played by deicers other than to melt ice; produce water, thus indirectly increase moisture content; and thaw concrete, thus making it susceptible to additional freezing in a state of greater saturation. Such research should be coordinated with closely related research now in progress which suggests that certain air entraining admixtures are more effective in producing and maintaining an appropriate stable air void system as the concrete hardens than others, especially when high alkali cements are used. Also certain combinations of air entraining admixtures and high range water reducing admixtures are reported to be capable of producing concrete having a satisfactory air void system while others are not.

III. OBJECTIVES

A. Assemble and assess the reports of frost resistance of concrete that does not comply with current requirements and lack of frost resistance of concrete that does comply.

B. Report apparent need, if any is found, for relaxation or tightening of requirement of good practice.

C. Obtain laboratory results confirming or refuting proposed changes.

D. Adopt revised requirements, if needed, or explain purported anomalies.

E. Cooperate with ASTM Committee C-9 to revise ASTM C666 to improve precision, accuracy and relevance.

F. Cooperate with ACI 201 to incorporate funding in its "Guide to Durable Concrete."

IV. CURRENT ACTIVITIES - Work related to this topic is going on in an uncoordinated fashion. NRMCA is working on factors affecting the interaction of mineral admixtures and air void systems. PCA has worked on relation of air void system requirements and water-cement ratio. Many agencies have studied nonfrost resistant concrete that they have encountered, often with inconclusive results as to why it behaved poorly.

V. URGENCY - This topic was rated 1 on a scale of 1-11 by the TRB Committee on Research on Physical Factors Affecting Concrete Durability at its meeting in January 1982.

PROBLEM NO. 52

I. NAME OF PROBLEM - STABILITY OF THE AIR VOID SYSTEM OF CONCRETE AS INFLUENCED BY CHEMICAL ADMIXTURES, POZZOLANS, CEMENT PROPERTIES AND OTHER FACTORS

II. THE PROBLEM - There is a significant incidence of scaling and deterioration of air entrained concrete exposed to a freezing and thawing environment, particularly in the presence of deicing chemicals. In many instances evaluation of the air void system of the hardened concrete yields a lower air content and higher bubble spacing factor than normally deemed necessary. In some cases the air void system in cores taken from the structure is much inferior to that present in specimens representing concrete on discharge. Transporting and placing of the concrete appears in some instances to have a detrimental effect on the air void system. Sometimes the air content in the hardened concrete is much lower than that which was measured on the fresh concrete. It is known that some fly ashes require high admixture doses or cause rapid loss of air entrainment, but properties of other ingredients, i.e., cement, air entraining admixtures, water reducing admixture, or the fine aggregate, can also have an important influence on air void stability.

III. OBJECTIVES

A. To determine the mechanism or mechanisms which cause the decrease in air content and increase in bubble spacing factor in plastic concrete during agitation, handling and placing operations.

B. To determine for those concrete mixtures which do tend to have unstable air void systems what kind of mixing, agitating, handling and placing operations cause greater problems. For example, is speed of mixing or agitating in truck mixers important or is frequency of duration of compactive effort a factor in damaging the air void system?

C. To determine what classes of air entraining admixtures are more advantageous in providing stable air void systems when used with combinations of materials or production and placing procedures which tend to cause loss of air in concrete.

D. To determine the influence of

the various types of chemical admixtures, particularly those materials that increase the measured air content in concrete, on the stability of the air void system.

E. To develop improved techniques of measuring air void parameters (air content, specific surface and spacing factor) on fresh or hardened concrete. Specifically, means are needed to distinguish between fly ash cenospheres and air voids in polished surfaces of hardened concrete.

F. To develop a laboratory recommended practice for the evaluation of combinations of materials in paste, mortar or concrete with respect to their effect on the stability of the air void system.

IV. CURRENT ACTIVITIES - Several companies and research organizations are currently doing research in this important area of interest. However, no firm conclusions have been developed yet toward the achievement of the above objectives.

V. URGENCY - Of highest urgency is the achievement of objectives with respect to the air void system in fly ash concrete since a significant amount of fly ash is now being used both for energy savings and economic reasons both in blended comments and as a separate pozzolanic admixture. This category includes the use of normal range water reducers since often these admixtures are used in conjunction with fly ash in concrete. Second level priority concerns the air void system properties in non-fly ash concrete containing normal and high range water reducing admixtures. High range water reducing admixtures are relatively new in the North American market, but some researchers have found inadequate air void systems in concrete containing these admixtures, particularly when used to produce concrete with low water-cement ratio and medium to stiff consistency. Normal range water reducing admixtures, ASTM C494 types A, D and E, should also be investigated since the use of these admixtures is very widespread and there is evidence in some cases that they have a detrimental effect on the air void system.

PROBLEM NO. 53

I. NAME OF PROBLEM - SIGNIFICANCE OF LABORATORY TESTS AS RELATED TO CONCRETE FIELD PERFORMANCE

II. THE PROBLEM - Many laboratory tests are run on concrete in an effort to predict performance of similar concrete in the field. Laboratory freezing and thawing, alkali-aggregate reactivity and concrete strengths are examples of such tests, which are run under controlled laboratory conditions with the performance of the concrete under actual field conditions.

III. OBJECTIVES

A. Evaluation of the problem of establishing failure criteria in the field.

B. Development of laboratory tests that will relate properties of concrete to concrete failure in the field.

C. Evaluation of current laboratory tests for their usefulness in relating properties of concrete to concrete failure in the field.

D. Developing procedures of using test results to predict probability of failure.

What constitutes failure of concrete in a transportation related structure is most difficult to answer. It is suggested that for each service environment and each level of service, failure criteria must be established. In order to make the task manageable the research problem should be restricted to highway concrete pavement and concrete bridge decks. Failure criteria to be established might consider factors such as micro-macro-cracking, deflection, disintegration, abrasion, volume change and aesthetic qualities. Scaling, D-line cracking and popouts are typical of outward signs that should be evaluated as to how much can be tolerated before failure is reached.

Existing tests along with any new test procedures should be selected and demonstration projects should be developed to show how the test results can be used to predict failure.

IV. CURRENT ACTIVITIES - Many Departments of Transportation in the course of daily activity are collecting the information that should prove to be essential in accomplishing this project. A survey of these activities should be considered part of this project. As an example of what is meant several agencies used ASTM C 666, Standard Method of Test for Resistance of Concrete to Rapid Freezing and Thawing, and in so doing collected a considerable amount of data (in the form of durability factor, weight change and length change) for concrete specimens that are representative of concrete being placed in the field. An organized attempt to correlate existing and new data with field performance should be fruitful. Coordination with ASTM Subcommittee C09.03.15 on Weathering of Concrete would be appropriate, since this Subcommittee is collecting laboratory data.

V. URGENCY - This problem is urgent from the standpoint that it has been an ongoing one that ultimately has probably cost the nation billions of dollars over the years.

PROBLEM NO. 54

I. NAME OF PROBLEM - IDENTIFYING ALKALI REACTIVE SILICEOUS CONSTITUENTS IN CONCRETE AGGREGATES

II. THE PROBLEM - The highway network around the Pentagon; a naval dry dock in Charleston, South Carolina; bridges in the road system of the Georgia DOT; several dams and locks belonging to the Corps of Engineers; and other structures have developed alkali-silica reaction to a damaging extent, and examination of the concrete has shown that the quartz in the aggregate has participated in the reaction. The reaction typically develops slowly over 20 years or more, but can be unsightly and even dangerous to the structural integrity of the structures affected. Some of the instances of alkali-silica reaction leading to distress

in concrete structures have been recorded (1, 2, 3, 4, 5) in which the reactive aggregates have been rocks of types that would not be expected to be reactive with alkalies in cement using current criteria. The rock types involved have included phyllites, argillites, graywackes and metamorphosed subgraywackes, granite, gneisses, shales, vein quartz and quartzite. Differing opinions as to the reactive constituents and on the mechanism of reaction have been expressed (4, part IV; 1, 5, 6). Although detailed petrographic examinations have been published for some reactive varieties (4, part II) the identification of reactive constituents is not sufficiently exact. For example, it is said that "some" graywackes are reactive. Metamorphic subgraywackes have been found to be reactive aggregates in two TVA dams.

III. OBJECTIVES

A. Define more precisely which aggregate constituents are alkali-silica reactive and which are not.

B. Determine if, in addition to defective structure, perhaps the presence of trace elements also triggers alkali reactions.

C. Examine large numbers of particles which are known to be reactive in concrete and search for a common causal feature or features.

Specific objectives include:

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

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

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

D. Verify whether or not the quartz affected, which occurs as vein quartz and quartzite, is all highly metamorphic quartz with a high angle of undulatory extinction.

E. Verify whether or not the mica in some granite gneiss takes part in the reaction as has been alleged.

F. Set forth criteria for recognition of reactive quartz and quartzite.

G. Reproduce the reaction in the laboratory.

H. Determine the environmental conditions which trigger the reaction, and which slow down or prevent the raction and expansion.

I. Determine whether the conditions in the cement paste such as water-cement ratio, porosity, percentage of alkalies and availability of calcium or conditions surrounding the concrete such as temperature and moisture content fluctuations are the same for these constituents as those reported for the minerals and rocks showing classical reactivity.

J. Determine if the environmental conditions influence differently the rocks high in forms of silica more reactive than quartz compared with those high in quartz.

IV. CURRENT ACTIVITIES

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

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

C. Some work has been done in Canada and USAE Waterways Experiment Station on this topic.

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

V. URGENCY - While some of the affected structures require repair and monitoring in the future to maintain assurance of satisfactory performance, others of similar age are affected by alkali-silica reaction but are serving their purpose and can be expected to continue. In order to establish a way to recognize reactive metamorphic quartz, a standard convention for the orientation of the quartz grains needs to be established; this is basic research that should be carried on at a university strong in optical mineralogy and crystallography. Tests carried out at 60 degrees C in moist storage need 36 months to develop expansion of 0.10 percent. Since the recent studies have increased the number of rocks known to be alkali reactive and have even more increased the rocks suspected of being alkali reactive, it is essential to obtain more precise information to aid in distinguishing between reactive and nonreactive types of rocks.

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

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

A. General estimate of cost to accomplish: $500,000.

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PROBLEM NO. 55

I. NAME OF PROBLEM - FLY ASH FOR CONCRETE WITH POTENTIAL ALKALI-AGGREGATE OR SULPHATE EXPANSION

II. THE PROBLEM - It is known that the judicious use of a properly selected fly ash can improve the properties of concrete with respect to alkali-aggregate reaction in moist exposures and with respect to attack by sulfates in ground water, surface waters or in various other industrial or environmental uses of concrete. However, more information is needed concerning the protection mechanisms involved, and what procedures or guidelines should be used to qualify a fly ash for such use within a more reasonable time period is involved in the application of ASTM C 441 for alkali-aggregate reaction and the extended research tests for resistance to sulfate exposure. These procedures can easily involve the better part of a year to obtain results. Fly ash is much more prevalent and available today in most every region, and its availability will increase as more coal burning power plants are brought on line. The diversity of the chemical and physical properties of present fly ash sources makes it difficult to test many alternatives in long term alkali reactivity tests or sulfate exposure tests. Fly ash can and will be used on a wide variety of commercial and government agency construction in years to come. Many ready mixed concrete producers are now equipped to use fly ash in conjunction with a wide variety of other locally available materials. The older major project approach which allowed many months and sometimes years for the necessary preapproval tests of materials will not be very helpful for use on smaller projects where many materials might be considered in alternate bids and where time constraints will be tighter.

III. OBJECTIVES - Establishment of clear-cut guidelines or tests which can be applied in a timely manner to assess the value of particular materials combinations using fly ash, and blended cement, in meeting objectives of reducing the risk of detrimental expansion due to alkali-aggregate reaction or the failure of concrete in service due to sulfate attack. If fly ashes now on the market could be applied to better utilize local aggregate and cement resources it could result in greater economy for concrete construction and perhaps avoid problems where specific fly ashes may actually aggravate concrete durability problems. For example, greater use may be feasible for local aggregate resources known to be deleteriously reactive under some circumstances or special low alkali cements or particularly low C3A cements may not need to be imported if suitable combinations can be developed using fly ash or blended cement.

IV. CURRENT ACTIVITIES - ASTM C01.29 is evaluating a new "accelerated" sulfate resistance test which may give meaningful results in a period of several months. The Bureau of Reclamation has procedures to assess the performance of pozzolans with respect to sulfate resistance. Dunstan has proposed a specific formula for use in evaluating the sulfate resistance of combinations of materials used in concrete. This procedure needs investigation. The Virginia Highway and Research Council is investigating the use of fly ash as an alternative to the use of Type II cement. Concerning alkali-aggregate reaction ASTM Method C 441 is used by many to evaluate the effectiveness of fly ashes to reduce expansion when used with reactive pyrex glass. More consideration, however, should be given to the actual properties of the aggregate and cement proposed for use on the work. One disturbing report is the 25 year evaluation of reactivity of concrete with Kansas-Nebraska aggregate

(BuRec Report REC-EXC-78-5) where the long term performance was not well related to results of short term tests. Pozzolans performed poorly in helping control the reactivity.

V. URGENCY - Progress on these problems is not a critical urgency in the sense that there are numerous concrete failures which must be avoided; however, as stated by Frohnsdorff, Clifton and Brown in STP 663 with respect to the evaluation of admixtures for mitigating alkali-aggregate reactions: "The tests outlined will be increasingly needed as the production of low alkali cement decreases, the availability of good natural aggregates decreases and the use of recovered waste and by-product materials in cement and concrete increases." A similar argument can be made for the long term need for better guidelines for the role of fly ash in producing sulfate resistant concrete, particularly in regions where high levels of sulfate occur in ground water.

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A2E03 - Mechanical Properties of Concrete - V. Ramakrishnan, Chairman

PROBLEM NO. 56

I. NAME OF PROBLEM - NONDESTRUCTIVE METHODOLOGY FOR DETERMINATION OF CONCRETE CONDITION

II. THE PROBLEM - Current practice generally requires either dependence on correlation between concrete cylinder crushing strength or destructive type tests such as coring or semidestructive tests such as pull out or probe testing for determining the in situ condition of concrete. None of these are entirely satisfactory and result in a lack of knowledge of the actual strength of the in-place concrete resulting in the use of larger than needed design safety factors to insure adequate structural integrity. These are based on statistical sampling and therefore do not provide overall concrete condition evaluation. Many of the parameters used in currently determining concrete condition are still not adequately defined and measure different conditions not necessarily related to actual performance.

There presently exist several methods of nondestructively evaluating the quality and condition of in-place concrete. Among these are electromagnetic waves (radar), microseismic (pulsed echo), infrared and thermography, resonance, radioactivity, ultrasonic, electrical resistivity and hardness. The state of the art of each varies and measures different parameters, some still not adequately defined. Although differences exist as to what in-place strength is condition evaluation appears to be within the realm of possibility. Some such as radar require field correlation and further development of computer data analysis techniques. Others require more extensive program development to allow determination of feasibility and adequacy of field condition evaluation. It appears that present technology is available for making condition evaluation possible.

III. OBJECTIVES

A. To evaluate and determine which of the present nondestructive technologies may best be used in arriving at the condition of concrete.

B. To recommend appropriate methods and develop standard procedures for these.

C. To encourage the use of in-place testing with the recognition that such systems, leading to an overall maintenance management program, would provide significant economic advantages.

D. To publish these findings in suitable journals and available publications.

IV. CURRENT ACTIVITIES - In-place test methods are being developed in such diverse places as Southwest Research Institute, Illinois Institute of Technology, The Port Authority of New York and New Jersey and various private consultants. As an example SwRI has a contract to determine tunnel concrete invert conditions and is pursuing both radar and electrical resistivity methodology.

The Port Authority is developing radar and corresponding computer data readout techniques for infrastructure concrete condition surveys. Microseismic and resonance methodologies are being presented as viable techniques by various consultants. TRB has already presented evidence of radar's proficiency under a contract with the Georgia Institute of Technology, which culminated in a paper published in early 1982, while other techniques are being investigated in New York, North Carolina, Pennsylvania, West Virginia, Virginia and Vermont.

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

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

Development of such an instrumentation system would also be of top priority in the maintenance management area for evaluating a rapidly deteriorating infrastructure coupled with a decreasing maintenance budget and the complete lack of other systems capable of providing rapid condition evaluation information on a current basis.

PROBLEM NO. 57

I. NAME OF PROBLEM - FACTORS AFFECTING THE BOND STRENGTH BETWEEN NEW AND OLD CONCRETE USING CEMENT PASTE AS A BONDING AGENT

II. THE PROBLEM - Over the years the only method that has been used successfully to bond new and old concrete together has been the various epoxies developed and refined. These are expensive and are not always foolproof. Because the thermal coefficient of expansion of the epoxy bonding agent is different than the concrete materials themselves weathering does produce stress at the interface between the two materials. They have not proven satisfactory in all cases.

III. OBJECTIVES: We should orient the research to evaluate the factors that affect the bond strength developed between new and old concrete when using cement paste as a bonding agent. Probably these factors are related to water/cement ratio in the bonding agents themselves, the thickness and amount of bonding agent that is used, the water/cement ratic of the fresh concrete bonded to the surface, the cleanness and texture of the old concrete and other variables as yet unknown. We should, however, be able to evaluate these variables and others and determine what constitutes good practices in developing these bonds. We need to stop the practice of soaking old cement before grouting new concrete to it.

IV. CURRENT ACTIVITIES - Iowa has used a cement paste to bond new concrete to old concrete in many thousands of square yards of concrete where a thin bonded overlay was placed on bridge decks and on grade. We have had a limited amount of experience with using cement paste to bond new concrete to damaged pier columns and to prestressed concrete beams that have been impacted by high loads. Our success to date has been phenomenal although we have not documented what might constitute good practices; or where we have had failures, what might be the causes of these. We believe by working with the data that we currently have and developing a research program around the variable parameters much valuable information can be added to current knowledge.

V. URGENCY - Our highways and interstate systems are deteriorating fast. We do not have the money to replace the entire structures, whether it is roadbed or structural concrete in bridges and culverts.

A low cost bonding agent that can be added to the existing section or replacing parts of the section utilizing this bonding agent could be very valuable and cost effective in the repair of concrete items on our deteriorating highway system.

We are currently behind in the repair and reconstruction of thousands of miles of interstate and many structures. Good data on bonding of new concrete to old concrete could save millions of dollars in repair and reconstruction costs nationwide. The potential cost savings available in repairing backwalls, abutments, wings, pier columns and other deteriorated and damaged sections by simply cleaning off the old section, applying a cement paste, placing new concrete to the correct section and profile immediately against the desired areas, and making the patch and the old concrete behave as a unit is a goal that we should look for and strive for at an early date.

PROBLEM NO. 58

I. NAME OF PROBLEM - MECHANICAL PROPERTIES OF CONCRETE SUBJECTED TO VARIOUS RATES OF LOADING AND DYNAMIC LOADING

II. THE PROBLEM - Examples where concrete structures are subjected to dynamic loading include: vehicle impact, earthquake loading, sudden collapse of form work during construction, explosive and blast loading and impact of flying objects. To analyze the response of structures subjected to such short rise time loading a knowledge of the constitutive relationships of materials subjected to varying strain rates is essential. Although some information on the failure strength under dynamic loading is available little is known concerning other mechanical properties of concrete subjected to high strain rates.

Recently many tests have been conducted to determine the impact strength of concrete. These include: drop weight tests, impact tests using projectile, explosure tests and pendulum type Charpy tests. Although such tests are useful in determining the relative merits of different concretes (such as comparing plain concrete with fiber reinforced concrete) the results from such tests depend

on the testing parameters, and they are not well adapted for obtaining basic and useable material properties (such as modulus of rupture or stress-strain curve). A need exists to develop test methods which can yield basic material properties, which then can be compared with those obtained under static loading.

III. OBJECTIVES

A. To prepare a comprehensive state-of-the-art report on various test methods and their results for concrete subjected to dynamic loading.

B. To develop methods which can yield fundamental material properties which can be used in design and which can be compared with those readily obtained under static loading.

C. To obtain various mechanical properties of concrete subjected to varying strain rates and ascertain the influence of (1) composition, (2) environment (temperature and humidity), (3) manner of loading.

IV. CURRENT ACTIVITIES - Research on behavior of concrete subjected to dynamic loading is being carried out in many countries. This was evident, for example, in a recent symposium: Interassociation Symposiun on Concrete Structures Subjected to Impact and Impulsive Loading, Berlin, West Germany, where more than 60 papers were presented from about 25 countries.

V. URGENCY - A better understanding and knowledge of the behavior of concrete subjected to high strain rate would help increase the safety of structures subjected to dynamic loading. This is critical since structures designed to fail in a ductile manner under static loading may fail in a catastrophic manner under impulsive loading.

PROBLEM NO. 59

I. NAME OF PROBLEM - SATISFACTORY HEAT TREATMENT OF HARDENED CONCRETE

II. THE PROBLEM - Hardened concrete containing wax beads or thermosetting polymers must be heated to remove moisture and to melt the wax, or polymerize the concrete. Cracks are frequently found in these concretes after they have been subjected to a heat treatment. The cracks tend to decrease the strength and increase the permeability of the concrete and thereby nullify the benefit sought through the use of the wax beads or the polymer additives which primarily is to decrease the permeability of the concrete.

III. OBJECTIVES - The objective of the research would be to develop guidelines for satisfactory heat treatment of hardened concrete. More specifically, an effort will be made to (a) identify the characteristics of the concretes and the heating processes which contribute to cracking, and (b) describe them in quantitative terms so that the phenomenon of crack formation can be fully understood and appropriate steps can be taken to minimize or eliminate the cracking.

IV. CURRENT ACTIVITIES - Internally sealed concrete and polymer impregnated concrete (PIC) are the names typically applied to two types of bridge deck protective systems which have been tried on an experimental basis in recent years. Approximately 20 bridges have been constructed with internally sealed concrete overlays and a similar number have been repaired or constructed with PIC that requires a heat treatment for impregnation and polymerization. Cracks have been noted in the hardened concrete on many of these structures after the concrete has been subjected to the heat treatment. Guidelines for applying heat treatments have been developed by the FHWA but no one has been able to fully explain the process by which the cracks form or to identify all the contributing factors.

V. URGENCY - On the basis of laboratory findings internally sealed concrete and PIC appear to provide excellent potential for protecting bridge decks from deicing salts. When properly sealed with melted wax or polymers the concretes are virtually impermeable. However, until satisfactory field heat treatments can be obtained on a regular basis the full benefits of the systems cannot be realized. Consequently, the research proposed here is urgently needed.

A2E05 - Chemical Additions and Admixtures for Concrete -
T. J. Larsen, Chairman

PROBLEM NO. 60

I. NAME OF PROBLEM - EFFECT OF ADMIXTURES ON SLUMP LOSS ON CONCRETE

II. THE PROBLEM - Concrete mixtures which do not contain admixtures sometimes suffer untimely loss of workability, described as "slump loss," and this may be inefficient and costly. Admixtures sometimes alleviate and sometimes aggrevate slump loss. In the latter case the situation can sometimes be remedied and sometimes not. Elimination of the admixture is not always the answer for it may be needed for other purposes. The effect of admixtures on slump loss has been the subject of much speculation, but in few cases are all the fundamental mechanisms involved fully understood.

III. OBJECTIVES

A. Representative admixture types commonly used, ASTM C 494, should be evaluated under carefully controlled laboratory conditions with a variety of cements known to suffer untimely slump loss with admixtures and without admixtures. When the field phenomena are successfully recreated in the laboratory, the most complete analysis that is possible should be made of the total situation and all mixture components, with special emphasis on cement and admixture composition (both physical and chemical properties).

B. The data analysis should lead to a set

of hypotheses, each of which should suggest critical experiments to confirm or deny that hypothesis.

C. Recommended remedial actions should evolve from confirmed hypotheses.

IV. CURRENT ACTIVITIES

A. Several limited empirical projects have been conducted. Speculative theories have been evolved. However, these investigations lack the necessary depth and scope to generate convincing or widely applicable solutions to the field problems.

B. Suggested key words: admixtures, slump loss, early hydration, cement composition and test methods.

V. URGENCY - Significant time and money are being lost on a widespread scale because this problem and what to do about it are not well understood.

PROBLEM NO. 61

I. NAME OF PROBLEM - ADMIXTURES IN HOT WEATHER CONCRETING

II. THE PROBLEM - Admixtures such as retarders and water reducing retarders are used during hot weather concreting to regulate the time of setting of concrete. In addition to selecting admixture type or combination of admixtures the dosage rate may vary, depending on the environmental conditions and on the structure cross section. For instance, a higher retarder rate may be used in the morning than in the afternoon of a hot day. Also, the temperature within the structure will depend on its dimensions. Presently, no guidelines are available to suggest admixture type to use to avoid coincidence of maximum environmental and hydration temperature.

III. OBJECTIVES - Available research data and other information will be used to draw pertinent information to prepare guidelines for the use of admixtures in hot weather concreting. These guidelines will provide a trouble-shooting chart for problems that may arise and for their correction.

IV. CURRENT ACTIVITIES - The belief is that sufficient information exists in the literature for preparation of the guidelines. However, substantiating data may be required from laboratory investigations.

V. URGENCY - A sufficient amount of concrete is discarded during hot weather concreting to justify the investigation. The justifications for concrete rejection are high temperature, low slump, low air content and the concrete is not placeable without retempering with increased water-cement ratio. The belief is that some of the concretes placed may have inferior properties due to the causes mentioned. These discrepancies may be circumvented by the proper use of admixtures.

PROBLEM NO. 62

I. NAME OF PROBLEM - DEVELOP A METHOD FOR DETERMINING THE FLY ASH CONTENT OF HARDENED PORTLAND CEMENT-FLY ASH CONCRETE

II. THE PROBLEM - The use of fly ash as an ingredient in portland cement concrete is on the increase. There is no reliable or accepted method for determining or even estimating the fly ash content of hardened concrete. This puts the purchaser of the fly ash concrete at a great disadvantage and gives the manufacturer of the concrete the opportunity to use more ash per unit volume than specified.

III. OBJECTIVES - Establish a method, either chemical or physical, for determining the fly ash content of portland cement-fly ash concrete.

IV. CURRENT ACTIVITIES - A chemical analysis of hardened fly ash concrete for its SO_3 content is being used in a few laboratories to estimate the amount of fly ash present. However, in order to relate the measured SO_3 content to fly ash content the percent SO_3 in both the cement and fly ash used in the concrete must be known and quite different. This information is seldom available and appropriate samples of the two are almost unavailable.

V. URGENCY - The cause for fly ash concrete problems cannot be reliably determined without having some method for measuring the fly ash concrete.

PROBLEM NO. 63

I. NAME OF PROBLEM - VERIFICATION OF ADMIXTURES UNIFORMITY BY INSTRUMENTAL METHODS

II. THE PROBLEM - A few users employ Section 6.1.1 of ASTM specification C 494-81, or may be using another instrumental method that is not referred to in Sections 6 and 18 of ASTM C 494-81, in order to verify conformance or as a supplementary conformance test to show uniformity of successive lots of admixture. The suggested interpretation of the test results may be too vague or misinterpreted by the user. For example, Section 6.1.1 of ASTM C 494-81 states that the infrared absorption patterns be "essentially similar." This is a subjective and qualitative factor which is sometimes misinterpreted to mean that absorption patters of successive lots, when superimposed, must be identical. This misinterpretation fails to recognize all sources of variance in the method and assumes that any change is due to a change in the admixture composition. In order for the results from this test method, or any other instrumental test method, to be more realistic and meaningful to the user some quantitative ranges of variation in parameters are needed.

III. OBJECTIVES

A. Identify and quantify factors affecting variance in the test results, for each of the instrumental methods, using different operators and different instruments for a fixed set of reference admixture samples and using one specific technique of sample selection and sample

preparation. The set of reference samples to be used would be within the normal variation for one particular admixture as established by the quality control department of the manufacturer.

B. Analyze the resulting data to generate allowable quantitative ranges of variation for each parameter of the infrared absorption spectra or any other instrumental method that defines no statistically significant difference within a predetermined confidence limit.

IV. CURRENT ACTIVITIES - Essentially none exist.

A. Suggested key words: admixtures, infrared, or any other instrumental methods, test methods.

V. URGENCY - Use of admixtures has become widespread and is steadily increasing. It is just as vital that they meet meaningful, quantitative uniformity requirements as it is for all other components of concrete mixtures.

A2E06 - Basic Research Pertaining to Portland Cement and Concrete -
Geoffrey Frohnsdorff, Chairman

PROBLEM NO. 64

I. NAME OF PROBLEM - USE OF POZZOLANS AND ADMIXTURES TO IMPROVE CONCRETE DURABILITY

II. THE PROBLEM - In recent years concrete structures, e.g., highways, bridges and city streets, are deteriorating rapidly due, in part, to a lack of durability of the concrete. The deterioration of concrete structures, which appears to be on the increase, is probably caused by the deleterious effect of deicing salts on the frost resistance of the concrete and in some areas also on expansion and cracking due to alkali-aggregate reaction.
During the next few decades many of the existing concrete structures will have to be replaced or extensively repaired. If the "life cycle" costs of new structures are to be significantly reduced an increased level of research activity is urgently needed to find ways of improving the quality and durability of the concrete.

III. OBJECTIVES - To improve the durability of concrete highway structures by:

A. Carrying out basic research into the effect of pozzolans, e.g., fly ash, blast furnace slag and silica fume, on the physical and chemical properties of concrete.

B. Finding methods of transferring the results of current and future research into practical use in the field.

C. Developing admixtures and other methods, e.g., controlled curing temperatures, to adjust the workability and strength development of concrete incorporating pozzolans so that construction is not held up because of slow strength development.

IV. CURRENT ACTIVITIES

A. Several companies and research organizations are currently conducting research in this general field but there is no coordinated effort being made. More research is being done in Canada, Denmark, Germany, Holland, Norway and the United Kingdom. In Europe, where a considerable volume of fly ash and blast furnace slag is produced annually, a considerable amount of research is being carried out.

B. Suggested key words: concrete, pozzolan, fly ash, blast furnace slag, silica fume, admixtures, durability, life cycle costs.

V. URGENCY - Many concrete structures, bridges, highways and city streets, the infrastructure upon which the United States transportation industry depends, are in urgent need of repair or replacement. Recent estimates are that just to maintain the present level of service 1.6 trillion dollars will need to be spent during the next decade (U.S. News and World Report, Sept. 27, 1983). This amounts to a projected expenditure of 6.5% of the GNP annually for the next decade. Much of this expenditure will be spent on the manufacture and placement of concrete. Recent experience is that much of the concrete used in bridge and highway construction lacks long term durability. If the life cycle costs of new concrete structures are to be significantly reduced research is urgently needed to find and develop methods of improving the resistance of concrete to attack by frost and alkali-aggregate reaction.

A. Cost Estimate - It is difficult to estimate the cost of achieving an objective which depends on the successful outcome of scientific research. An alternative approach is to consider what percentage of the construction cost it would be reasonable to spend on research with the aim of reducing the life cycle costs of new structures, for example, by 10%. Assuming that about 1 trillion dollars will be spent on concrete construction during the next decade it seems probable that this objective could be attained by the expenditure on research of only 0.002% of the construction costs. This would amount to an annual expenditure of 2 million dollars on research. On the basis of cost estimates of recent research proposals in the field of cement and concrete research this level of funding would probably be sufficient to achieve, in part, at least the stated objectives.

PROBLEM NO. 65

I. NAME OF PROBLEM - DETERMINING THE EFFECTS OF ENVIRONMENTAL CONDITIONS ON THE REACTIVITY OF ALKALI REACTIVE QUARTZOSE ROCKS IN CONCRETE

II. THE PROBLEM - Identify, with a short term test, alkali-silica reactive rocks and minerals, subgroup these rocks, and determine the effects of environmental conditions on the reactivity of alkali reactive quartzoze rocks in concrete.

Examination of concrete structures made with phyllites, argillites, graywackes, metamorphosed subgraywackes, granitic rocks, granite gneisses, quartz and quartzites as aggregates showed the same evidence of damage as concrete made with the classical alkali-silica reactive minerals and rocks. While the reactivity of the classical alkali reactive aggregates is firmly established by field examinations and laboratory tests examination showed that in the aggregates listed quartz participated in the alkali reaction and that the reaction and expansion developed frequently very slowly over 20 or more years.

Technological tests carried out by K. Mather at 60°C and moist storage needed 36 months to develop expansion of 0.10 percent. Tests of such long duration are normally impractical for the concrete industry in search of aggregate sources and for aggregate control during concreting.

Although detailed petrographic examination results have been published for some reactive varieties of the rocks listed below the identification of reactive species is not sufficiently exact to separate the reactive from the nonreactive varieties.

Rocks belonging to the proposed alkali reactive quartzose subgroup are:

(a) rocks with about 95 percent of silica in the form of quartz and/or chalcedony such as quartz aggregations (vein quartz) and quartzite, and
(b) silicate rocks rich in quartz such as argillites, graywackes, arenites (quartzose sandstones), granitic rocks and granite gneisses.

III. OBJECTIVES

A. Define more precisely which rocks and varieties of them are alkali-silica reactive and which are not.

B. Establish the signs of alkali reactive quartz caused by defective lattice structure and determine if the presence of trace elements also triggers alkali reactions.

C. Examine large numbers of particles whose reactivity in mortar or concrete is established and search for common causal feature or features.

Specific objectives include:

A. Develop criteria to demonstrate reactivity in slowly reactive rocks within reasonable testing time. The method using high metamorphic quartz is promising.

B. Verify if the quartz affected by alkalies is all highly metamorphic quartz with a high crystal lattice disturbance as shown by a large undulatory extinction angle.

C. Establish criteria for recognizing reactive quartz in thin sections or by other means. In thin sections of a rock verify the influence on reactivity (1) by the size of the undulatory extinction angle and (2) by the number of quartz grains with undulatory extinction. Determine a general rule for the number of thin sections to be examined to represent an aggregate source.

D. Investigate possible other parameters in rock that will help to confirm the alkali reactivity of quartz.

E. Verify if the mica in various reactive rocks takes part in the reaction as has been alleged.

F. Establish the mechanism of the reaction, including those mechanisms that cause low quartz to become reactive.

G. Determine the favorable and unfavorable environmental conditions which trigger the reaction and which slow down or prevent the reaction and expansion. Determine if the conditions in the cement paste such as water/cement ratio, porosity, percentage of alkalies and availability of calcium or conditions surrounding the concrete such as temperature and moisture content fluctuations are the same for these constituents as those reported for the minerals and rocks showing classical alkali-silica reactivity. Determine if the environmental conditions influence differently the rocks consisting of silica compared with those high in quartz.

IV. CURRENT ACTIVITIES

A. Some work has been done at the USAE Waterways Experiment Station on this topic and in Canada on the metamorphic quartz in various rocks and particularly in various thin sections of the same rock.

B. Suggested key words: alkali-silica reaction, undulatory extinction angle in quartz, alkali reactive silicate rocks, argillite, graywacke, arenite, quartzite, quartz, granitic rocks, granite gneiss.

V. URGENCY - As the studies of the alkali-silica reaction continue more rocks are found to be alkali-silica reactive, more locations are found to contain alkali-silica reactive rocks; however, the same rock types may be nonreactive. Many large concrete structures such as docks, dams, hydrogeneration stations, bridges and pavement for which long satisfactory performance is expected contain slowly alkali reactive aggregates and some show deterioration of concrete. To prevent premature damage of concrete it is essential to be able to use a short time method to distinguish between reactive and nonreactive rocks. Because some of the rocks are very widespread such as granites and granite gneisses it would be too expensive and unrealistic to test all rocks listed for alkali reactivity using normal technological tests. It is important, therefore, to develop the short petrographic method of undulatory extinction in quartz to identify potentially reactive rocks.

The research is highly relevant because it affects all North American areas having concrete pavement and highway construction. In order to establish the presence of metamorphic quartz grains a standard determination for optic orientation of the quartz

grains needs to be established.

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3. Dolar-Mantuani, L. "Undulatory Extinction in Quartz Used for Identifying Alkali-Reactive Rocks," Conference on Alkali-Reaction in Concrete, Cape Town, Paper 36, p. 6, March 30-April 3, 1981.

PROBLEM NO. 66

I. NAME OF PROBLEM - SULFATE RESISTANCE OF BLENDED CEMENTS

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

With prospects for higher coal use in the future the use of material such as fly ash from coal burning will be extremely important. It was previously predicted that 30 million tons of fly ash will be produced by 1980 in the U.S.A. It is now predicted that this quantity will be very much higher by 1984. Use of this resource so as to reduce energy consumption in other segments of the economy would be beneficial. When fly ash is mixed with hydraulic cement it is possible to produce a high quality hydraulic binder with definite benefits, which also extends the production of the portland cement industry which uses much energy. The current levels of fly ash addition result in a reduction of the energy required for producing 100 lbs of a hydraulic cement (Type IP) by about 10-15 percent. Considering the energy critical future we face the development of systems of optimum fly ash cement which in effect will use less energy for production of a high quality hydraulic binder is of national importance.

Many aspects of the use of blending materials such as fly ash, slag and natural pozzolans including those relating to the properties of unhardened concrete and the mechanical properties of the hardened concrete are sufficiently understood to permit preliminary, unoptimized, use of such blends. Such is not, however, the case with the property of sulfate resistance. There existed in the U.S.A. in 1981 only two nationally standardized approaches to obtaining sulfate resisting concrete. Neither of these is suitable for use in evaluating the sulfate resistance of blends of portland cement and other materials such as pozzolans and slags. The methods are (a) a limit on calculated tricalcium aluminate and (b) the added sulfate mortar bar test (ASTM C 452). The history of efforts to develop a test suitable for both portland and blended cements has recently been summarized (K. Mather, 1978). Recent work has revealed that, in contract to what had often previously been assumed, namely that the incorporation of significant amounts of pozzolanic materials of types that meet relevant national specifications cannot but improve sulfate resistance, some pozzolans (especially Class C fly ashes as defined by ASTM C 618) actively make mixtures in which they are used less sulfate resistant than had the mixture contained only portland cement (K. Mather, 1980). Thus, there is a need to characterize relative sulfate resistance of blended cement systems and relate it to levels of environmental sulfate attack so that appropriate precautions may be taken to insure adequate resistance without incurring unnecessary additional materials costs. Thus, the guidance in the relevant guide may be revised (ACI Committee 201, 1977).

III. OBJECTIVES

A. To determine the factors affecting the performance regarding sulfate resistance of concretes made from blended cements of the portland-pozzolan and portland-blast furnace slag types in relation to the needs of highway construction.

B. To develop necessary methods for the characterization of blended cements in terms of phase composition, phase distribution and reactivity so as to permit reasonable assurance of adequate sulfate resistance.

C. To optimize the use of blended hydraulic cement systems.

IV. CURRENT ACTIVITIES

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

B. Suggested key words: concrete, blended cements, fly ash, blast furnace slag, performance, characterization, test methods, sulfate attack, sulfate resistance, durability.

V. URGENCY - Because relevant research

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

REFERENCES

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6. ACI Committee 201, "Guide to Durable Concrete," ACI Journal, Dec. 1977, ACI Manual of Concrete Practice, Part 1, 1980.

F - Construction, Garland W. Steele, Chairman

A2F01 - Rigid Pavement Construction - M. Lee Powell, III, Chairman

PROBLEM NO. 67

I. NAME OF PROBLEM - CONCRETE RESURFACING

II. THE PROBLEM - With the emphasis on infrastructure more information is needed so that highway engineers will have supporting data to design and specify concrete resurfacing. There is need for development of simplified thickness design method and data on the characteristics of bonded resurfacings. Additional data is needed to better define the desired properties of the bond breaker medium in an unbonded resurfacing design. Traffic control data on concrete resurfacing is needed.

III. OBJECTIVES

A. Develop simple procedures for the highway engineer to adequately design and justify each of the concrete resurfacing types.

B. A study of existing projects to evaluate the cost-effectiveness and energy savings of the concrete resurfacing.

C. An evaluation of the cost-effectiveness of the resurfacing as related to the increased 80,000 lb load limit.

D. Evaluation of the various types of bond breakers to determine cost-effectiveness and performance characteristics.

E. A study of traffic control on current projects to determine cost-effectiveness with relationship to safety and completion time.

IV. CURRENT ACTIVITIES

A. NCHRP Project 20-5, Topic 13-04, "Resurfacing with Portland Cement Concrete."

B. The interest in concrete resurfacing is increasing and pavements are being designed without the information outlined above.

C. Suggested key words: concrete resurfacing, design, interface, traffic control.

V. URGENCY - Very urgent due to the increased highway users fee making more funds available for concrete resurfacing. NCHRP 20-5, Topic 13-04 states, "Performance data indicate that a relatively low maintenance service life of 20 years can be expected and many resurfacings have provided 30 to 40 years of service." Engineers need the supporting data NOW to design and justify concrete resurfacing.

PROBLEM NO. 68

I. NAME OF PROBLEM - ACCEPTABLE LIMITS FOR ALIGNMENT OF DOWELS IN PCC PAVEMENT

II. THE PROBLEM

A. Current specification tolerances for installation of dowel bars are not realistic and cannot reasonably be met.

B. Recent studies indicate that broader specifications can be tolerated.

C. Dowel emplanting with special vibratory mechanical equipment is the most cost-effective method of dowel installation.

D. Emplanted dowels have given excellent performance since the mid 1950's but there is little knowledge of the actual position and alignment for this or other conventional methods of installation.

E. Recent rigid enforcement of existing specifications has eliminated the use of the emplanting method even though there is little evidence if any of pavement distress due to misalignment.

F. We must know the limitations of both dowel assemblies and emplanters so that reasonable specifications can be written to insure performance and economy.

III. OBJECTIVES

A. Determine from field investigations of previously constructed pcc pavements the relationship between alignment of dowel

bars and pavement distress related to misalignment of dowels.

B. Investigate projects under construction as well as the various methods used to install dowels and the tolerance to which they can be installed using reasonable quality control procedures.

C. Suggest recommended specifications and equipment needs for the proper installation of dowels in pcc pavements.

IV. CURRENT ACTIVITIES - Small studies in Alabama, Florida, Louisiana, Tennessee, Texas and Georgia. "A Comparative Analysis of Dowel Placement in PCC Pavements," M. G. Beeson, James Burati, Jr. (TRB 1982 Meeting).

V. URGENCY - Very urgent due to increased cost of at least $1.00/sq. yd. for dowel bar assembly installation vs. emplanting of dowels. This approximates about $30,000 per mile for interstate pavement. Rated one of the three most important needs by A2F01.

PROBLEM NO. 69

I. NAME OF PROBLEM - OPTIMIZING CONCRETE PAVEMENT REHABILITATION OPERATIONS

II. THE PROBLEM - The emphasis on 4R and the infrastructure of our nation's highways has created a great deal of work on concrete pavement rehabilitation without any real understanding of the cost-effectiveness of the various operations involved.

A. What is the best time in the life of the pavement to perform each of the concrete pavement rehabilitation operations (undersealing, slab replacement, space repair, grinding to restore profile, joint and crack repair, load transfer and shoulder repair)?

B. What is the life expectancy of each CPR operation?

C. What is the cost-effectiveness of each?

D. How to control the construction aspects of subsealing?

E. What is the most cost-effective joint sealer for any given joint spacing or condition?

III. OBJECTIVES

A. Prepare a synthesis on the life expectancy and cost-effectiveness of the various concrete pavement rehabilitation operations for the entire CPR system.

B. Determine from field investigations the relationship between performance and the time of rehabilitation in an effort to optimize the timing of each rehabilitation operation.

C. Undersealing is an art not a science. Determine what controls are needed in materials and construction so as to educate in quality construction those contractors who need this information.

D. Determine from field investigation the most cost-effective joint and crack sealant for various conditions.

IV. CURRENT ACTIVITIES

A. NCHRP 1-21, "Repair of Joint-Related Distress in PCC Pavements."

B. Demonstration projects throughout the country by the American Concrete Pavement Association in cooperation with NCHRP 1-21 and state and federal agencies.

V. URGENCY - This is considered highly important with the new user fee funds being used for pavement rehabilitation. This research is needed to supplement the findings of NCHRP 1-21. The proper timing for performing each CPR operation can save a great deal of money; there is an optimum time and cost for each CPR operation. This research need was rated as one of the three top priorities by the A2F01 Committee.

A2F02 - Flexible Pavement Construction - Gerald S. Triplett, Chairman

PROBLEM NO. 70

I. NAME OF PROBLEM - IDENTIFYING CAUSES OF SEGREGATION DURING THE PRODUCTION OF BITUMINOUS MIXTURES

II. THE PROBLEM - For many years production of asphalt concrete mixtures involved batch or continuous plants with gradation units and pugmill mixers. Recent innovations include elimination of gradation units and utilization of drum mixers for mixing and provisions for short or long term storage in surge bins or silos.

The elimination of gradation units and pugmills and the utilization of surge bins and silos with drum mixers or batch plants has increased significantly the probability of occurrence of segregation. Harmful segregation, if undetected or not corrected, can produce a pavement structure with built-in areas of weakness and with reduced service life.

Methods need to be developed to evaluate effectively the components of bituminous production and storage equipment as related to their effects upon segregation during production.

III. OBJECTIVES - Develop sampling and testing procedures for evaluating specific components of bituminous production and storage equipment. Such procedures should lead to the establishment of criteria for defining the occurrence of significant and detrimental segregation of bituminous mixes. This should include:

A. Sampling plans which address the location points for sampling, the minimum sample size for determing significance, the definition of reasonable probability levels which establish equitable risk factors for producer and user.

B. Establish criteria for judging maximum variability assignable to equipment characteristics which account for the variability assignable to sampling and testing errors.

C. Identify specific causes of segregation as related to the characteristics of a particular element of production equipment and the interaction of production equipment.

D. Effects of production rate and operating techniques on segregation.

E. Interaction of mix properties and construction equipment characteristics.

IV. CURRENT ACTIVITIES - No known research is underway at this time concerning the effects of plant equipment on the segregation of bituminous mixtures. Some research has been conducted in the past by equipment manufacturers.

V. URGENCY - Significant and harmful segregation is a chronic problem in the production of bituminous mixtures. Uncorrected segregation problems seriously reduce pavement serviceability. Definition of detection methods, the assignment of significant sources of variability and guidelines for correction of segregation of problems are needed urgently.

A2F03 - Earthwork Construction -
Charles M. Higgins, Chairman

PROBLEM NO. 71

I. NAME OF PROBLEM - IMPROVING TRENCH BACKFILL MONITORING PROCEDURES AND TRENCH BACKFILL DESIGN

II. THE PROBLEM - Excessive pavement distress develops over trenches dug for utilities, storm drains, sewers, etc., due to the lack of adequate compaction of backfill material. The state of the art of monitoring backfill does not insure adequate compaction of trench backfill.

III. OBJECTIVES

A. Establish a trench backfill procedure to include type of backfill material, methods of compaction and procedure for backfill to minimize trench settlement and overlying pavement distress.

B. Establish guidelines as to the proper monitoring of trench backfill.

IV. CURRENT ACTIVITIES - No known activities currently underway.

V. URGENCY - Excessive pavement distress over trenches causes rough pavement requiring pavement resurfacing and, in extreme cases, complete trench re-excavation and backfill with a new pavement. Costs associated with correction of trench backfill are substantial.

PROBLEM NO. 72

I. NAME OF PROBLEM - DEEP COMPACTION OF GRANULAR SOILS

II. THE PROBLEM - Frequently during wharf construction loose granular soil deposits exist or must be placed as underwater fill behind costly bulkheads or on slopes under expensive wharf structures. It is often deemed necessary to compact these materials to reduce the possibility of structural collapse under moderate to catastrophic earthquakes.

III. OBJECTIVES

A. To determine under what conditions compaction of these materials is desirable or beneficial.

B. To objectively determine the most productive and economical means for achieving desirable compaction.

C. To determine the optimum means for evaluating deep compaction.

IV. CURRENT ACTIVITIES - Current deep compaction activities are mainly in the hands of proprietory interests who are marketing patented procedures.

V. URGENCY - Resolution of the problems outlined in this proposal could result in a considerable energy savings as well as having a sizeable economic impact.

PROBLEM NO. 73

I. NAME OF PROBLEM - USE OF NUCLEAR DEVICES FOR DENSITY/MOISTURE TESTING

II. THE PROBLEM - Though first and maybe second generation nuclear devices have been researched extensively the more recent devices have not. Also many new users, because of inexperience, do not have the knowledge to tell if a claim concerning the capabilities of a nuclear device is realistic or not.

III. OBJECTIVES - A study is needed to determine (a) the capabilities and (b) the best mode of use of the nuclear devices to measure density and mixture. Also their variabilities under different modes of use should be determined.

IV. CURRENT ACTIVITIES - Suggested key words: nuclear testing, density, moisture, density testing, moisture testing, construction control, compaction, compaction control, consolidation.

V. URGENCY - In view of the importance of compaction control on the longevity of embankments and pavements and the increase in demand for maintenance funds this problem is viewed as highly important.

PROBLEM NO. 74

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

II. THE PROBLEM - The one universal approach to

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

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

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

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

IV. CURRENT ACTIVITIES

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

B. Suggested key words: rapid test, embankment construction, nondestructive test, engineering sufficiency.

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

PROBLEM NO. 75

I. NAME OF PROBLEM - MORE EFFICIENT UTILIZATION OF WET EARTH MATERIALS IN EMBANKMENT CONSTRUCTION

II. THE PROBLEM - The problem of drying wet soil is a major deterrent to construction progress. The traditional process is almost entirely dependent on the weather and entails many hours of aeration and manipulation to bring the embankment material to the desired moisture content. The procedure is costly in time, labor and energy. Methods, equipment and additives need to be developed to permit more efficient drying or stabilization of wet earth materials being placed in compacted embankments. Methods that heretofore were considered too costly may now merit reconsideration in the light of rising energy costs and shortages. The problem grows more acute each day. Without progressive, energy saving procedures the cost of embankment construction in money and energy may become completely prohibitive.

III. OBJECTIVES - To develop methods which will permit more efficient utilization of wet earth materials in embankment construction with resultant savings in energy and increased construction activity during weather not conducive to conventional drying.

IV. CURRENT ACTIVITIES - Suggested key words: earthwork, wet earth materials, drying, energy consumption, energy optimization.

PROBLEM NO. 76

I. NAME OF PROBLEM - IMPROVED MOISTURE-DENSITY REQUIREMENTS

II. THE PROBLEM - Compaction of soil and rock materials is one of the most effective means for improving the engineering properties of those materials for use in highway embankments and pavements. Compaction requirements, usually based upon AASHTO T-99 or AASHTO T-180, have been used by many agencies for years. The efforts to achieve the required moisture content and density significantly affect construction costs and associated energy consumption. Excessive compaction requirements are wasteful and of no significant benefit.

Compaction requirements would clearly be most cost-effective if related to the required engineering properties of the embankment or roadbed. The engineering properties, in turn, depend upon the location of the soil and rock material within the structure and the imposed loads during construction and during the life of the structure. Should the embankment and the subbase be divided into zones with different compaction requirements for each?

III. OBJECTIVES

A. To determine the required engineering characteristics (which should include but not be limited to volume stability and bearing capacity) for different zones in embankments and pavement bases.

B. To determine the practical advantages (which should include but not be limited to economics and rate of construction) of varying the moisture-density requirements from one zone to another.

C. To develop recommendations for improved moisture-density requirements for highway embankments and pavement bases.

IV. CURRENT ACTIVITIES - The study "Improving Embankment Design and Performance," being conducted at Purdue University, is related to the subject study.

V. URGENCY - Embankment construction is typically the largest single item in highway construction. Any reduction in unit cost will result in significant savings in overall construction costs.

A. Estimated Cost: $150,000 if laboratory and field tests on one construction project are included and $400,000 if a wide variety of soil materials and construction equipment are included.

PROBLEM NO. 77

I. NAME OF PROBLEM - IMPROVED TECHNIQUES FOR MEASURING THE ACCEPTABILITY OF COMPACTED SOIL

II. THE PROBLEM - Soils used in earthwork construction are normally compacted to improve their strength and reduce settlement. During construction the normal existing field control to meet these objectives is by indirect means using moisture and soil density criteria developed in the laboratory. Indirect control weakens the feedback process from construction engineer to designer. This increases the probability that changed field conditions (from that assumed in design) will not be recognized and/or won't be recycled through the design process; this often results in either under design or over design. Under design normally results in failure to meet service objectives and is accompanied by higher maintenance costs and premature reconstruction; both of these factors are accompanied by higher energy demands. Over design usually results in higher than necessary construction costs accompanied by higher energy usage.

Field control via methods that tie directly to materials characterization used in design would have the following advantages:

A. Value engineering principles could be more readily used to take advantage of new techniques or field conditions not anticipated during design.

B. It would be possible to directly address the problem that laboratory processing of materials sometimes does not accurately predict performance characterization (or acceptability) of field processed soil.

C. It is much easier for construction engineers to feedback critical information to designers to insure the original service objectives will be met. This is especially important where materials performance properties within the project change significantly and where frequent materials changes can be expected.

III. OBJECTIVES - The goal for research in this area would be to develop new methods or validate existing procedures that enable more optimal usage (minimize costs and energy consumption) of soil materials.

New technology would:

(a) develop methods of measuring properties of field processed soils that insure original design requirements are met;
(b) reduce construction costs and construction energy demand through more optimal usage of soil materials;
(c) open opportunities for contractors to use value engineering in earthwork construction.

IV. CURRENT ACTIVITIES

A. Although some work has been done in this area very little recognition was given to possible benefits in energy conservation and possible application of value engineering to the problems.

B. Suggested key words: compaction, soil properties, stability, embankments, quality control, energy, value engineering.

V. URGENCY - The problem of determining the acceptability of field processed soils has long been recognized as a major problem in earthwork construction. Task Force A2T61 recommended this subject for further research because of the opportunity for significant energy savings by more optimal use of soil materials.

A2F07 - Fabrication and Inspection of Metal Structures - Robert N. Kamp, Chairman

PROBLEM NO. 79

I. NAME OF PROBLEM - WELD REPAIR PROCEDURES AND CRITERIA

II. THE PROBLEM - Repair of welds and members which are rejected during fabrication is a costly process. Present codes and specifications do not address this subject in any detail. Repaired weldments have resulted in service fractures. The cracking found in the I-79 Neville Island Bridge and the new Pt. Pleasant Bridge have both been the result of weld repairs. Repair procedures for both weldments and cosmetic repairs to plates need to be developed which result in economical repairs which increase rather than decrease the service life. The present state of the art leaves many engineers with the concern that "the cure is worse than the illness."

III. OBJECTIVES - Determine the proper welding procedures to be used to repair defects found in weldments and in place surfaces.

A. The use of repair procedures other than welding should be evaluated.

B. Removal of plate surface defects by grinding should be evaluated.

C. Parameters such as type and method of excavation, preheat, electrode size, process, post heat, etc. should be evaluated to determine the best method of repairing internal weld defects.

The results of this study should be in a form allowing them to be readily incorporated into present specifications. Definite repair guidelines and limitations on variables should be included.

IV. CURRENT ACTIVITIES

A. Research in progress is unknown.

B. Suggested key words: welding, weld repair.

V. URGENCY - The results of this study will reduce the cost and increase the service life of welded bridges. The cracking which has occurred from weld repairs has resulted in the expenditure of millions of dollars for field retrofitting. This research should eliminate many of these problems and costs.

PROBLEM NO. 80

I. NAME OF PROBLEM - SENSITIVITY EVALUATION OF NONDESTRUCTIVE INSPECTION METHODS

II. THE PROBLEM - Metal bridges are inspected by visual and other nondestructive methods. In addition to properties of the metal and the local stress level the transition from subcritical to critical crack growth depends on the crack size. Data on the size of cracks that can be detected with a high degree of reliability under field conditions are not available for the nondestructive inspection methods. Knowledge of the characteristics of NDI methods under field conditions will allow reliability evaluation of members subject to fatigue crack growth and specification of fracture toughness consistent with growth of cracks to a size that can be detected with confidence.

III. OBJECTIVES - To determine the statistical distributions for the sensitivities of the principal NDI methods under field conditions so that the probability of not detecting a crack of specified size with a given nondestructive method can be estimated with confidence and the best inspection method for a given set of conditions can be determined.

IV. CURRENT ACTIVITIES

A. No known research is in progress.

B. Suggested key words: nondestructive tests, x-ray inspection, magnetic particle tests, penetrants, ultrasonic tests, cracks, crack detection, crack propagation, fatigue, inspection.

V. URGENCY - Research is needed for proper specification of material properties in fracture critical members as the critical crack size must be great enough to be detected with assurance and little information is available regarding capabilities of nondestructive inspection methods for detecting cracks of a specified size.

PROBLEM NO. 81

I. NAME OF PROBLEM - EVALUATION OF WELD QUALIFICATION TESTS

II. THE PROBLEM - The new specifications for fracture critical members require extensive weld qualification testing. Numerous tests of weldments to meet these qualification requirements have been performed. No one at present is synthesizing the results to determine variability of the results when the same procedures are used by different fabricators or by the same fabricator at different times. In addition, the successful welding proce-

dures used for various weldments are not being summarized. These test results are very valuable information. They provide the data to determine the variability of weldment performance when the presently essential variables are the same and consequently the need for requalification if the variables are unchanged. A summary of the successful procedures would provide fabricators and states with a guide for selection of proper procedures for future weldments.

III. OBJECTIVES

A. Analyze the results of the weld qualification tests that have been performed on fracture critical members.

B. Determine the variability of weldment performance when identical procedures are used by different fabricators and/or the same fabricator at different times.

C. Evaluate the successful qualification results to provide a guide for procedures to be used in future weldments.

IV. CURRENT ACTIVITIES

A. No known research is in progress.

B. Suggested key words: welding, weld testing.

V. URGENCY - The results should reduce the cost of fabrication of welded bridges by eliminating the duplication of tests on weldments made with identical procedures.

PROBLEM NO. 82

I. NAME OF PROBLEM - DEVELOPMENT OF REFERENCE BLOCKS FOR USE IN ULTRASONIC INSPECTION OF STEEL STRUCTURAL WELDMENTS

II. THE PROBLEM - A variety of test blocks are now used by various agencies for qualification of ultrasonic test procedures for weld inspection. Development of a standardized series of blocks would allow general acceptance of procedure qualification, eliminate duplication of the qualifying process for different agencies and result in greater uniformity of inspection. Surface and coupling characteristics of ASTM E428 and other reference blocks are not similar to characteristics of fabricated structural steel.

III. OBJECTIVES - Develop a series of test blocks with surfaces comparable to as rolled and/or other surface conditions typical of newly fabricated steel (lightly rusted or sandblasted might also be appropriate) and with defects that adequately simulate the cracks and other planar defects which are best detected by the ultrasonic method.

IV. CURRENT ACTIVITIES

A. Research in progress is unknown.

B. Suggested key words: ultrasonic testing, nondestructive testing, inspection, flaw detection, quality control, test blocks, reference blocks, ultrasonic reference blocks.

V. URGENCY - Successful development and a favorable cost-benefit ratio appear nearly certain.

H - Evaluations, Systems and Procedures, Charles S. Hughes, Chairman

A2H01 - Instrumentation Principles and Applications Earl C. Shirley, Chairman

PROBLEM NO. 83

I. NAME OF PROBLEM - ACCEPTANCE OF NEW NUCLEAR GAGES FOR DENSITY AND MOISTURE TESTING

II. THE PROBLEM - Nuclear moisture and density gages were researched extensively during the 1960's and are now widely used by state transportation departments and other agencies. Most of the research, however, was on first and second generation devices and the more recent models have not been studied to any extent. Also, in many agencies the individuals responsible for the earlier research are no longer directly involved with the gages. As a result many current users do not have the experience to tell if claims concerning the capabilities of a nuclear device are realistic or not.

III. OBJECTIVES

A. Determine the capabilities and limitations of various nuclear gage models for determining density and moisture.

B. Establish standard procedures for agencies to use in qualifying new equipment and in evaluating gage characteristics such as depth of influence, sensitivity to chemical composition and sensitivity to surface roughness.

IV. CURRENT ACTIVITIES - Suggested key words: nuclear testing, density, moisture, density testing, moisture testing, construction control, compaction, compaction control, consolidation.

V. URGENCY - In view of the importance of compaction control on the longevity of embankments and pavements and the increase in demand for maintenance funds and in view of the widespread use of nuclear moisture and density gages this problem is viewed as highly important.

PROBLEM NO. 84

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

II. THE PROBLEM - A variety of nuclear gage models are currently available commercially for determining the density of bituminous concrete. The depth responses, i.e., the relative contributions of each depth increment of the pavement to the gage readings, differ, however, among the various models. As a result density determinations on layered systems must be interpreted carefully. This

problem is particularly critical in situations where 20 to 40 mm overlays are being placed on existing bituminous pavements.

For example, during the investigations of some prematurely distressed overlays it was observed that the densities obtained by the nuclear gages during construction had been influenced by the density of the underlying original pavement. The original bituminous pavement, before resurfacing, had reached very high densities due to traffic compaction, and these densities were affecting the nuclear gage readings taken on the 20 to 40 mm overlays. This resulted in misleading nuclear values for the overlay densities, giving the appearance that all values met the specification requirement of 95 percent of the design density.

This problem is not generally encountered on new construction projects, but it is being faced more and more frequently with the increasing number of resurfacing projects being undertaken by the various highway departments.

III. OBJECTIVES

A. Establish the depth of influence (the effective depth to which the nuclear gage reads the density) and the contribution of each depth increment to the gage reading for the various models of commercially available nuclear gages.

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

C. Develop practical standard procedures to account for the influence of both depth and the densities of the underlying layers in arriving at the most accurate density of the surface layer. Alternatively, develop equipment and procedures which will reduce the depth of influence of nuclear gages to less than the thickness of the surface layer.

IV. CURRENT ACTIVITIES

A. The California Department of Transportation is currently supporting development of new nuclear equipment and techniques for monitoring densities in thin overlays in their HP&R Project D-3-65, "Asphalt Concrete Compaction Study." A recently published interim report from that study, FHWA/CA/TL-82/07, outlines three candidate equipment techniques and recommends further development and evaluation. Nuclear gage manufacturers are also reported to be developing new gages for thin overlay measurements currently.

B. A report of field testing of a nuclear density device, in the Proceedings of the Association of Asphalt Paving Technologists (Vol. 32, 1963, by Hughes and Ralston), discussed the depth of influence but did not suggest a practical procedure to account for the underlying layers. A limited study using two nuclear gages (Troxler and Campbell) was conducted in 1975 by the Bureau of Materials, Testing and Research, Pennsylvania DOT, using various combinations of precast bituminous concrete slabs.

Depending upon the density of the top layer the two gages had different depths of influence. The maximum depth was estimated at 50 mm.

C. Suggested key words: bituminous concrete, asphalt concrete density, nuclear density, overlays, nuclear gage, rapid test methods, construction.

V. URGENCY - Highway agencies are engaging in growing numbers of resurfacing jobs. Overlays of 20 to 40 mm thickness are common as efforts are made to stretch the tax dollars available for resurfacing. If the nuclear gages are to be used to determine the actual density of the top layer developing procedures to account for the depth of influence and the densities of the underlying layers is a critical need. Preliminary results of a TRB Committee A2H01 survey of current highway agency practice in controlling compaction also show this to be the primary research need.

PROBLEM NO. 85

I. NAME OF PROBLEM - QUALITY ASSURANCE PROGRAMS FOR AIR AND WATER QUALITY

II. THE PROBLEM - When measuring air or water quality the project engineer or other professional responsible for the measurements must determine the appropriate calibration methods for the monitoring equipment and the intervals for recalibration. There are several levels of sophistication in instrument calibration. The more sophisticated and time consuming methods are used in the laboratory every several months; while the simple methods are used hourly, daily or weekly in the field, depending on the type of equipment. When standard calibration procedures are not used both the accuracy and the comparability of field measurements can suffer. In addition, personnel performing field measurements have attained varying degrees of expertise in operating monitoring equipment. If they are not periodically briefed or recertified in the operation of the monitoring equipment an additional source of error may arise.

III. OBJECTIVES - Establish formal quality assurance programs for the collection of air and water quality data, including:

(a) procedures for the laboratory calibration of equipment within specified limits using materials and equipment traceable to the National Bureau of Standards;
(b) guidelines or procedures to insure proper field calibration of equipment and a determination of the effect of using these simplified calibration procedures on the accuracy of the data; and
(c) measures to train and certify personnel in the proper conduct of field measurements.

IV. CURRENT ACTIVITIES

A. In recognizing the need for quality assurance programs California Department of

Transportation personnel have developed programs for water quality testing and air quality monitoring aimed at satisfying the needs of their state. Other states also take steps to insure proper calibration of equipment (traceable to the National Bureau of Standards), proper use of measurement techniques and sufficient training of personnel. However, techniques and procedures vary among states and even among agencies within individual states.

B. Suggested key words: quality assurance, air quality measurements, water quality measurements.

V. URGENCY - With increased public awareness of environmental pollution associated with transportation facilities and increased frequency of legal action against transportation agencies quality assurance programs are needed to insure the uniform collection of environmental pollution data and to insure the validity of measurement results. The development of quality assurance programs is urgent and such programs can be implemented by appropriate transportation agencies throughout the country.

A2H02 - Quality Assurance and Acceptance Procedures -
E. J. Breckwoldt, Chairman

PROBLEM NO. 86

I. NAME OF PROBLEM - QUALITY ASSURANCE THROUGH PAVEMENT FEEDBACK SYSTEM

II. THE PROBLEM - A quality assurance program within the transportation agency involves, besides material sampling, testing and inspection, review and update of these procedures based on performance of the finished product. Conceptually, it is a feedback system and emphasizes the interrelations among various disciplines within the agency. Typically, a highway or transportation agency collects a large volume of data on a pavement system. However, most of this is fragmented and, therefore, not geared to providing answers desired concerning planning, design, construction and maintenance needs. An organized method of collection, storage, retrieval and analysis of the volume of data is needed to provide all disciplines a tool for their functional activity. For example, we need to identify the material characteristics that could be related to pavement performance. Likewise, relevant performance criteria need to be defined in order to relate them to specifications and back to construction quality criteria.

III. OBJECTIVES - To develop an integrated quality assurance system the following specific objectives must be accomplished:

A. Define various subsystems relevant to quality assurance feedback system.

B. Identify, within each subsystem, various attributes that may have a bearing on the overall performance and decision making process.

C. Define a method of collection and an automated data handling system for storage and retrieval of the overall system.

D. Develop guidelines for relating performance data to material characterization and specifications.

IV. CURRENT ACTIVITIES - A few states, notably Texas, California, Colorado, Illinois and Louisiana, have developed or are developing a computerized system for some or all of the subsystems considered to be a part of the overall system. The FHWA is preparing a report on the Construction Data Retrieval System which should be forthcoming soon. Very little information is available on material characteristics and pavement performance relationships, mainly due to lack of efficient and practical data base.

V. URGENCY - The soundness of a quality assurance system within an agency can only be judged when it can be related to the performance of the finished product. Present practices do not come anywhere close to providing information relative to the interrelation between design, construction, maintenance and performance. The problem of finding a solution is obviously a multidiscipline one and will involve pavement and maintenance committees. However, regardless of where the origin lies it is an urgent one.

PROBLEM NO. 87

I. NAME OF PROBLEM - REVIEW OF SAMPLING AND TESTING PROCEDURES IN REGARD TO QUALITY AS RELATED TO PERFORMANCE OF THE END PRODUCT

II. THE PROBLEM - Many testing and sampling procedures are rooted in tradition and may not be controlling the performance of the end product. Some materials are being undertested and others are being excessively tested without regard to performance related materials properties.

III. OBJECTIVES

A. Reevaluate basic performance related material properties.

B. Take a fresh and innovative look at sampling and testing requirements.

C. Prepare a report on the specification changes needed that will relate sampling and testing to performance.

D. Provide more cost-effective sampling and testing.

PROBLEM NO. 88

I. NAME OF PROBLEM - COST-EFFECTIVENESS - SAMPLING AND TESTING

II. THE PROBLEM - The quantity of sampling and testing is not always commensurate with the cost or importance of the product. Sampling and testing should relate to factors such as initial cost of product, cost of testing, cost of not testing, variability of manu-

factured or project-produced product, percent failures, criticality of performance, e.g., bridge deck failures, bearing pad failures or potholes in pavement. Sampling and testing are very expensive items, and programs should be cost-effective.

III. OBJECTIVES

A. Determine what samples and tests on what items can be minimized or discontinued without reducing confidence in end-product quality.

B. Survey existing practices in state testing operations.

C. Prepare suggested guidelines, multistate/nationwide, on optimum sampling frequency.

D. Reevaluate sampling and testing frequencies in regard to factors stated under problem above.

PROBLEM NO. 89

I. NAME OF PROBLEM - BENEFITS AND DISBENEFITS OF QUALITY CONTROL IN INSPECTION AND TESTING BY THE CONTRACTOR AND FEASIBILITY OF EXTENDING CONTRACTOR RESPONSIBILITY FOR QUALITY CONTROL

II. THE PROBLEM - As with most new programs there are many contractors and state highway agencies that are still rather skeptical about the contractors performing their own quality control as related to quality assurance programs. This issue has generated much controversy and has polarized opinions, but there are not many facts to support arguments on either side of the issue. The problems are the lack of definition of terms used and the lack of knowledge of benefits obtained such as cost, ease of contract administration and speedy construction.

III. OBJECTIVES

A. Identify philosophical, legal and contractual bases for use of state or owner process control and contractor process control alternatives.

B. Identify relative costs and benefits for both types of control procedures in specific dollar terms by reviewing actual experiences of states and contractors where contractor process control has been adopted.

C. Identify personnel requirements under both procedures.

D. Identify specific impact of contractor process control on small contractors in terms of dollar costs. Is it more or less as compared with that of larger contractors?

PROBLEM NO. 90

I. NAME OF PROBLEM - DEVELOPMENT OF MORE EFFECTIVE RAPID TEST METHODS AND PROCEDURES AND A SYNTHESIS OF SAME

II. THE PROBLEM - Modern high production plants have outdistanced the ability to adequately test and control production. There is a need to provide quick reliable test results so that the contractor can modify the operation on a timely basis.

III. OBJECTIVES

A. Accept or reject on a timely basis.

B. Develop a new or modified rapid testing procedure for each of the various types of construction.

C. Develop a snythesis that contains information on all known rapid test methods for major construction items. Indicate which methods offer possible alternatives to currently used control or acceptance test procedures for major construction items. Include a section providing information on appropriate standard sampling procedures for major highway items.

PROBLEM NO. 91

I. NAME OF PROBLEM - DEVELOPMENT OF A DECISION FUNCTION FOR OPTIMIZING THE FREQUENCY OF OBSERVATION MADE ON A PRODUCTION PROCESS OR LOT OF MATERIALS OR CONSTRUCTION FOR (A) CONTROL PURPOSES AND (B) ACCEPTANCE PURPOSES

II. THE PROBLEM - An acceptable standard for determining the resources that should be committed to quality assurance activities (control and acceptance) is needed. The most satisfactory approach would be a mathematical model that could be solved to indicate the optimum number of observations or inspection activities by treating the cost of quality assurance as a premium expressed as a percentage of the probable amount of possible loss.

III. OBJECTIVES - Develop a decision function that will yield a value in terms of numbers of observations or units of inspection time that, within a given confidence interval, would be expected to result in an optimum balance between the buyer's and seller's risks, the probable amount of possible loss and a practical number of observations or units of inspection time.

A2H03 - Mineral Aggregates -
Richard C. Ingberg, Chairman

PROBLEM NO. 92

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

II. THE PROBLEM - Information on the relationship between aggregate properties and field performance of untreated aggregate base course is generally lacking. As a result the optimum use of materials, considering cost, energy and resource conservation, for various levels of performance may not occur.

Recent advances have been made in mechanistic pavement design which consider the response of pavement to dynamic and

repetitive loads. However, research on the influence of aggregate properties on this response has not kept up with pavement thickness design advances.

The entire realm of problems ranging from defining the purposes 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, allowable strains and deformations over time. Aggregate properties such as density, gradation, durability, 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.

III. OBJECTIVES

A. Investigate and define purposes of aggregate base course in relation to present knowledge and needs.

B. Define performance requirements of aggregate base course in terms of significant aggregate properties at various levels of traffic for the dynamic repetitive loading experienced by pavements.

C. Evaluate existing 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. Current related research includes work at the Georgia Institute of Technology entitled "A Study of Factors Affecting Crushed Stone Base Course Performance." Several other research studies in the United States and abroad have been completed, or are in progress, on various narrow specific aspects of the problem. However, a comprehensive and systematic plan is needed to provide research direction.

B. Suggested key words: aggregate base course, flexible pavements, performance requirements, characteristics, construction control, testing, cost, energy.

V. URGENCY - The highway construction industry is facing increasing pressure to reduce materials costs and improve energy 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.

PROBLEM NO. 93

I. NAME OF PROBLEM - THE ADVERSE EFFECT OF SODIUM CHLORIDE 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 deicing salt (sodium chloride) on aggregates that contributes 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 of Volume II of the Quarterly Journal of Engineering Geology, 1978.

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

PROBLEM NO. 94

I. NAME OF PROBLEM - DEVELOPMENT OF CRITERIA FOR EVALUATING THE EFFECTS OF CONSTRAINTS ON SUPPLY AND DISTRIBUTION OF AGGREGATES

II. THE PROBLEM - While the overall supply of aggregates in the United States is virtually inexhaustible there are many areas of the country in which either (a) aggregates of suitable quality must be transported long distances or (b) constraints exist to the efficiency development of large quantities of available aggregates such as the inner city areas of large metropolitan communities. Transportation agencies need economic, technical and social criteria to properly evaluate their supply and use constraints in order to effectively decide which aggregate sources could be developed most cost-effectively and with greatest acceptability by the public for use in construction and/or rehabilitation of transportation facilities. These criteria are especially important in light of today's rapid shrinkage of transportation construction budgets from loss of revenues and inflation.

III. OBJECTIVES - Develop economic, technical and social criteria for evaluating the constraints involved in using large quantities of aggregates for construction and rehabilitation of transportation facilities due either to long haul distances or site conditions which limit production of large quantities of aggregate.

IV. CURRENT ACTIVITIES

A. There are no known studies currently going on in this area. Previous work done in connection with TRB Special Report 166, "Optimizing the Use of Materials and Energy in Highway Construction," and NCHRP Topic 12-09, "Energy Involved in Construction Materials and Procedures," has helped to identify some of the problems in this area. A good overview of the subject of aggregate supplies is contained in "Stretching Our Aggregate Supplies," by James R. Dunn, in Transportation Research News No. 72, September - October 1977.

B. Suggested key words: aggregate supplies, aggregate costs, aggregate sources, aggregate source evaluation.

V. URGENCY - The supply of aggregates continues to decrease in urban and suburban areas due to social factors. As the local supplies become unavailable increased haul distances quickly make bringing in aggregates economically unattractive. Criteria are needed to weight these factors and make a systematic judgment as to which aggregate source(s) to use.

J - Stabilization, Donald G. Fohs, Chairman

A2J04 - Soil-Portland Cement Stabilization - Ara Arman, Chairman

PROBLEM NO. 95

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 stabilizer 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 ($E_t \neq E_c$).

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.

A. General Estimate of Cost: $220,000.00.

PROBLEM NO. 96

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), curing 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.

A. Cost of Research Effort: $185,000.

A2J06 - Chemical Stabilization of Soil and Rock - Thomas M. Petry, Chairman

PROBLEM NO. 97

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

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

IV. CURRENT ACTIVITIES

A. No present research known to be in progress.

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

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. 98

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 do not provide an understanding of how the mechanisms function within the soil-chloride mixture. There does exist substantial evidence that chlorides do cause significant alterations 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. Chloride stabilization is currently being performed but little information is being generated on the theoretical aspects of the reaction mechanisms involved. The data available are being developed by chloride producers such as Dow Chemical Co. and the Salt Institute members or their contract research organizations.

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

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. 99

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

A. Develop test methods, procedures and data analysis techniques for use in evaluating chloride stabilization of soils.

B. Develop a mix design manual employing the test procedures and data analyses developed.

IV. CURRENT ACTIVITIES

A. No present research is known to be in progress.

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

V. URGENCY - In the use of chlorides as a 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.

K - Soil Mechanics, Raymond A. Forsyth, Chairman

A2K01 - Soils and Rock Instrumentation - William H. Hansmire, Chairman

PROBLEM NO. 100

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. Measurement 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 fabrics. Furthermore, for field use these latter gages are difficult to waterproof and to protect during installation.

III. OBJECTIVES - 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 developmental work. 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 high priority since the use of geotextiles and fabric reinforcement offers the possibility of significant savings in construction of both highway and railroad embankments over soft soils.

PROBLEM NO. 101

I. NAME OF PROBLEM - IMPROVED LANDSLIDE MEASUREMENT 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.

Sub-Audible Rock Noise (SARN) measurement technology from the tunneling industry was used in California to warn of impending major movement. There is need to further develop these and other technologies to obtain accurate dependable systems.

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

(a) measuring movements of up to 2 feet with an accuracy of 1/4 inch,
(b) survival under field environment (frost, ice, salt, rain, snowplows, etc.), and
(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. No investigators contacted are satisfied with the present measurement systems.

V. URGENCY - The need for an adequate measuring system (or systems) is increasing as the need for improving highway (transportation) safety is increasing.

PROBLEM NO. 102

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

IV. CURRENT ACTIVITIES - None.

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

A2K02 - Embankments and Earth Slopes - Robert D. Holtz, Chairman

PROBLEM NO. 103

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 tieback 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. 104

I. NAME OF PROBLEM - SOIL-FABRIC INTERACTION BEHAVIOR

II. THE PROBLEM - The rapid increase in the use of geotechnical fabrics 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-fabric interaction mechanism is not well understood. This makes economical but safe designs difficult.

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

IV. CURRENT ACTIVITIES - Some research is 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. 105

I. NAME OF PROBLEM - DEEP IN SITU STABILIZATION FOR THE CORRECTION OF SETTLEMENT AND STABILITY PROBLEMS

II. THE PROBLEM - Many of the new deep stabilization techniques developed during the past 20 years are becoming more attactive and feasible each day. Methods such as stone columns, dynamic consolidation and deep chemical stabilization have provided solutions where conventional treatments were unfeasible. Designers of these systems presently rely on

past experience and empirical approaches to develop adequate treatment procedures.

Research is needed to define design procedures, construction control measures and resulting soil parameters. Rational and cost-effective designs, which address settlement and stability characteristics of the stabilized soil, are sorely needed.

III. OBJECTIVES

A. Develop cost-effective rational design guidelines for the above mentioned techniques. Theoretical analysis, laboratory and field testing and documented case studies will be required.

B. Encourage the acceptance and implementation of these and other new techniques at appropriate locations.

C. Encourage the development of new and improved methods of deep in situ stabilization.

IV. CURRENT ACTIVITIES

A. Most states have had little or no experience with these techniques.

B. Suggested key words: settlement, stabilization, stone columns, chemical stabilization, dynamic consolidation.

V. URGENCY - The unique problems which were the catalysis in development of these methods are no longer extraordinary. Restrictions of right-of-way, environmental constraints, maintenance of traffic and time have all become equally important to economics in design of facilities. Many of our conventional treatment measures are no longer considered acceptable at some locations and it appears that future developments will further limit our available tools.

PROBLEM NO. 106

I. NAME OF PROBLEM - DEVELOPMENT OF A RATIONAL DESIGN PROCEDURE FOR MEMBRANE REINFORCEMENT OF SOFT SOILS

II. THE PROBLEM - The use of geotextiles 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 fabric for optimum performance at a given site have not yet been established since the fabric-soil interaction has not been characterized analytically. Testing techniques are fabric industry related and not necessarily geotextile applicable.

III. OBJECTIVES

A. Develop an analytic procedure consistent with empirical experience to characterize the interaction of the fabric 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 fabric properties so that the evaluations are applicable to geotextile applications.

IV. CURRENT ACTIVITIES - Fabric reinforcement for fill construction has been successfully utilized at a number of sites on an experimental basis. The simple model of using the fabric grab tensile strength as a resistance force in conventional slip failure analyses is of such magnitude as to be unacceptable.

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

PROBLEM NO. 107

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 dewatering.

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. Damages 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 chance 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 - Foundations of Bridges and Other Structures
Bernard E. Butler, Chairman

PROBLEM NO. 108

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 - Develop an improved design procedure for pile groups that relates single pile load test behaviour with soil and pile parameters, group efficiency factors and overall group performance.

IV. CURRENT ACTIVITIES

A. The Federal Highway Administration 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 timber piles in sands. Current FHWA research involves load transfer measurements on actual bridge foundation piles and correlation of data with PLGP1 predictions. Small scale model studies and centrifuge testing are also underway. Many more tests are needed to refine and verify the PILGP1 method.

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

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 constructions.

A. 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 $1,000,000.

PROBLEM NO. 109

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 correlating 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 transferred from the structure to the footing. A true picture of the load-settlement-time relationships is necessary to perform an accurate evaluation of spread footing reliability.

III. OBJECTIVES - 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. 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.

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

V. URGENCY - There are many situations where spread footings could be used instead of expensive pile foundations, but they are not used because of the 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.

A. Cost Estimate: $75,000 - $100,000.

PROBLEM NO. 110

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. 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.

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

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.

A. Cost Estimate: $150,000 - $200,000.

PROBLEM NO. 111

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. Transportation 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 believe 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 - 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. DURRENT ACTIVITIES

A. 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.

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

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.

A. Cost Estimate: $175,000.

PROBLEM NO. 112

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 documentation. 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 - 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 which is 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. 113

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 investigates.

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 test 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. Develop methods for the evaluation of the suitability of compacted fills to carry bridge abutment loads constructed of (1) granular, (2) heterogeneous, and (3) various cohesive materials.

B. Study the stress distribution under spread footings constructed with above approach fills.

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

IV. CURRENT ACTIVITIES

A. 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, and (3) a laboratory study of bearing capacity of foundations on a sloped embankment completed at the University of Ottawa, Canada, for the Ontario Ministry of Transportation and Communications, and an associated field trial now underway. Further studies are proposed by FHWA on the Behavior and Efficiency of Spread Footings.

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

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.

A2K04 - Subsurface Soil-Structure Interaction -

Michael G. Katona, Chairman

PROBLEM NO. 114

I. NAME OF PROBLEM - LONG TERM EFFECTS ON THE STRUCTURAL INTEGRITY OF BURIED CULVERTS

II. THE PROBLEM - It is generally known that buried culverts often experience adverse changes in structural responses (deflections, stresses) due to long term time effects well after the installation is completed. Such effects are attributed to viscous consolidation of the soil mass and are influenced by environmental factors such as seasonal changes, moisture content and temperature variations. Although well documented experimental data is relatively scarce long term deflection increases on the order of 50 percent have been observed for some large diameter culverts.

Within the last decade modern analysis procedures (e.g., finite element method) have made great advancements in realistic predictive capabilities for the design/analysis of buried culverts. However, attention has been limited to analyzing the construction sequence without consideration of long term effects.

III. OBJECTIVES - Advance the current soil-structure analytical capabilities to include consideration of long term effects for buried culverts. In essence, time-dependent constitutive models for soils with parameters reflecting environmental changes must be formulated and ultimately implemented into analysis procedures. To meet this objective the research effort would include a literature review along with extensive laboratory and field experiments.

IV. CURRENT ACTIVITIES

A. Highway research in progress is unknown.

B. Perhaps some information can be obtained from tunneling technology.

C. Suggested key words: soils, time-dependent effects, culverts, environmental factors.

V. URGENCY - The long term effects on buried culverts is significant and should not be ignored in the modern finite element programs used for culvert analysis and design. Accomplishment of this research will provide a greater assurance of achieving safe designs over the life of the culvert.

PROBLEM NO. 115

I. NAME OF PROBLEM - SOIL MODELS TO SIMULATE UNLOADING CONDITIONS

II. THE PROBLEM - The nonlinear stress-strain behavior of soils can generally be modeled with acceptable accuracy with the Hyperbolic stress-strain model provided that the stresses are monotonically increasing. However, modeling unloading conditions presents problems because accurate models to represent the unloading stress-strain conditions have not been developed, and

there are related numerical problems with the finite element solution. Unloading conditions are important for the analysis of problems such as:

- compaction loads on backfill soil;
- rerounding of buried pipes due to internal pressure;
- parallel trench installations for buried pipe;
- braced excavation;
- dredged anchored bulkheads.

III. OBJECTIVES

A. Conduct a literature search to collect available data on the stress-strain behavior of various soils for unloading conditions.

B. Perform laboratory and field tests to extend the available data to include various soil types and to study the void ratio and other conditions on the unloading stress-strain properties.

C. Develop a general soil model for unloading stress-strain behavior for which the model parameters can be readily determined from conventional soil tests.

D. Use the developed model for finite element solutions of several different types of loading, unloading and reloading problems.

E. Verify the finite element solution with a physical model/prototype test.

IV. CURRENT ACTIVITIES

A. Highway research in progress is unknown.

B. Suggested key words: soil models, finite element method, numerical methods, stress-strain behavior.

V. URGENCY - The effective utilization of the finite element method for soil-structure interaction problems involving decreasing stress states depends on the ability to model the nonlinear unloading stress-strain behavior of soil. At present time this is generally done in an ad hoc manner without due concern for energy restrictions, uniqueness, etc. Accomplishment of this research would greatly enhance the usefulness of the finite element method for the solution of soil-structure interaction problems.

PROBLEM NO. 116

I. NAME OF PROBLEM - RELATIVE SLIPPAGE AT SOIL-CULVERT INTERFACE

II. THE PROBLEM - Finite element methods have been used extensively to model long span metal culverts during the construction sequence. However, one aspect that remains unresolved among various researchers is the relative importance of slippage along the soil-culvert interface, i.e., does slippage actually occur to a significant degree in long span installations and, if so, does it cause significant changes in the overall structural responses. The point in question is primarily concerned with actual field behavior not with particular interface models that have been implemented in finite element programs.

III. OBJECTIVES - The objective of this research is to undertake a field experiment (or possibly laboratory experiment) on a fully instrumented long span system divided into three test sections each with a different interface condition. On one section slippage would be promoted, say by a greased membrane material covering the culvert. Another section would inhibit slippage, say by short studs on the culvert (porcupine fashion). The last section would be standard, no special treatment of the interface. By comparing the structural responses of the two extreme interface conditions the relative importance of slippage can be quantified. Further, the performance of the standard interface condition can be identified as to which of the two conditions is most representative.

IV. CURRENT ACTIVITIES

A. Highway research in progress is unknown.

B. Other research in progress is unknown.

C. Suggested key words: interface slippage, culverts, soils.

V. URGENCY - Slowly but surely the finite element method, once considered to be solely in the domain of sophisticated analysis and research, is becoming a commonplace tool for the design and analysis of soil-structure systems. At the same time progress is being made in establishing unanimity of opinion with regard to various modeling techniques and procedures. The proposed research is intended to carry this progress a step further by addressing the vexing problem of interface slippage.

A2K05 - Mechanics of Earth Masses and Layered Systems - Robert D. Stoll, Chairman

PROBLEM NO. 117

I. NAME OF PROBLEM - MECHANICS OF MEMBRANE REINFORCED EMBANKMENTS

II. THE PROBLEM - The application of fabrics for engineering purposes has increased in recent years. Fabrics have been used for filters in drainage systems, erosion control membranes, pavement overlay reinforcement, reflective crack prevention and bridge deck "salt" membranes. Some have also cited the successful application of fabric membrane for reinforcement to improve the stability of embankments on soft soil foundations. However, not much technical information regarding the basic mechanics, or the basic theory, and design criteria has been developed and reported.

III. OBJECTIVES - The objective is to evaluate the system and develop theoretical information necessary to understanding the basic mechanics of soil-membrane interaction and to establish design criteria.

In order to study the mechanics and the interaction of membrane and soil the following research procedures are suggested:

(a) Compile state-of-the-art information on the use of membranes for earthwork reinforcement.
(b) Laboratory test and evaluate the engineering properties of commercially available membrane products.
(c) Develop soil-fabric interaction theory.
(d) Develop methods, criteria and specifications for design and construction of membrane reinforced embankment.
(e) Study the performance of the membrane reinforced embankments with field instrumentation.
(f) Evaluate the field data and verify the design equations (if any) from the field performance studies.
(g) Report the research results and make recommendations for future studies.

IV. CURRENT ACTIVITIES - The use of prefabricated bituminous surfacing (PBS) in military road and airfield construction in India and southeast Asia during the Second World War by the British Army was probably the earliest application of membranes in soil and site improvements. The U.S. Army Corps of Engineers has also utilized membranes and fabrics for waterproof and dust control surfacing, for rapid construction of military airfields and heliports, for permanent road and airfield pavement foundations with encapsulated soil layers. In recent years the use of fabrics for engineering purposes has increased rapidly. Such uses have included fabrics for erosion control; for filters in drainage systems; for soil reinforcement in highway embankment, earth dams and soft soil foundations. Several industries have published catalogues and bulletins for promoting fabric products in engineering applications and reporting the engineering properties of such fabrics and membranes. The use of fabrics and membranes was the subject of several articles published in Highway Focus of the Federal Highway Administration, Vol. 9, No. 1, May 1977, and in the Proceedings of the International Conference on the Use of Fabrics in Geotechnics, Paris, April 20-21, 1977. A Transportation Research Circular, April 1979, cited more than 250 papers regarding test methods and use criteria for fabrics. Most recently the California Department of Transportation used fabrics for earthwork reinforcement over soft foundation soil in construction of a test section for the east approach embankment to Dumbarton Bridge in the fall of 1979.

V. URGENCY - The proposed research is considered highly important to evaluate the mechanics of the membrane-soil system and to evaluate the current applications of membrane reinforced embankment, especially on soft soil foundation to save time and money by preventing possible failures in future construction projects.

PROBLEM NO. 118

I. NAME OF PROBLEM - STABILIZATION OF EARTH MASSES WITH ROOT PILES

II. THE PROBLEM - Root piles have been successfully employed for stabilization of natural earth slopes and for consolidating and reinforcing foundation soil. The applications of root piles are still in an experimental stage using empirical design approach. Research is needed to explore a rational method for design and construction of root piles. Theoretical development to assess the soil-root pile interaction behavior is an essential research need.

III. OBJECTIVES

A. Compile current information on application of root pile in correction of landslides, in stabilization of man-made and natural earth slopes, in consolidating and reinforcing foundation soil against settlements and lateral movements due to deep excavation or heavy vertical and lateral loads.

B. Develop theoretical methods for analyzing the interaction behavior between the root piles and soil masses.

C. Develop rational design methods to determine the size, pattern and number of root piles for each practical application in different soils.

IV. CURRENT ACTIVITIES (AND BACKGROUND)

A. Root piles are cast-in-place reinforced concrete piles. These piles are normally constructed in clusters like tree roots in the ground by rotary or percussion drilling rigs through masonry and soils. Casings are progressively thrust into the hole to prevent any caving in of the ground. High strength steel reinforcing bars are inserted in the hole. The casting mix, compressed coarse sand, cement and water with some additives, is placed under controlled pressure while the casing is progressively withdrawn. The completed piles will have much larger effective diameters than the drilled holes since the pressure grout will densify the surrounding soil. As a result a strong bond will develop between the root piles and the surrounding soil. The root pile will have not only larger load bearing capacity than ordinary pile of comparable size but also will consolidate and reinforce the foundation soil against settlement and lateral movements.

B. The application of root piles for "underpinning" was first reported in the April 16, 1964 issue of the Engineering News Record (page 51). It stated, "An underpinning system developed in Italy was used to restore crumbling foundation beneath a 600-year old Church in England."

C. Application of root piles for the stabilization of a steep cut slope along a roadway was reported in September 1971 in an issue of the Civil Engineering and Public Works Review, 8 Buckingham Street, London.

D. In 1972 Dr. Fernando Lizzi of Italy

delivered a series of lectures on "application of root piles" at the University of Illinois, Urbana, Illinois; Massachusetts Institute of Technology, Cambridge, Massachusetts; and U.S. Bureau of Reclamation, Denver, Colorado.

E. Kenneth Ware reported the use of root piles in the construction of the Washington Metropolitan Area Rapid Transit System for underpinning the footing foundation of the existing buildings adjacent to the excavation of an underground tunnel.

F. In 1976 a research project was initiated by the combined effort of the Federal Highway Administration, U.S. Department of Transportation and the U.S. Army Engineer Waterways Experiment Station to study field behavior of the root piles constructed on U.S. Highway 61 South near Vicksburg, Mississippi and on U.S. Forest Service Highway 7, in Glenn County, North Carolina. These root piles were installed to stabilize potential landslide of the earth slopes along these two highways. These root piles were instrumented with strain gages to measure the strains developed in the root piles. The research program mentioned above was attempted to study the strain behavior of the root piles on actual slope stabilization projects. Because an ample factor of safety was designed in actual slope stabilization projects the strain in the root piles and the movements of the earth slop are very small and may not be even measurable. In order to measure the visible soil-pile interaction behavior tests to failure of full scale models of earth slopes or deep excavations with and without root piles must be conducted. Full instrumentation of strain gages and movement devices are required in these full scale models.

V. URGENCY - Due to broad areas of root pile applications and for engineering economy an urgent need for developing full scale model studies of root piles is recommended.

PROBLEM NO. 119

I. NAME OF PROBLEM - FIELD INSTRUMENTATION AND CORRELATION STUDY ON ELASTIC AND DYNAMIC SOIL PROPERTIES

II. THE PROBLEM - For many years engineers and scientists have been applying theory of elasticity in soil mechanics, soil dynamics and foundation engineering problems. This is mainly because of the availability of the mathematical solutions in the theory of elasticity and also because of the approximately elastic behavior of soils in small strain problems. Terzaghi utilized extensively the theory of elasticity in his classic textbook on "Theoretical Soil Mechanics." The development of solutions in the areas of foundation vibrations and the dynamic response during earthquakes are all based on the assumption of the linear or nonlinear elastic behavior in soils. In recent years the method of finite element has been utilized extensively in analysis of soil-structure interaction problems under either static or dynamic loadings. The elastic properties of soil are the required input data for such analysis. This input data includes modulus of elasticity, poisson's ratio and damping factor. Unfortunately, the development of the analytical design techniques has advanced far ahead of the development of methods for evaluating reliable soil properties. Since the accuracy of the results of an analytical method must depend on the accuracy of the parameters used the process of obtaining truly representative elastic and dynamic soil properties is still the most difficult and urgent research need in soil mechanic and foundation engineering.

There are a number of laboratory and field methods and instruments available for the determination of elastic and dynamic soil properties. These methods and instruments include the resonant column apparatus; the cyclic load triaxial compression device; and the cyclic simple shear technique for laboratory measurements of shear moduli and damping factors of soils; the steady state vibration technique; the refraction survey; the Ragleigh wave dispersion method; and the down-hole, up-hole and cross-hole methods for measuring in situ elastic and dynamic soil properties. Testing results obtained by each method varied in wide range. A correlation study of the laboratory and in situ elastic and dynamic soil properties coupled with field instrumentation and dynamic tests on highway embankments for verification of the dynamic behavior of soil and the accuracy of the dynamic soil properties is needed.

III. OBJECTIVES - The objective is to evaluate the correlation between the laboratory and in situ soil properties and to verify the soil behavior and the accuracy of the dynamic soil properties by field instrumentation and dynamic tests on highway embankments. Suggested research procedures include:

(a) Compile state-of-the-art information on laboratory and in situ tests on elastic and dynamic soil properties.
(b) Study the correlation of laboratory and in situ elastic and dynamic soil properties from available data in the literature.
(c) Select an ideal highway embankment or earth dam for a demonstration project; conduct laboratory and in situ tests on elastic and dynamic properties using various testing methods; install comprehensive instrumentation including static and dynamic soil stress meters, vertical and horizontal deformation measuring devices, accelerometers and reference monuments.
(d) Perform theoretical analyses of static and dynamic behavior of the demonstration project by finite element method using the elastic and dynamic soil properties obtained from various laboratory and in situ tests and from the results of correlation studies of laboratory and in situ soil properties in the state-of-the-art literature review.

(e) Conduct dynamic tests on the demonstration project using steady state vibration and blasting; the static and dynamic stresses, strains and accelerations response will be observed during the tests.
(f) Compare the theoretically analyzed results of the embankment behavior with those measured in the field.
(g) Develop emperical equations to describe the elastic and dynamic soil properties in relation to type of soil, strain amplitude, moisture content, void ratio, stress history, number of cycles of loading and etc.
(h) Table and formulate all available elastic and dynamic soil properties for various types of soil for practical use in dynamic response analysis and earthquake resistance design of earth structures and engineering foundations.
(i) Prepare a final research report.

IV. CURRENT ACTIVITIES - Individual studies and tests of dynamic soil properties have been cited in many literatures. Theoretical analyses of dynamic response of earth dams and highway embankments have also been performed by many practical geotechnical engineers. Limited field instrumentation to study the dynamic behavior of earth dams and highway embankments have also been reported in geotechnical engineering publications. A comprehensive correlation study of the laboratory and in situ elastic and dynamic soil properties and the verification of the accuracy of such dynamic soil properties by comprehensive field instrumentation and dynamic tests on highway embankments have not been reported.

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

PROBLEM NO. 120

I. NAME OF PROBLEM - MODELING TENSION BEHAVIOR IN GRANULAR MATERIALS

II. THE PROBLEM - In a layered pavement system the lower part of a granular base course layer is subjected to tensile stresses. Since the granular material cannot take any significant level of tension a redistribution of stresses and strains occurs in the system. With the present trend of returning to thicker granular bases as petroleum prices increase research in this important area is of immediate importance.

III. OBJECTIVES - The main objective is to develop a realistic analytical model of the granular base which mechanistically handles the problem of tension in the granular material. Specific objectives are to:

A. Develop a thorough understanding of the behavior of granular materials using carefully instrumented pavement sections.

B. Develop a realistic analytical model that is compatible with observed material response.

C. Verify response predictions.

D. Analyze the effect of various factors such as grain size, gradation and density on pavement response.

IV. CURRENT ACTIVITIES - Limited work is presently being conducted at the Waterways Experiment Station (Walt Barker and R. H. Ledbetter), the University of Illinois (L. Raad), Georgia Institute of Technology (R. D. Barksdale), Virginia Polytechnical Institute & State University (C. S. Desai), University of Nottingham (S. F. Brown). Also it is understood that work is being conducted at the University of Minnesota (Otto Strock) and McGill University (R. N. Yong).

V. URGENCY - Because of rapidly rising petroleum prices considerable interest is once again being shown in the utilization of granular bases in pavement construction. However, suitable methods of predicting granular base response are not presently available. Therefore, an urgent need exists for developing a mechanistic model and information on the fundamental behavior of granular materials.

A2K06 - Subsurface Drainage -
Lyle K. Moulton, Chairman

PROBLEM NO. 121

I. NAME OF PROBLEM - PREDICTING PERMEABILITY OF MATERIALS FOR PAVEMENT SUBDRAINAGE

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

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

III. OBJECTIVES - The general objective of this project is to develop a procedure for determining the saturated hydraulic conductivity (permeability) of highway materials from basic material properties. The specific objectives are:

A. Determine the basic material properties which directly affect permeability.

B. Establish a predictive permeability model based on material properties which

can be used in pavement design.

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

IV. CURRENT ACTIVITIES

A. Many state highway agencies have conducted and/or are currently conducting laboratory and field studies involving pavement system drainage. In addition, FHWA reports on an in situ field permeability testing method, a highway subdrainage manual and improving subdrainage and shoulders of existing pavements are avilable. However, little has been done to develop a practical and reliable method for predicting the permeability of highway bases and subbases.

B. Suggested key words: soil permeability, soil drainage, pavement layers, base courses.

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

PROBLEM NO. 122

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

II. THE PROBLEM - An important factor affecting pavement performance and life is the presence of water in the pavement system. In the northern United States deterioration of asphalt and concrete pavements is greatest in the late winter and spring when repeated freeze-thaw cycles occur. The excess water in the pavement materials, subbase and subgrade contributes to rapid structural damage to the pavement under traffic loads. Subdrains and/or drainage layers in the pavement are the only available methods for removing this water. However, often the subdrain system is frozen and may be inoperative. Recent studies in an FHWA project entitled "Improving Subdrainage and Shoulders of Existing Pavements," conducted at the University of Illinois, indicated that there is an optimum subdrain depth for various climatic regions. The study indicates that a more thorough investigation is needed to develop procedures for designing subdrain systems which operate effectively in the freeze-thaw environment.

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

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

IV. CURRENT ACTIVITIES

A. Excerpt for the FHWA reports on the research conducted at the University of Illinois on "Improving Subdrainage and Shoulders of Existing Pavement." No known studies are currently underway.

B. Suggested key words: frost action, subsurface drainage systems.

V. URGENCY - The Federal Highway Administration's "Highway Subdrainage Manual" and the Federal Highway Administration's "Water in Pavement" workshops presented throughout the United States demonstrated the need for drainage in pavements. In northern states the efficiency of pavement underdrain systems may be seriously impaired in the pavement section and at the outlet during the critical freeze-thaw period when a significant amount of pavement discress occurs.

L - Geology and Properties of Earth Materials,
Clyde N. Laughter, Chairman

A2L01 - Exploration and Classification of Earth Materials -
Martin C. Everitt, Chairman

PROBLEM NO. 123

I. NAME OF PROBLEM - APPLICATIONS OF THE NEW GENERATION OF REGIONAL HIGH ALTITUDE PHOTOGRAPHY AND PLANNED HIGHER RESOLUTION LANDSAT SATELLITE FOR EXPLORATION OF TRANSPORTATION CORRIDORS

II. THE PROBLEM - This new imagery planned for use in 1982-1986 has thematic map capability for vegetation and geology with higher resolution than present. Their application for exploration for transportation corridors has not as yet been fully defined or described.

III. OBJECTIVES - Although the capability of high resolution in high altitude photograph is well documented the higher resolution planned for the newer satellite imagery will have untested uses in transportation planning and exploration. There should be research to coordinate the two new systems to maximize utilization of data. We have not seen any reports of ongoing research of this nature.

IV. CURRENT ACTIVITIES

A. The TRIS data base for key words "High Altitude Photograph" and "Landsat" was scanned in preparation of this statement.

B. Simulation studies have already been

done over a variety of terrain types for other purposes (e.g., agricultural crop studies, soil erosion and land use), but not for transportation.

C. Suggested key words: satellites, satellite program, high altitude photography, landsat.

V. URGENCY - Any delay in planning research for these two new sources of data will be detrimental to continued state-of-the-art use of remote sensing by the transportation field.

PROBLEM NO. 124

I. NAME OF PROBLEM - DEFINITION OF LEGAL LIABILITY OF INDIVIDUALS INVOLVED IN EXPLORATION AND CLASSIFICATION OF EARTH MATERIALS FOR TRANSPORTATION PURPOSES

II. THE PROBLEM - Individual employee engineers and geologists have generally felt immune from professional liability lawsuits. Unfortunately, this has changed in the last few years and individuals themselves are being sued, along with their employer, agency or company. The conditions for this to occur are changing and current trends in professional liability are not clearly defined.

III. OBJECTIVES - The present state of legal (both contractual and tort) liability of individuals involved in exploration and classification of earth materials for transportation purposes should be concisely defined in a brief document.

IV. CURRENT ACTIVITIES

A. The TRIS data base for key words "legal," "exploration," "classification," "earth" and "soil" was scanned in preparation of this statement.

B. There does not appear to be any coordinated effort to resolve this problem by the legal profession.

C. Suggested key words: legal action, legal responsibility, liability.

V. URGENCY - The rapid increase of legal threats to professional engineers and geologists in the performance of their duties is having serious impact on their willingness to make detailed judgments.

PROBLEM NO. 125

I. NAME OF PROBLEM - PHYSICAL PROPERTIES OF SOILS RELATED TO GEOPHYSICAL SUBSURFACE EXPLORATION

II. THE PROBLEM - The physical properties of conductivity, density and velocity of soils and bedrock are measured by geophysical techniques. The correlation of the measured physical properties with soil types and/or bedrock is one of the major components of the interpretation of geophysical data. The correlation between physical properties of soils and/or bedorck may vary from area to area; however, broad ranges of physical properties can be correlated with soil types and bedrock. Correlation data are available in numerous textbooks and articles, but a comprehensive study or library search of such data is not available.

III. OBJECTIVES - The physical properties of soils are affected by numerous factors and may vary from area to area. The proposed study, which may take the form of a library search, would present the data in a systematic way. The data may be grouped as related to differing climatic and geographical regions, i.e., tropical, temperate, arctic, foothills, plains, etc. The objective of this study is to further the understanding and behavior of the physical properties of soils and bedrock under varying climatic and geologic conditions, which would lead to improved interpretation of the geophysical data.

IV. CURRENT ACTIVITIES

A. The TRIS data base for key words "geophysical exploration" and "soil physical properties" was scanned in preparation of this statement.

B. The Federal Highway Administration Materials Division is currently sponsoring research in two projects dealing with this topic--Project 5-B-2, Tunneling Technology and Project 4-E, Remote Sensing and Geophysical Testing. Some reports have been issued.

C. Suggested key words: geophysical exploration, geophysical measurements, soil physical properties, correlation, subsurface exploration.

V. URGENCY - The need for a systematic study of physical properties is a long standing one. The availability of a set of data resulting from the proposed study would enhance many fold the value of geophysical surveys, thus improving their cost-effectiveness. The problem is considered urgent.

PROBLEM NO. 126

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

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

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

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

III. OBJECTIVES

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

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

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

IV. CURRENT ACTIVITIES

A. The Federal Highway Administration Materials Division is currently sponsoring research in two projects dealing with this topic - Project 5-B-2, Tunneling Technology and Project 4-E, Remote Sensing and Geophysical Testing. Some reports have been issued.

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

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

PROBLEM NO. 127

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

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

A. Gradation changes caused by faulty sampling equipment and techniques.

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

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

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

III. OBJECTIVES

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

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

IV. CURRENT ACTIVITIES

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

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

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

A2L04 - Frost Action -
David C. Esch, Chairman

PROBLEM NO. 128

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 to 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. Validate by observations of actual pavements in service the pavement 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 modelling 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 investigations 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. 129

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 17 impose springtime load restrictions by a variety of methods. Many of these methods are based on engineering judgement and, therefore, are subjective. A need for an objective approach to establish load limitations and to assess penalties for overloads exists. Field measurements of the pavement system strengths should be the base data used to establish the load limits and the duration thereof. Nondestructive deflection measuring devices such as the static Benkelman beam and plate bearing tests and dynamic loading Dynaflect Falling Weight (FWD) and Road-Rater are good indicators of pavement strength changes and could well be used to establish objective base data.

III. OBJECTIVES - The general objective of this research is to establish a systematic procedure for applying load limitations on flexible pavements that could be widely accepted and implemented. The specific objectives are:

A. 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. Develop a system for establishing when the load limits should be applied to and removed from a particular road based on indicators of in-place strength.

C. Develop a rational method for assessing damage caused to pavements during critical periods by load in excess of those determined in objective A.

D. Determine an implementation procedure which considers 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. Establish guidelines to assist county and town highway personnel in posting temporary local load limits in the absence of extensive data.

IV. CURRENT ACTIVITIES - State transportation agencies in Alaska, Idaho and Pennsylvania have published reports on deflection based load limitation schemes. Six states have implemented a load limitation system based on some type of deflection measurement. No ongoing research is available.

V. URGENCY - It is paramount to obtain the maximum useful lives from our present pavements. The rational application of springtime load limits based on objective pavement measurements would substantially increase service life since more load related distress occurs during the remainder of the year. General adoption and implementation of this procedure 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.

PROBLEM NO. 130

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 climatic 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 foremost supplier of roadway subgrade insulation, Dow Chemical Company, has refused to supply insulation for roadway burial in the U.S.A. unless the user agency agrees to indemnify them from lawsuits through the mechanism of a "hold harmless" agreement. This situation has nearly eliminated the consideration of insulation products for the control of frost heave in the U.S.A. However, road insulation usage is common in Canada under a different legal system and the absence of an indemnification requirement. Many rumors exist about accidents, lawsuits and settlements related to insulated roads; but nothing has been written to guide the road designer in reaching rational decisions on whether 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 design;
(b) applying surface skid resistance modification efforts;
(c) justifying the decision to insulate based on economy;
(d) applying roadway insulation only in nonbraking areas or to short lengths of roadway; and
(e) refusing to insulate hazardous frost heave areas and doing nothing to correct them.

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 "Skega" rubber-modified asphalt pavements in Sweden and Alaska demonstrates some promise of this material in increasing icy road friction levels.

V. URGENCY - The use of buried roadway insulation has nearly been eliminated in the U.S.A. by the refusal of Dow Chemical Company to sell insulation board as a result of legal concerns over their past promotion of this product as a roadway insulation. New manufacturers have recently commenced production of a competing product adequately resistant to water absorption, and a fresh look at all aspects of subsurface insulation will benefit designers and road users.

A2L05 - Engineering Geology -
David L. Royster, Chairman

PROBLEM NO. 131

I. NAME OF PROBLEM - DESIGN OF HORIZONTAL DRAINS IN SOIL OR ROCK

II. THE PROBLEM - Recent equipment developments have caused a rapid expansion in the use of horizontal drains in all types of soil and rock. At present there is no proven way of determining where and to what length and slope such drains should be drilled for optimum effect except where the geology is well enough known to permit seeking specific joints, faults or strata.

There is no general way of predicting the shape or extent of the zone of influence of the drains. Drilled drains are expensive and can be useless or even detrimental if poorly located. Present placement methods may provide more drainage than is necessary. It is desirable to know the service life and have a better understanding of the behavior of these drains during the service life.

The design and construction of collector systems affects the ultimate performance of the entire drain installation. Types of materials and methods of handling the

collected water need study.

III. OBJECTIVES - The objectives of this research are to answer the following questions:

A. With respect to soil and rock conditions:

(1) What is the optimum location, spacing, slope and casing type for drains?
(2) What is the zone of influence around the drains?
(3) How should pipe size and slot size be determined?

B. How should performance be monitored?

C. How can the need for individual pipe or system maintenance be determined?

D. How can maintenance best be accomplished?

E. What are the characteristics and performance of various collector system designs?

F. What service life can be expected?

IV. CURRENT ACTIVITIES

A. The TRIS data base was surveyed using the key words "horizontal" and "drains."

B. The only research currently active is a project in California jointly sponsored by the Federal Highway Administration and the California Department of Transportation. The study, titled "The Effectiveness of Horizontal Drains," is a survey of existing installations to determine how well they have performed. A study of design methods is not included. This project was estimated for completion in June 1979.

The TRIS data base also lists a Federal Highway Administration pilot project on horizontal drain maintenance reported in 1974 in "Special Reports on the Use of Equipment and Methods of Maintenance." No other recent or current research related to the key words was found.

C. Suggested key words: drain, subsurface drainage, horizontal drains, drain performance, drawdown.

V. URGENCY - A large amount of horizontal drain work is being done, especially in the control of landslides. Criteria leading to successful installations and accurate estimates of bid quantities would be valuable to designers and construction engineers.

PROBLEM NO. 132

I. NAME OF PROBLEM - ROCK FALL BEHAVIOR - FIELD STUDIES

II. THE PROBLEM - In mountainous areas construction of new transportation facilities is starting to encroach on steep slopes as available land in the valleys is developed for other uses. A major hazard these new routes face is rock falls from the steep upper slopes. These rock falls can block highways and/or damage vehicles and cause risk of loss of life. It is difficult to predict from present kinematic models the movement patterns of rocks and total travel distances as they bounce down rock faces and talus slopes. In order to define realistic zones of high risk it would be necessary to have field measurements of typical rock fall conditions which can be used to develop empirical guidelines for general rock fall behavior predictions.

III. OBJECTIVES

A. Provide field measurements of typical combinations of slope geometry, rock type, climate and rock fall records for one or more selected study areas.

B. Develop empirical predictions of rock fall behavior based on the available records.

C. Use the above data to delineate hazardous areas and provide guidance for selecting collection bench widths or protective ditch dimensions.

D. Use the above data to calibrate kinematic models for use in making predictions of the hazards of rock falls in new areas.

IV. CURRENT ACTIVITIES

A. At present there are two kinematic models available to calculate the path of falling rock - Cundell's dynamic block model and Piteau's bouncing ball model. Existing field studies have been conducted by the Corps of Engineers and by graduate students at the University of British Columbia to collect comprehensive information on the slope angle of talus slopes. However, there are no data on the distance that rocks roll past the toe of the slope nor on the relationship between block size and distance travelled. Some preliminary data on this relationship has been collected by the firm of Golder Associates and could be available to the researchers.

In preparing this research needs statement the TRIS data base has been surveyed using the key words "rock falls," "talus slopes" and "rock slide hazards." No current research projects involving rock fall trajectory prediction were found. The California Department of Transportation has an active project relating to mitigation of rock fall hazards but this appears oriented more toward restraint and catchment mechanisms.

Previous research on rock fall trajectory and slope design has been conducted by the Washington State Department of Transportation. The results, reported by A. M. Ritchie in Highway Research Record No. 17, should form a good starting point for the suggested project.

Two published papers may also supply information useful to the research. The first is a French monograph of the Groups d'Etudes des Falaises titled "Rock Falls on Roads - Mapping Methods" and is available from the Transport and Road

Research Laboratory. The monograph reports techniques of developing hazard risk assessment maps for rock falls along roads. The second paper is titled "A Simple Dynamic Model of Rock Falls: Some Theoretical Principles and Model and Field Experiments" by I. Statham and published by the International Colloquium on Physical Geomechanical Models - Bergamo, Italy, 1979. This document is also available through the Transport and Road Research Laboratory.

B. Suggested key words: rock falls, roadway hazards.

V. URGENCY - In some areas there is undue restriction to transportation facility routing and other development because there are no guidelines as to the magnitude of the rock fall hazard zones. Conversely, there are other areas which are being developed that are within high risk zones of rock fall damage. Decisions involving many dollars are currently being made on the basis of inadequate or no data and these decisions later result in significant maintenance cost for the rights-of-way due to rock falls.

PROBLEM NO. 133

I. NAME OF PROBLEM - APPLICATION OF GEOSTATISTICAL METHODS TO IMPROVING THE INTERPRETATION OF SUBSURFACE DATA

II. THE PROBLEM - Interpreting the characteristics and properties of soil and rock materials between data points represented by borings is becoming more critical as funds available for exploration decrease and liability exposure for such interpretations by engineers increase. The use of statistics in probability methods is becoming more common in geotechnical engineering. Statistical techniques such as kriging and randomization have been applied in the minerals industry to more realistically estimate variations between borings. It appears likely that these techniques or similar ones could provide a more rational basis for interpreting soil layering and/or selective properties between discreet boring points.

III. OBJECTIVES

A. Review existing geostatistical techniques to identify methods with potential applications for subsurface exploration interpretation.

B. Evaluate by use of demonstration projects limitations and suitability of the methods to specific geotechnical data needs, i.e., estimating material quantities and physical properties.

IV. CURRENT ACTIVITIES - Recent publications that discuss statistical techniques such as kriging and randomization include:

(a) Huijbregts, C.J., "Regionalized Variables and Quantitative Analysis of Spatial Data," Display and Analysis of Spatial Data, Wiley-Interscience, 1975.

(b) Royle, A.G. and Hosgit, E., "Local Estimation of Sand and Gravel Reserves by Geostatistical Methods," Transactions of Institute of Mining and Metallurgy, Vol. 83, pp. A53-A62, April 1974.

(c) Olea, R. A., "Measuring Spatial Dependence with Semivariograms," Kansas Geological Survey Series on Spatial Analysis, Lawrence, Kansas, p. 29, 1977.

(d) Green, B.F., "A Practical Interactive Program for Randomization Tests of Location," American Statistician, Vol. 31, pp. 37-39, 1977.

In addition, a series of eight articles published in the Engineering and Mining Journal between May 1979 and February 1980 by various authors provides a good overview of geostatistics as it is applied in the mining field.

No current research to demonstrate application of these techniques is known.

V. URGENCY - The need for methods to support engineers' interpretation of data between borings is increasing as funds available for exploration decrease and the public's tendency to litigate is increasing.

PROBLEM NO. 134

I. NAME OF PROBLEM - APPLICATION OF PHOTOGRAMMETRIC METHODS TO MONITORING OF SLOPES

II. THE PROBLEM - Interstate and modern highway construction has resulted in the creation of more and larger rock cuts. Natural weathering of the rock in these cuts tends to cause increasing rates of failure with time, and these failures have potential hazard to users. After failure it is frequently impossible to reconstruct previous conditions; thus, the precise cause of failure often cannot be determined.

Concurrently, agencies are faced with increasingly tight maintenance budgets. Efficient inexpensive monitoring of slopes is needed to aid in maintenance planning. Many agencies have sophisticated photogrammetric groups for map production. These groups have the expertise to conduct terrestrial photogrammetric monitoring of rock slopes but such works is rarely requested.

III. OBJECTIVES

A. Prepare a state-of-the-art summary on photo logging of rock slopes defining:

(1) the geotechnical data required and constraints concerning data accuracy, repetitive coverage, etc.
(2) photogrammetric options and economics including alternative equipment and procedures.

B. Prepare a review of cases where these techniques have been applied and a critique of each application.

C. Undertake one or more demonstration projects.

D. Prepare a "guidebook of recommended practice" to assist engineers in applying the technique to future studies.

IV. CURRENT ACTIVITIES

A. A TRIS data base was surveyed using the suggested key words.

B. The use of terrestrial photogrammetry to study slope stability in open pit mines has been reported in the April 1971 "Photogrammetric Record," a publication of the Photogrammetric Society (England). More recent work in this area has been conducted by the Canadian Department of Energy, Mines and Resources, Mines Branch, Ottawa, Canada. No other current research projects were found by the TRIS search.

C. Suggested key words: photogrammetry, rock slopes, equipment, methods, slope stability.

V. URGENCY - The existence of many large rock slopes having increasing failure potentials, coupled with ever tighter maintenance budgets, suggests that improved rock slope monitoring methods would be valuable to many transportation agencies.

The need for a systematic study of physical properties is a longstanding one. The availability of a set of data resulting from the proposed study would enhance many fold the value of geophysical surveys, thus improving their cost-effectiveness. It is considered that the problem is urgent.

PROBLEM NO. 135

I. NAME OF PROBLEM - CONSTRUCTION METHODS FOR HORIZONTAL DRAINS

II. THE PROBLEM - Over the past several years numerous techniques for drilling and installing horizontal drains have been developed by contractors; however, little information has been published or made available on the effectiveness of these techniques. Designers may not be aware of the extent of current technology and have difficulty preparing proper specifications.

III. OBJECTIVES

A. Prepare a state-of-the-art summary covering:

(1) equipment capabilities,
(2) drilling methods and techniques,
(3) borehole guidance procedures and capabilities, and
(4) hole stabilization techniques.

B. Review existing installations to determine the geologic conditions, drilling techniques used, production rate achieved, costs and problems encountered.

C. Survey requirements and needs for environmental controls.

D. Develop a demonstration project to evaluate newer techniques and equipment available and determine opportunities and limitations with respect to geologic materials and conditions.

IV. CURRENT ACTIVITIES

A. The TRIS data base was surveyed for the key words "drilling equipment" and "horizontal drains."

B. No research covering this area was found in the literature survey. A study jointly sponsored by the California Department of Transportation and the Federal Highway Administration titled "The Effectiveness of Horizontal Drains" is a survey of existing installations. This survey may gather historial data on installation methods used.

C. Suggested key words: drilling equipment, drilling methods, drilling machines, horizontal drains, subsurface drainage and drainage practices.

V. URGENCY - The use of horizontal drains is increasing, especially in the eastern half of the United States. Many new contractors are entering the field using methods and techniques which have not been available recently. Designers in preparing specifications for bid purposes are having difficulty properly specifying approaches and techniques to achieve the desired effect resulting in construction difficulties, improperly constructed drains and, in some cases, legal action by contractors.

A2L06 - Environmental Factors Except Frost - Malcolm L. Steinberg, Chairman

PROBLEM NO. 136

I. NAME OF PROBLEM - CONTINUING MONITORING AND ANALYSES OF METHODS OF CONTROLLING EXPANSIVE SOILS

II. THE PROBLEM - Expansive soils can be estimated as causing nine to ten billion dollars in damages in the United States last year. The problem is worldwide where climatic conditions and clay soils result in expansive movements. It affects a wide variety of transportation facilities including airports, rail systems, highways and canals. A great deal of work has been done by many engineers around the world, at the universities, laboratories, agencies and in construction. Many solutions have been taken from the laboratory and are being applied on construction problems throughout the United States. An orderly analysis, at regular intervals, of their effectiveness is needed to provide a measure of true economy of the various methods as well as a cost saving procedure of significance.

III. OBJECTIVES - The ability to evaluate effectiveness, economy and practical choice of options in the reduction of costs of the expansive soil movement is a general goal. The specific objectives are:

A. Determine what type of control measures are being currently tested under field

conditions.

B. Analyze their effectiveness and examine the ways this effectiveness is being measured.

C. Bring forward continually more effective modes of controlling the expansive soil problem and permit less effective methods to be equally well recognized.

IV. CURRENT ACTIVITIES

A. Highway research on the moisture and expansive soil problem is being conducted at the University of Illinois.

B. Transportation research studies are being conducted at Texas A&M University.

C. The comprehensive examination of the expansive soils problem by the Waterways Experiment Station.

D. Research at the Sandia Corporation, the U.S. Air Force and University of New Mexico.

E. Testing by the Mississippi State Highway Department.

F. Testing by the South Dakota Department of Transportation.

G. Testing by the Colorado Department of Transportation.

H. Testing by the Arizona State Highway Department.

I. Testing by the Texas Department of Highways and Public Transportation.

V. URGENCY - This problem becomes more expensive with the passing of time. As man develops more sophisticated structures, pavements and more intensively uses the land the destruction caused by the expansive soil becomes more and more expensive. Man has been faced with the problem of using his resources with ever increasing wisdom and economy. Engineers are required to meet these needs or face the loss of the public acceptance that his profession is attempting to solve significant worldwide problems. This research could form an effective bridge between the university laboratory, governmental agencies, private and public construction in solving a problem of international significance.

PROBLEM NO. 137

I. NAME OF PROBLEM - THE EFFECTS OF ENVIRONMENT CHANGES ON ROCK FILL MATERIALS

II. THE PROBLEM - Rock fill materials are placed as large pieces in thick lifts. As a consequence the voids in the fill are also large. So long as the rock pieces remain intact the deformations of the fill are likely to be predictable. However, should these pieces break down due to environmental changes (causing wetting and drying and freezing and thawing of the pieces) the fragments drop into the voids. The subsequent deformations of the fill are both large and unpredictable and it will usually be rendered incapable of performing its intended function.

When rock materials are nondurable they must either be mechanically stabilized by thorough degradation and compaction in thin tight lifts or be made durable by use of suitable additives. Accordingly, it becomes necessary to develop prediction techniques for the effects of environmental changes on fill rocks whose durability is suspect. Prominent among such rocks are siltstones and shales which often slake with cycles of wetting and drying.

III. OBJECTIVES - The determination of the effects of environmental changes on rock fill material of suspect durability is most reliable in prototype structures. However, such determinations are extremely lengthy in time and involve very costly sampling. Accordingly, the specific research objectives are phrased in the context of laboratory studies of rock durability.

A. Survey all recent studies on durability classification of shale and other potential rock fill materials of marginal durability (henceforth simply called "shale").

B. Select suite of tests and single classification system after suitable laboratory experimentation with representative North American shales.

C. Concurrently with objective B determine the mechanism of slaking, viz., air breakage, dissolution of cementing agent, swelling, combinations. Relate to geomorphic factors as possible.

D. Draw conclusions (as possible) for major shale classification groupings with respect to use in rock fills, emphasizing (1) compaction practice or (2) stabilization by additives.

IV. CURRENT ACTIVITIES

A. Studies for Ontario Ministry of Transportation.

B. Studies for Indiana State Highway Commission and Federal Highway Administration.

C. Studies for Bureau of Mines.

D. Studies for U.S. Forest Service.

V. URGENCY - A considerable momentum and high level of interest in this topic exists due to recently completed FHWA studies and the current activities listed above. However, these efforts have not achieved the highly desirable specific objectives of item III.

Improper evaluation of shale durability has led to excessive pavement roughness in thousands of highway embankments in the last decade.

M - Railway Systems, George H. Way, Jr., Chairman

A2M01 - Track Structure System Design -
Robert E. Kleist, Chairman

PROBLEM NO. 138

I. NAME OF PROBLEM - TRACK SYSTEM OPTIMIZATION

II. THE PROBLEM - With the many track configurations, variations in maintenance operations and cycles and types of train operations (vehicle type and speed) there exists no definitive method to select an optimum track rehabilitation (upgrading and maintenance program).

Increases in axle load, train length and speed and deferred track maintenance have and are accelerating deterioration of track structure throughout the nation. While much has been done by individual railroads to rehabilitate their trackage higher annual maintenance costs may be predicted for the future. With continuing increases in the cost of materials and labor the railroad engineer is faced with the complex problem of resource allocation.

The availability of track geometry data has provided but one tool to aid the engineer in this difficult decision process. Details of actual track conditions coupled with predictive tools that require system and component life cycles, which vary with the many track and load conditions, are needed to adequately restore and maintain the railroad system as a national resource.

III. OBJECTIVES - Development of a general predictive methodology which will provide the railroad Chief Engineer and staff the means to optimize resource allocations. Subobjectives include:

(a) an understanding of the life cycle of the track both as a system and as components under varying conditions,
(b) means of nondestructively determining the existing conditions of the railroad network, and
(c) data base which is an inventory of both the track system (components and geometry) and rolling stock loads (magnitude, frequency and yearly totals).

IV. CURRENT ACTIVITIES - Presently the railroad industry is conducting research covering the railroad system. The industry has research by individual railroads and suppliers and jointly funded activities through the Association of American Railroads, American Railway Engineering Association, Railway Progress Institute and other groups including transit authorities. Also, the Track Train Dynamics Research Program is actively conducting and sponsoring projects.

V. URGENCY - The railroads spend huge sums each year on the operations and maintenance of the railroad network. While past experience does provide a tool to allocate resources it is general knowledge that a better method could save millions of dollars. With the unpredictable inflation and energy situations, combined with the need to maintain a viable railroad network, it is imperative that research of this type be given the highest priority.

PROBLEM NO. 139

I. NAME OF PROBLEM - VIBRATION OF TRACK AND SUPPORT

II. THE PROBLEM - The advent of recent energy price increases have reaffirmed the importance of railways as a mode of transport for the movement of bulk commodities. To meet the challenge, track design, construction and particularly maintenance practice are being improved to satisfy the needs of changing load patterns; however, the rate of progress is slow and the availability of documented design procedures is limited. For instance, the governing document for track specification in North America is the Manual of Recommended Practice of the American Railway Engineering Association (AREA) which does not contain a procedure of design and leaves such matters as the determination of ballast depth to the individual operators who rely on their own experiences.

The dynamic response of vehicles to track irregularities and elastic parameters has been recognized with high speed services. Computer simulations supported by confirmatory service operations and testing have led to more stringent tolerances on alignment and track maintenance. For high speed passenger traffic with light wheel loads and speed exceeding 120 mph continuous raft foundation of concrete or bituminous material has been considered to replace conventional ballast systems. Resilient pads are being introduced between rails and sleepers or raft to minimize dynamic loads.

At the other end of the loading spectrum where axle loads reach 60 tons with maximum speeds of 60 mph modifications in track paramaters are receiving less attention. Heavy axle load unit train operations running at generally reduced speeds adopt basically the same philosophies of track design that have been developed for faster passenger operations. While this may be adequate for "static" track response in terms of bearing pressures and maintenance of alignment it is clearly apparent that the dynamic response is not as accommodating. Frequent reports of rail-head corrugation on lines used with unit train rolling stock clearly indicate an excitation of the track into its fundamental resonant mode leading to periodic rail overloading and track deformation.

Conventional ballasted track is a comparatively loose assembly of rails, fastenings, ties and ballast designed to transmit the dynamic forces from a moving vehicle to the underlying roadbed. It depends for its vertical alignment upon the ability of the ballast and roadbed to sustain the repeated applications of contact stress due to the passage of each wheel over the hard spots caused by each tie. The ballast layer itself is characterized by a high angle of internal friction, a high modulus of elasticity effective over an extended period and as a result of its angular shape and a high resistance to displacement of its particles under dynamic action.

Nevertheless, when subjected to the action of dynamic repeated loads the ballast layer undergoes cumulative irreversible (plastic) deformation which is recognized as ballast subsidence or voiding. The typical

relation between load repetition, frequency and ballast settlement is complex and not clearly understood. Even less understood is the correlation between the rate of tie settlement and ballast contact pressure and ballast acceleration. A further complication arises when the load is distributed by the flexible rail to adjoining and subsequent ties.

III. OBJECTIVES - The overall objective is the improvement of railway track support through better understanding of the use of ballast material and the sizing and spacing of rail ties.

This objective implies the need to increase the resistance of the track structure to the development of irregularities due to vibrations and repeated loading from traffic and due to the effects of the weather. The program should be mainly concerned with the optimization to vibration and repeated loading (a) of ballast, subballast and subgrade materials and (b) design of the ballasted track structure including tie sizing and spacing and the selection of rail.

IV. CURRENT ACTIVITIES - Some work on track resonance is being done in Europe and Japan related to lighter axle loads. Little or none is related to heavy axle loads.

V. URGENCY - The Maintenance of Way budget represents about one-third of the expenses of railway operation with about one-third of these expenses going to the replacement and upkeep of track. Thus the urgency for this project should be among those given top priority.

PROBLEM NO. 140

I. NAME OF PROBLEM - EVALUATE CONCEPTS TO UPGRADE EXISTING TRACK TO ACCOMMODATE INCREASED AXLE LOADS OR INCREASED SPEEDS

II. THE PROBLEM - Railroad track in the U.S. has deteriorated in overall quality during the past two decades. Increased axle loads are responsible for a great portion of this situation (closely related to Problem No. 3).

III. OBJECTIVES - Tabulate and evaluate all known concepts for possible upgrading of track to meet current loads.

IV. CURRENT ACTIVITIES

A. FAST track.

B. AAR TTD studies.

V. URGENCY - All railroads are actively engaged in their individual methods. Overall advice on evaluation of all techniques would be of help.

PROBLEM NO. 141

I. NAME OF PROBLEM - ESTABLISH A UNIFORM STANDARD OF ACCEPTABLE TRACK STIFFNESS FROM A TRAIN RESPONSE VIEW

II. THE PROBLEM - The classification of track standards is currently measured by the many individual components of the track. This method does not provide a safe level of operational measurement by which to judge a track.

III. OBJECTIVES - Using track "stiffness" as a single measurement of relative operational safety develop a method of measuring track "stiffness" which can be used as a minimum safe level, a design specification or load determinant.

IV. CURRENT ACTIVITIES

A. Some activity by D.O.T.

B. Dr. Arnold Kerr, Princeton University.

V. URGENCY - Present evaluation methods are not meeting needs of the evaluation in American and Canadian railroads.

PROBLEM NO. 142

I. NAME OF PROBLEM - INVESTIGATE THE TRADE-OFF BETWEEN REDUCING AXLE LOADINGS OR IMPROVING TRACK

II. THE PROBLEM - In the U.S.A. rail axle loadings have been increasing steadily over the past two decades due to large volume cars being designed and built. These increased axle loads have caused deterioration to track structure which is an economic loss to the railroads offsetting much if not all of the gain made by increased car loadings.

III. OBJECTIVES - Determine the true dollar value of increased axle loadings after deducting track deterioration.

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 - Most of the damage has been done or is irreversibly continuous. The study could help in future axle load design.

PROBLEM NO. 143

I. NAME OF PROBLEM - LONGITUDINAL STRESS MEASUREMENT OF RAIL UNDER OPERATING CONDITIONS

II. THE PROBLEM - Continuous welded rail exists in nearly 70,000 miles of U.S. and Canadian railroads. This rail is restrained from expanding and contracting and, therefore, builds up longitudinal stresses either compression or tension at the rate of about 200 psi for each degree of temperature change Fahrenheit. Dynamic stresses introduced by rail vehicles add to the thermal stress to create the possibility of buckling or breaking of track.

III. OBJECTIVES - Develop a device which will measure the longitudinal internal stress in rail and determine whether this stress is tensile or compressive. The device must be capable of measurement and recording stresses while moving along the track at any speed

between 2 mph and 80 mph. The device would be used on a variety of existing track testing vehicles.

IV. CURRENT ACTIVITIES

A. Some activity in DOT R&D.

B. British rail has developed a nondestructive method of detecting longitudinal forces in CWR. (This device must be fixed to the rail and, therefore, is not practical for repeated testing of many miles.

V. URGENCY - Railroads urgently need such a device with which to make periodic checks of CWR to locate potentially dangerous locations at which a build-up of stresses might cause buckling or break and possibly result in a derailment.

PROBLEM NO. 144

I. NAME OF PROBLEM - TRACK RAIL LUBRICATION EVALUATION

II. THE PROBLEM - Most transit systems use rolling stock with fixed axles and wheels. In negotiating curved track the wheel flanges and rails make sustained contact causing accelerated wheel and rail wear and annoying noises we call squealing.

III. OBJECTIVES - A lubrication evaluating program combining field and laboratory measurements is recommended to determine the criteria needed for a lubrication system.

IV. CURRENT ACTIVITIES - Current practice is use of rail lubricators of the mechanical or high pressure type. Both systems are automatically actuated by a passing train. Typical problems occur with over and under lubrication from location to location. FAST currently has a lubrication test which could provide a basis for lubrication evaluation.

V. URGENCY - Little research has been expended over the years toward developing new and evaluating existing track lubrication systems.

It is estimated that a significant noise reduction can be achieved with the use of a lubrication system. In addition, these installations have the added benefit of increasing the useful life of wheel and rail components.

PROBLEM NO. 145

I. NAME OF PROBLEM - EVALUATION AND DEVELOPMENT OF STANDARDS FOR GUARD RAIL ON CURVES

II. THE PROBLEM - The criteria for the use of guard rail on curves varies from one transit system to another. It is evident that the criteria for the use of guard rail on curves of transit systems has not been established.

III. OBJECTIVES - Study, develop and evaluate basic standards for transit operation for guard rail and its applications

IV. CURRENT ACTIVITIES - Many transit properties rely on past practices and cut-and-dry definitions to determine if guarding of curve is required.

V. URGENCY - Because of the added cost of guarding curves and the reliance on standardization of track construction there is a need to clearly define the use of guard rail criteria.

PROBLEM NO. 146

I. NAME OF PROBLEM - INVESTIGATE TIE PLATE CANT FOR TRANSIT

II. THE PROBLEM - Most transit systems use the standard cant of 1:40. This may not be the most efficient cant in relation to wheel and rail wear in transit applications.

III. OBJECTIVES - An evaluation program should be undertaken for rapid transit operations using the "worn wheel contour," standard AAR tapered wheel tread and the conic wheel design with the various canted plates, to determine if a different tie plate cant would be more advantageous.

IV. CURRENT ACTIVITIES - Recently the Union Pacific Railroad installed four test sections utilizing 1:40, 1:30, 1:20 and 1:14 canted tie plates. The 1:40 cant resulted in the wheel load on the gauge side of the rail head; the 1:20 cant resulted in the wheel load on the field side of the rail head; the 1:14 cant resulted in the wheel load on the field side of the rail head; the 1:30 cant resulted in the wheel load on approximately the center of the rail head.

V. URGENCY - There has been no determination of optimum rail cant for rapid transit operations.

PROBLEM NO. 147

I. NAME OF PROBLEM - COMPARISON OF BONDED JOINTS TO WELDED JOINTS FOR TRANSIT

II. THE PROBLEM - One of the most critical components of rail construction is the rail joint. The rail joint is designed to unite rail sections into one continuous rail. The rail joint also serves to hold the rail ends accurately, evenly and firmly in place to assure even rail surface and rail alignment.

III. OBJECTIVES - An evaluation program should be undertaken to compare the bonded joints as an alternate to the welded joint.

IV. CURRENT ACTIVITIES - Most transit properties use welded rail joints.

V. URGENCY - Since present transit properties are continually rehabilitating existing trackage and new properties are under construction or are being planned an evaluation of these two types of joints would be most advantageous.

PROBLEM NO. 148

I. NAME OF PROBLEM - EVALUATE NEW TRACK SYSTEMS FOR NOISE AND VIBRATION REDUCTION FOR TRANSIT

II. THE PROBLEM - It has become increasingly evident that transit noise and vibration are major problems in metropolitan areas.

III. OBJECTIVES - Noise and vibration attenuation has become an important consideration in all facets of rapid transit operations. Rail, rail joints, fasteners and track bed are contributing factors in transmitting noise and vibrations to adjacent property. There may be locations along the route of new subways that are suitable for more attenuation than welded rail with resilient fasteners can offer, but may not warrant the greater degree and more costly attenuation provided by the floating slab track. To satisfy that condition other systems would be necessary.

Such systems as STEDEF ballastless track and slab track should be tested and evaluated for the amount of attenuation such a system could offer. Other sound reducing track components should also be looked into at this time.

IV. CURRENT ACTIVITIES - Not applicable.

V. URGENCY - This is probably the most urgent transit need at the present time with the news media reporting major public concern with this problem.

PROBLEM NO. 149

I. NAME OF PROBLEM - ECONOMIC TRANSIT AXLE LOADS AND SPEEDS, CURVES AND TANGENTS

II. THE PROBLEM - While safe speeds for transit operations over curve and tangent have been established and axle loads have been limited by criteria for roadway structural design economic limits for such considerations have not been investigated and determined.

III. OBJECTIVES - Development of a model that will consider all costs associated with transit operation including but not limited to such major considerations as labor, roadway, electric traction systems and vehicle maintenance, vehicle amortization and energy. The model would evaluate such costs in terms of operating alternatives and produce economic analyses on which to base management decisions.

IV. CURRENT ACTIVITIES - The Association of American Railroads is currently developing a comprehensive train energy model which will evaluate operating alternatives in terms of energy and will generate data for related economic models also being developed by AAR.

V. URGENCY - The transit industry is continually faced with the need for making decisions on a broad spectrum of operating considerations. Demonstrations and field tests are expensive to set up, difficult to evaluate and results are frequently inconclusive. There is a real need for a model that will identify optimal operating procedures and reduce the field testing requirement to one of validation.

PROBLEM NO. 150

I. NAME OF PROBLEM - TRANSIT WHEEL/RAIL PERFORMANCE

II. THE PROBLEM - Wheel/rail performance is of major concern to railroad and transit operators. However, differences in loading characteristics between railroad and transit operations result in dissimilar wheel/rail performance. Safe wear and fatigue limits for wheel/rail and problems associated with wheel flats and rail corrugations need further study.

III. OBJECTIVES - Establish technically based safe wear and fatigue limits for wheels and rail as well as improved inspection and maintenance cycles. Establish tolerances for wheel flats and rail corrugations consistent with the adverse affect on track and equipment.

IV. CURRENT ACTIVITIES - The Association of American Railroads is engaged in several metallurgical studies relating to railroad wheel/rail problems including consideration of rail cleanliness, engine burn repair welds, thermite weld testing, rail crack propagation, rail lubrication, wheel failures, acoustic wheel inspection, wheel stress, hot wheels and brake shoe evaluations. Much of this work has application in the transit industry; however, the AAR work should be evaluated from a transit perspective to identify problem areas unique to transit applications for further study.

V. URGENCY - The transit industry spends millions of dollars to maintain wheels and rails each year. If new technology could provide the basis for more economical maintenance cycles and/or improved safety limits for wheels and rail significant reductions in maintenance costs could result.

A2M02 - Rail Electrification Systems - Myles B. Mitchell, Chairman

PROBLEM NO. 151

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 supporting rationale.

III. OBJECTIVES - The objective is to identify and document areas of railroad electrification cost differences including wayside substastations, 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.

A2M04 - Rail Freight Classification Terminal Design - James A. Wetzel, Chairman

PROBLEM NO. 152

I. NAME OF PROBLEM - ROLLING RESISTANCE OF FREIGHT CARS IN CLASSIFICATION YARDS

II. THE PROBLEM - Effective design and operation of hump yard speed control systems require detailed quantitative data concerning the distribution of rolling resistance of freight cars as a function of car type, temperature, wind speed and direction, track type and curvature and other parameters. Better information of this type is needed to achieve improved speed control with fewer stalls and excess speed couplings.

III. OBJECTIVE - The objective is to develop a detailed and comprehensive data base regarding freight car rollability. It is to be sufficient to assure that speed control systems can be designed and used with improved effectiveness in all parts of the United States and for a wide variety of hump yard designs, operating circumstances and levels of technical automation and sophistication.

PROBLEM NO. 153

I. NAME OF PROBLEM - COUPLING FAILURES FOR FREIGHT CARS IN CLASSIFICATION YARDS

II. THE PROBLEM - Freight cars being classified in yards sometimes fail to couple automatically when humped or shoved by switch engines. These problems are often associated with passed drawbars or closed knuckles. The consequences of failures to couple are substantial including car delays, increased yard operating costs and employees injuries. Reduction of these problems requires greater knowledge of the nature and importance of the underlying causes (coupler design, employee error, yard procedures, etc.) and identification of the practicality and effectiveness of potential remedial actions.

III. OBJECTIVES - The immediate objective is to determine the relative importance of the major causes of yard coupling failures. Beyond this it is necessary to identify and review potential alternative remedial actions and assess the overall attractiveness of each in various circumstances.

PROBLEM NO. 154

I. NAME OF PROBLEM - RETARDER NOISE IN RAILROAD CLASSIFICATION YARDS

II. THE PROBLEM - Passage of a freight car through a retarder in a hump yard is sometimes accompanied by a loud squeal which is disturbing to neighbors, injurious to workers and sometimes in violation of environmental and employee safety regulations. Although research during the last decade has provided increased understanding of this phenomenon and has identified methods of reducing its impacts retarder noise remains a serious problem. Railroads often find it necessary to build sound barriers which are expensive, inconvenient for normal operations and are not generally perceived as being totally satisfactory.

III. OBJECTIVES - The objective is to further increase understanding of retarder noise and identify means of eliminating it at the source so that the requirements of environmental protection and employee safety can be met without elaborate and expensive shielding structures.

PROBLEM NO. 155

I. NAME OF PROBLEM - STALLING OF FREIGHT CARS IN HUMP YARDS

II. THE PROBLEM - When freight cars being humped fail to roll as far as intended, failing to reach the next car on the track, substantial delays can arise while a switch engine is used to move the car to its proper position. Safety hazards can also exist for employees involved in correcting the situation. The cost associated with this problem can be considerable. Causes can include speed control system malfunction or inadequacy, car variability, yard design flaws, weather, etc.

III. OBJECTIVES - The major objective is to determine the relative importance of the primary causes of stalls and to review and assess the alternative remedial actions: improved equipment, better speed control algorithms, enhanced understanding of car rollability, better track conditions, etc. In addition,

estimation of the overall costs associated with stalls is needed to permit evaluation of the desirability of making improvements in specific circumstances.

PROBLEM NO. 156

I. NAME OF PROBLEM - CHARACTERIZATION OF YARD SAFETY

II. THE PROBLEM - A significant number of personal injury accidents and fatalities occur in classification yards. Programs to improve yard safety are hampered by a lack of detailed statistical data and quantitative understanding of the circumstances surrounding yard accidents: the employees most likely to be injured; the equipment and rolling stock most often involved; and effects of age, years of experience, time of day, hours on duty, weather, lighting, communications, ambiguity of rules or instructions, etc.

III. OBJECTIVES - The objective of this research is to determine those factors most relevant to accident causation and to assess appropriate practical remedial actions. Equipment, procedures and human factors should all be addressed.

PROBLEM NO. 157

I. NAME OF PROBLEM - COSTS OF OVERSPEED COUPLING

II. THE PROBLEM - Overspeed coupling in both hump and flat classification yards is a significant cause of damage to equipment and lading. However, the actual magnitude of such damage and its relationship to coupling speed is not known with any precision. Consequently, this factor cannot play a major role in determining the cost-effectiveness of various levels of speed control system sophistication and automation. Instead, such decisions may be made more on the basis of experience, judgement and intuition and may fail to consider adequately current circumstances and new technology. Since damage is often not discovered until well after the impact it is quite possible that costs of overspeed coupling are not given appropriate importance in specification of speed control systems.

III. OBJECTIVES - The objective is to determine the costs of damage to lading and rolling stock occurring as a result of overspeed coupling. Specific objectives include characterization of costs as a function of speed, car type and lading.

PROBLEM NO. 158

I. NAME OF PROBLEM - BLOCKING STRATEGIES

II. THE PROBLEM - Proper blocking of freight cars--forming them into groups based on final or intermediate destination--is a very important aspect of railroad operations since it affects the number of yardings, costs and transit time for each shipment as well as overall car utilization. Blocking strategies interact strongly with yard design since they determine the overall yard switching capacity, and because implementation of particular strategies imposes specific requirements on subyard capacities, number of classification tracks, suitability to two-stage humping, etc.

III. OBJECTIVES - The objective is to clarify and charcertize alternative possible blocking strategies under various circumstances with emphasis on the interactions between blocking strategy and yard design and operating procedures. Specific attention should be placed on implied yard overall performance requirements and on critical design factors.

PROBLEM NO. 159

I. NAME OF PROBLEM - FLAT YARD DESIGN PRINCIPLES

II. THE PROBLEM - Flat switching yards, although generally smaller than hump yards, are much more numerous and are an important element of the railroad network. When the higher capacity of a hump yard is not required flat yards are chosen because of their lower capital costs. Relatively little research has been directed toward design and technology relevant to this type of yard. However, their labor intensiveness, operating costs and limited performance capability are a significant constraint on overall rail transportation service and efficiency.

III. OBJECTIVES - The objective is to determine the potential for improving performance of flat yards, reducing their operating costs and increasing safety through better design, operating procedures and technology. Specific concepts and principles by which improvements can be achieved should be identified and evaluated. Special attention should be given to innovative concepts and approaches.

PROBLEM NO. 160

I. NAME OF PROBLEM - HUMP YARD DESIGN PRINCIPLES

II. THE PROBLEM - The process of designing gravity operated (hump) classification yards includes making many critical interacting decisions involving geometrical layout, size of subyards and degree and type of speed control system sophistication. Although the industry as a whole has extensive experience in this area the knowledge base available to a specific railroad is often limited. In addition, changes in control technology, operating strategy, traffic demands, environmental constraints and even rolling stock characteristics may limit the degree to which past experience alone can be relied on.

III. OBJECTIVES - The objective is to develop and disseminate a clear and comprehensive array of general principles for the design of hump yards. All topics which significantly affect the final cost and performance of yards should be included. The principles should be applicable to new construction and to major rehabilitations and should be in a form clearly understandable to a wide variety of users.

PROBLEM NO. 161

I. NAME OF PROBLEM - RAILROAD NETWORK MODELING FOR YARD SITE SELECTION, SIZING AND DESIGN

II. THE PROBLEM - Decisions regarding the location of new classification yards and terminals, selection of existing facilities for major rehabilitation and yard consolidation are based in large part upon the effects expected on network traffic flows. Estimation of these effects is difficult because of the need to deal with complex railroad networks, alternative blocking strategies and schedules and a variety of potential traffic demand scenarios. Efficient and thorough consideration of these and other factors can be accomplished only by use of computer models structured specifically for this application so that adequate detail is included without requiring excessive amounts of input data. Benefits of creating a satisfactory model include (1) avoidance of the excess capital costs of overbuilding yards, (2) minimization of operating problems when yards are designed for insifficient capacity, (3) a better match between system capacity and demand and (4) less chance of premature obsolescence due to traffic changes.

III. OBJECTIVES - The objective is to develop a computer based railroad network simulation model which focuses on parameters which relate yard and network characteristics. Specific goals are that the model not be excessively data intensive or cumbersome to use, that it be sufficiently detailed and accurate to provide results which are useful and credible and that it facilitate examination of a wide variety of traffic and operating scenarios.