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Making the Most of the Second Half of SHRP:

Proceedings of the SHRP Midcourse Assessment Meeting

October 1990

Strategic Highway Research Program
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Foreword

More than four hundred invited representatives of state highway agencies, industry, and research organizations gathered in Denver August 1-3, 1990 to take a close look at SHRP's progress to date, and to suggest adjustments in order to maximize the potential for delivery of immediately useful products when SHRP winds down in 1992.

This document summarizes the major conclusions and recommendations emerging from the Midcourse Assessment meeting, but the document cannot duplicate the spirit and scope of this intensive workshop. The three-day agenda included as many as six concurrent sessions, as well as evening meetings. In addition, a large volume of written material was mailed to participants in advance of the meeting, and many speakers prepared formal papers summarizing their remarks.

The meeting drew the attendance of top leaders in the highway industry. The comments of the speakers at the opening plenary session on the morning of August 1 are summarized in Chapter I. Results of the four concurrent technical area workshops that took place on the afternoon of August 1, all day August 2, and on the morning of August 3 are presented in Chapters II, III, IV, and V. The key recommendations emerging from all of the meetings in each of the program areas are listed in the beginning of these chapters. Brief summaries of the workshop discussions follow. The discussions are not necessarily reported chronologically; instead, an attempt has been made to compile the key discussion points relating to a particular research objective that emerged in the course of the three-day workshop. Advisory Committee recommendations also are reported.

The comments of speakers at the closing plenary session the afternoon of August 3 are summarized in Chapter VI.

Included in the Appendix are the meeting agenda, lists of Advance Papers and Presentation Papers, rosters of Executive Committee, Advisory Committees, and SHRP State Coordinators, and a list of invited participants.

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Opening Plenary Session

SHRP Chairman John Tabb welcomed the participants to Colorado and introduced the speakers.

The first speaker, Transportation Research Board Executive Director and SHRP Executive Committee member Tom Deen, recalled that SHRP had been created "through bold and aggressive action by leadership that was willing to take the risks associated with radical innovation."

Deen recalled that "$150 million in new research was a gut-grabbing, breathtaking goal in the early 1980s...but equally astonishing was the short list of priorities the research was to address." While SHRP is yet to deliver the bulk of the tangible research products, Deen noted that there were countless ways that the effort could have gone off track by now--but hasn't.

"From the decline and the gloom of 1982, today research is at the top of everyone's agenda," Deen said. "We sense this change within TRB. Greater personal and corporate cooperation is evident. Anything as broad-based as SHRP has many roots. SHRP has brought research out of the basement and into the living room."

National Research Council Executive Officer Phil Smith said he was "hard-pressed to think of any National Research Council report that had more impact than the STRS study." (The SHRP program was first recommended by the Strategic Transportation Research Study: Highways, a special report published by the Transportation Research Board.)

"Targeting creates tensions," Smith said. "Targeted research creates higher expectations. Five years to produce results is a remarkably short time in any field of applied research. But one of the hazards of targeted research is that the arrows are very SHRP if you miss."

Smith called upon the meeting participants to assist SHRP by participating vigorously in discussions to address questions such as, "Should we change direction?" and "Where can we do some fine-tuning?

"Research has been so long neglected that precious stones lie everywhere," Smith said. "We must be sure we reach for the brightest among them."

Kermit Justice, President of the American Association of State Highway and Transportation Officials (AASHTO) and Secretary of the Delaware Department of Transportation, said involvement of the AASHTO states will intensify as SHRP moves into its second half.

"Research results do not put themselves to use automatically," Justice said. "Don't let what you decide here stay here. Take it home. Try it. Use it. Get involved here. Stay involved when you get back."

SHRP Executive Director Damian Kulash said he was "dazzled by the amount of participation" in the workshop: one hundred forty-four representatives from forty-five states and most of the Canadian provincial governments; fifty-nine industry representatives; sixty-five SHRP contractors; about fifty SHRP Advisory Committee members; fourteen Executive Committee members; and representatives of twenty-nine overseas highway agencies. He noted that it was the first meeting where SHRP State Coordinators, Executive Committee members, Advisory Committee members, Expert Task Group members, and contractors would have the opportunity to interact simultaneously. "There hasn't been another like it, nor is another planned," Kulash said.

"This workshop was arranged because we are at a key juncture," Kulash said. "We have learned a lot in the past five years about what can be done. We need to apply this new understanding to make the best use of our window of opportunity during the second half of the program."

Kulash noted that 1,216 days had passed since the program was initiated in 1987; 973 days are left: measured in time, the program is 56 percent complete. Fifty-three contracts have been executed and fourteen are pending, leaving only two major contracts to be awarded: measured in contracting activity, the program is 96 percent complete. Fifty-five million dollars has been spent and ninety-five million dollars remain: only 37 percent of the budget has been spent. In summary, he said, the research team is assembled; less than half the time is left, but more than half the money remains.

The remaining two and one-half years of the program will be a time of increasingly intense activity, Kulash said, when "we need for you to sustain, and even increase, the dedication and commitment that have brought us this far."

Specifically, Kulash asked the meeting participants to help SHRP look with fresh eyes at each part of the program and to decide where best to concentrate efforts in order to get the most out of the research.

"We need your guidance, intuition, and caution," Kulash said. "Don't wait until we're done to speak up. Now is when you can make a difference."

Kulash said SHRP would be pilot testing several of its first products during the coming year: a blister test for asphalt adhesion; concrete curing tables; a fiber-optic air-void meter; a pavement distress identification manual; and several devices to protect maintenance workers in short-term work zones.

Federal Highway Administration Executive Director Dean Carlson said, "The FHWA is proud of the fact that they were one of the several organizations that were heavily involved from the earliest stages in the conceptualization and technical development of the program." Carlson said that FHWA is addressing the major challenge of continuing the effort begun under SHRP by planning for technology transfer, and by planning for continuation of research in LTPP and other areas when SHRP winds down in 1992.

Carlson announced that a new position for a Special Assistant for SHRP Implementation has been created within the FHWA's new Office of Technology Applications. Dick McComb, who is currently a Division Chief in the Office of Implementation, and who was FHWA's first loaned staff representative at SHRP, will serve in this new position.

Carlson said FHWA's proposed Research and Technology Program will require increased involvement of the ultimate user groups from the time of program formulation to the final delivery of the successfully developed products. Representatives of user groups will provide input through a series of working groups and advisory councils. This will help provide for continuity in the post-SHRP period, he said, because often the representatives will have served SHRP in a similar capacity and therefore will be familiar with SHRP's accomplishments and their potential.

SHRP Chairman John Tabb, Director and Chief Administrative Officer of the Mississippi State Highway Department, told participants, "We are counting on you to start the implementation effort here and now by going back home to champion the

emerging products of SHRP within your own agencies. It's a big job to implement new technology," Tabb said. "It takes money, effort, time, and patience."

Tabb likened the effort required for SHRP implementation to that required for the transition to computers. In the computer transition, Tabb said, "A big front-end investment is required to buy the hardware. It takes time to install and learn software. There's plenty of frustration involved at first, but eventually you work out the budget and get the product to work for you. You learn to tailor the software to in-house requirements. Some people resist the change to computers, and some never make good use of them--they cling to the old ways. But for those who do make the change, once they get up to speed, they wonder how they ever got along without them."

Tabb said, "SHRP implementation, like computerizing, will require highway agencies to budget for the new capital expenditures for equipment. We'll have to expect a few problems at first as we work out the bugs. Some people will refuse to adopt the new ways of doing things. Some will resist change, but if we give them enough support, they will come around. The effort will be well worth it. We'll be able to build and maintain better quality highways, and to do so more cost-effectively."

2

Results of the Asphalt Workshops

Key Recommendations: Asphalt

- The development of the asphalt binder specification should continue to be based upon a balance of relationships between pavement performance and both chemical properties and physical properties.
- The emphasis in the asphalt research must continue to be on identification of the underlying chemical basis for permanent deformation, fatigue cracking, low temperature cracking, moisture sensitivity, and aging.
- Tests of physical properties referenced in the binder specification must have a sound correlation with the underlying chemical properties of the asphalt.
- The performance-based test methods and compaction procedure for support of the asphalt-aggregate mix specification and the asphalt-aggregate mixture analysis system (AAMAS) must be circulated for review soon.
- While an aggregate specification is beyond the scope of the program, exploration of the effects of the surface chemistry and porosity of the aggregate on adhesion and moisture sensitivity should receive continued emphasis.
- The adoption into practice of the performance-based binder specification and the mix specification will have significant economic impact on the state highway agencies, hot-mix producers and contractors, asphalt refiners, and other

components of the industry, in terms of capital equipment purchases, new personnel and training requirements, changes in operations, changes in crude oil sources, etc. Serious efforts to quantify these impacts to aid implementation of the specifications must begin now.

- The use of draft specifications issued periodically during the research program has proven a good tool as follows:

    1. To actively involve all facets of the industry in the development process; and

    2. To prepare the effected parties for impact of the specifications on their operations.

- The use of interactive user, producer, and industry task groups in the short-term implementation process for the two specifications is judged beneficial.

Proceedings of the Asphalt Workshops

The asphalt research activities are focused on delivery of two primary products: the performance-based asphalt binder specification; and the performance-based asphalt-aggregate mixture specification, including an asphalt-aggregate mixture analysis system (AAMAS).

Members of the SHRP staff and the management/technical support contractors reviewed the program goals and progress. They explained the current draft performance-based specifications for asphalt binders and for asphalt-aggregate mixes, and the strategy for further development of those key research products. The research contractors discussed key findings supporting the current development of the performance-based specifications.

Three workshops were then provided concerning the draft binder specification, mix specification, and validation techniques. The workshops were designed specifically to provide as much individual participation as possible.

Asphalt Advisory Committee Chairman Thomas Moreland specifically requested each participant to provide input related to identification of gaps in the specification development, selection of top priority research areas, assessment of the potential economic and operational impacts of the specifications, and identification of routes and barriers to successful implementation of the specifications.

Binder Specification Workshop

Participants in the binder specification workshop identified the following key findings for SHRP's consideration:

Hard Products Appraisal

- There should be a balance between chemical and physical tests. The emphasis to date has been primarily on the development of physical tests as surrogates for chemical composition tests.

- There is an immediate need for refinement of the blister test to ascertain aggregate dependency and its applicability to the moisture susceptibility of binders and mixes.

- SHRP and the A-001 contractor should continue to refine the specifications based on emerging research data.

- SHRP should continue to concentrate on developing specifications to minimize the six performance distress factors.

Gaps in Product Development

- Consideration should be given to inclusion of traffic levels in the binder specification. They are already included in the mixture specification.

Top Priority Research Areas

- Chemical composition (strong acid index) as presented in the draft specification must be related to the performance factors (permanent deformation, fatigue cracking, thermal cracking, aging, water sensitivity and adhesion). Further research is needed to determine which of these factors are affected.

- Compatibility tests should be developed to determine the internal stability of unmodified and modified asphalts.

Potential Economic Impacts

- A climate-based binder grading system will affect regional asphalt markets.

- State highway agencies need to plan for personnel, training, and equipment costs. At least two years of lead time is needed to provide for these costs in capital equipment budgets.

- The impacts of testing time and sample size on user agencies should be assessed carefully.

Routes and Barriers to Implementation

- The user-producer group concept was viewed as a feasible approach for successful implementation in the pre-1993 period.

- "User agencies" should include state highway agencies, major cities, and counties.

- "Producers" should include refiners, producers of aggregate and modifiers, equipment manufacturers, and hot mix producers.

Asphalt-Aggregate Mix Specification Workshop

Participants at this workshop provided the following input and recommendations:

Hard Products Appraisal

- The asphalt-aggregate mix analysis system (AAMAS) and specification methodology should be kept as simple and practical as possible.

- AAMAS will require a link between lab mix design and plant production.

Gaps in Product Development

- Field tests for quality assurance and quality control need to be identified or developed.

- Aggregate properties should be given increased emphasis in the specification.

Top Priority Research Areas

- The development of the mixture specification needs to be accelerated to assure its compatibility with the binder specification. In accordance with the contracting

plan, the development of the binder specification started before development of the mixture specification.

- The effect of large aggregates should be investigated thoroughly in relation to the development of the AAMAS and the mixture specification, particularly in relation to the accelerated laboratory tests being conducted under contract A-003A.

- The role of compaction in relation to laboratory mix design and field compaction should be resolved as quickly as possible.

- The timing of the modifier evaluation should be coordinated with the mix development.

- Provisions to assure the workability of the mix should be included in the specification.

- Development of tests for measurement of the compatibility of binder and aggregate should be accelerated.

Potential Economic Impact

- The need for capital investment in new equipment for the materials laboratories is an issue requiring the attention of state administrative officials.

- User-Producer Group meetings appear to be an effective means for encouraging early implementation, but states will have to provide funding so that user-agency personnel can attend the meetings and participate actively in specification development and review.

Routes and Barriers to Implementation

- State highway agencies have mix operation procedures related to both centralized and decentralized lab mix designs. SHRP will need to consider the operational impact of new specifications on both centralized and decentralized design practices.

- A comprehensive training program must be launched as early as possible.

- Continued active support from AASHTO is vital.

Validation Techniques Workshop

The following are the key findings of the workshop participants:

Soundness of Methods

- The approaches appear to be practical and achievable.
- Development of the mix tests needed for validation of the binder tests appears to be somewhat behind schedule.

Sources of Field Data

- The participants expressed concern about the A-005 contractor's sole dependence on the use of General Pavement Studies (GPS) for field data.
- The participants recommended that other state projects be considered as a source of field data. A checklist should be developed by the A-005 contractor for use in screening such state projects for relevant data, including items like materials, construction, environment, pavement distress history, and pavement structure.
- The Asphalt Institute's field studies, and FHWA and DOD experimental projects also should be considered as possible sources of field data.

Success in the Time Frame Available

- Contract A-005 needs to be accelerated. Operation time is short, and the A-005 project is very critical to the development of the specification.
- Mix validation appears to be progressing more slowly than the binder validation. Mix validation should be accelerated to assure success in the time available.

Alternate Approaches

- Engineering judgment must play a role in the validation process. It is not prudent to rely exclusively on the improvement of mathematical models.
- State test tracks and accelerated loading facilities should be employed as much as possible.

3

Results of the Highway Operations Workshops

Key Recommendations: Highway Operations

- Accelerate the development of a remote-controlled shadow vehicle for protection of maintenance workers from rear-end collisions.
- Encourage manufacturers to commercialize new maintenance equipment based on concepts developed through SHRP.
- Procedures for evaluating chemicals for snow and ice control should address possible damage to vehicle paint, obstruction of vision through the windshield, and physical harm to highway workers.
- The technology of controlling blowing snow through the use of snow fences and/or modified side slopes has progressed to the point that preparation of manuals and guidelines should be accelerated.
- SHRP should build an additional experimental snowplow as part of H-206, so more states can be part of the evaluation process.
- Findings and procedures developed by SHRP should be made available to, but never forced upon, the states.
- SHRP research on unconventional methods for disbonding ice and compacted snow from pavements appears unrealistically optimistic, and should be

terminated, with the exception of research related to cutting edges for snowplow blades.

- o SHRP should capitalize on new weather forecasting/information systems by studying use of pretreatment approaches for controlling snow and ice.

- o SHRP should continue to devote top priority to implementation. We must get the products into use.

Proceedings of the Highway Operations Workshops

The Highway Operations workshops included the following sessions: Maintenance Effectiveness Workshops (In two parts); Winter Maintenance (in two parts); Snow and Ice Disbonding and Removal; and Weather Information and Communications.

Each session included presentations by SHRP staff and contractors regarding the status of the research projects and the expected products. Panel discussions and open discussions followed. The results of each session are highlighted below, followed by a summary of the overall recommendations emerging from the Highway Operations workshops.

Maintenance Effectiveness Workshops

The maintenance cost-effectiveness program involves three separate areas of research: equipment, preventive maintenance procedures, and worker safety. There are a number of objectives in each area.

In the equipment area, goals are to develop new devices for evaluation of the need for pavement maintenance, and to develop new automated equipment for pavement maintenance and/or repair. In the materials area, SHRP is evaluating the relative effectiveness and cost of a number of different preventive maintenance treatments under a variety of climate and traffic conditions.

In the worker safety area, SHRP is developing innovative traffic control and safety devices to protect workers in short-term maintenance work zones.

Tasks geared specifically toward implementation of the products developed are included in every maintenance contract. A communications and training firm is under contract in

the Highway Operations program to assist with preparation of technology transfer materials, including videotapes, training courses, manuals, and so on.

Preventive Maintenance Procedures

The overall objective of SHRP's maintenance materials evaluation effort is to develop justification for a cost-effective preventive maintenance program by supplying good data on the effectiveness of various treatments in a range of conditions. Cost-effective preventive maintenance can reduce pavement deterioration and prolong pavement life.

The performance of commonly used preventive maintenance materials and processes is being monitored under a variety of traffic and climate conditions at test sites located on in-service highways. The treatments for flexible pavements that are under evaluation include chip seals, slurry seals, crack sealing, and thin overlays. For rigid pavements, the treatments include joint and crack sealing, and undersealing.

A number of factors in addition to the type of treatment (crack or joint filling, various types of overlays, and undersealing) are under evaluation in the field tests. Among the most important of these is the timing of treatment application, which is thought to have a significant effect on extension of pavement life.

Discussion

The importance of protecting the test sites from routine maintenance operations was stressed. Participants expressed concern about possible safety hazards emerging from leaving control sections unmaintained. It was agreed that if unsafe conditions arise, the regional engineering contractor should be contacted to take final readings before the test section is taken out of the experiment and repaired.

The importance of good construction quality control as SPS 3 and 4 test sites are installed and studied was stressed. The results have the potential to produce data that would be extremely useful in developing improved preventive maintenance procedures and techniques.

Worker Safety

Several devices for protection of maintenance workers in short-term work zones are now in the development and testing stages.

To reduce the number and severity of rear-end collisions with maintenance vehicles, devices under evaluation include: a snowplow and salt spreader truck-mounted attenuator; lighting devices for improved visibility of maintenance vehicles; and remote-controlled driverless shadow vehicles for protecting operators and controlling traffic through work zones.

For pedestrian worker accidents, the devices under study include: mobile barriers and crash cushions; electronic worker warning devices; flagger gates to permit the flagger to stand away from the traffic lane; and portable rumble mats to alert the drivers of errant vehicles.

The prototype devices are undergoing a variety of tests, including human factors laboratory tests, operational tests, crash tests, crashworthiness tests, traffic control tests, and open highway tests. The devices that satisfy the tests will be developed and turned over to cooperating highway agencies for open highway testing, with appropriate analysis and perhaps further modifications. State testing of safety and traffic control devices will start in September 1990.

Discussion

Development of the unmanned, mobile shadow vehicle should be accelerated. The Minnesota Department of Transportation is discussing development of such a vehicle. It was reported that the U.S. Army has developed remote control technology for tanks and other armored vehicles. Finding ways to use this work was encouraged.

The study of the unmanned shadow vehicle under contract H-109 should include evaluation of the feasibility of a radio-remote-controlled vehicle. This would replace the original proposal for a fully automatic, self-guided vehicle.

The plastic water- or sand-filled median barrier needs proper connecting devices for assembly of the units.

The flagger gate should be colored with red and white stripes meeting the requirements of the Manual on Uniform Traffic Control Devices (MUTCD).

In the human factors evaluation of new traffic control devices, efforts should be made to differentiate between short-term, novelty effects, and lasting effects that come with longer exposure. Such evaluations are difficult in a short-term project. Long-term analysis will be required to meet MUTCD requirements.

Equipment cost must be evaluated thoroughly in order to encourage manufacture of the new devices as soon as possible.

The importance of human factors evaluation was stressed, since the purpose of signs and markings is to influence driver behavior.

Traffic control now costs $0.42 of each construction dollar in some metropolitan areas. We must learn to install and remove traffic control devices more efficiently. Other challenges are to find ways to do more at night, and to complete the work with fewer workers exposed to traffic.

Equipment for Pavement Evaluation

SHRP is developing equipment for evaluation of the need for maintenance on both a highway network basis (using ground-penetrating radar); and on a project-specific basis (using wave propagation analysis techniques). These devices will be used to determine the type of maintenance treatment needed, and, more importantly, the timing of application (through use of deterioration models developed with frequently repeated measurements). The goal of the project is to produce equipment that can be used by maintenance personnel with only about one week of training.

Discussion

Maintaining equipment calibration may be a key challenge.

Winter Maintenance Workshops

Ice-Pavement Bonding

Results of basic studies of the ice-pavement bond have confirmed that the bond is very strong and that the likelihood of discovering a simple mechanical technique for ice removal is remote.

A number of potential routes for improvement of ice removal have been identified by SHRP research. One is the incorporation of a chemical freezing-point depressant in the upper portion of the pavement. However, due to known environmental problems with available chemical depressant products, and inability to identify alternatives, this approach was abandoned.

Evaluation of Deicing Materials

Development of standard testing procedures for the selection or purchase of deicing chemicals is nearly complete. The product of this project will be a Test Methods Handbook, with a structured set of test procedures suitable for characterizing chemical deicers and evaluating the impacts of chemical deicer usage. A second objective is to improve sodium chloride as a deicing chemical. Further work on this is awaiting a survey of salt producers to determine how much research already has been conducted.

Discussion

Wetting rock salt with calcium chloride can cause quicker melting to occur at temperatures substantially below the freezing point, at a reduced overall cost. As SHRP tests approach completion, coordination with ASTM is necessary to ensure that the procedures and tolerances developed will be accepted.

The test procedures for evaluation of deicing products that SHRP plans to produce will be useful, because such products are marketed to state highway agencies continually.

Environmental concerns are important, but the biggest complaints usually come from the public for not using enough salt.

It is important to pilot test new materials tests at field laboratories before they are considered for adoption as standard tests.

Test procedures for deicing chemicals should consider the speed of ice melt, so run-off does not occur too fast. Consideration must be given to the potential harmful effects of these chemicals on maintenance workers. Damage to vehicle paint and contamination of vehicle windshields also should be evaluated.

Snow Fences

Variables of wind velocity, topography, and fence geometry were studied and modeled for use in the design of facilities to control snow drifting. Guidelines have been developed for the design, placement, orientation, height, and capacity of snow fences and other control measures. Field tests in the western states were successful, and New York is now testing the procedures in the Buffalo area.

Discussion

A key recommendation was to accelerate preparation of snow fence design manuals and placement guidelines so they can be disseminated to the state highway agencies as soon as possible. These products already were under development. Group consensus was to speed up development of the manuals, rather than continue research.

Extension of the blowing snow control theories holds much potential for control of blowing sand and dust.

Sensors for Monitoring Road Conditions

The United States and Canada spend close to $1.5 billion annually for snow and ice control. SHRP estimates that savings of 5-10 percent, or $75-150 million, could be realized through use of improved pavement condition monitoring systems, coupled with better weather information and communications technology. The improved information and communication would make it possible to deploy and/or terminate snow and ice control operations at the optimum time to minimize operations costs and the use of chemicals.

Discussion

Coordination of pavement monitoring systems is an area that needs further consideration.

Storm management systems have great practical promise. The German Autobahn has been instrumented for maintenance management purposes. The new control system in Denver, especially on an I-70 viaduct, has helped reduce accidents and made it possible to dispatch snow and ice control crews more efficiently.

In areas where there is heavy snowfall, fatigue-related accidents are a serious concern, and better road condition information can help manage employee shifts for optimum effectiveness and safety.

Improved Snowplows

SHRP is developing improved snowplow configurations. The work is concentrated on: reducing the amount of energy spent to compress the snow immediately ahead of the cutting edge; improving the flow over the moldboard; and improving the flow in the cast region. Modeling and testing are confirming the theories that have been developed. A full-scale experimental model is under construction for testing this winter. Prototype

components include a modified tripping edge, moldboard shape adjusting systems, and a variety of cutting edges.

Discussion

It was proposed that a second experimental snowplow be made available so more states can test it. (Existing plans are for field testing only in Wyoming.) Fabrication of an additional experimental plow also will provide a backup in case of mechanical problems or accidental damage.

Participants suggested that the final product of the snowplow investigations might be a number of different snowplow models for various situations, instead of a single adjustable design. The existing plan was to deliver two prototypes, one of which would be adjustable by hydraulic controls. The other would be a fixed design to accomplish a specific task. The experimental model is adjusted by turnbuckles, while the prototype will be adjustable by hydraulic rams. The experimental model--or first generation plow--is what the auto industry would call a "mule," and it will undergo many trial-and-error operations during the study stage.

A representative of an equipment manufacturer presented information he had gathered regarding state concerns about new snowplow designs. These include cost, availability of parts, complexity of maintenance, ease of mounting on existing trucks, cast distance, and avoidance of complex competitive bidding procedures for purchase.

The need for any new equipment must first be sold to top management. Liability and warranty issues also must be addressed.

There was a discussion of SHRP's policy regarding patents, which permits patent rights to be retained by the contractor. Patents are encouraged in order to promote commercial product development. The federal government retains "march in" rights that may be exercised if the private license-holder does not make a good-faith effort to manufacture and distribute the product at a reasonable price.

New Techniques for Ice Removal

Three separate approaches for disbonding of ice and packed snow have been evaluated: (1) modifications of pavements to facilitate disbonding. e.g. chunk rubber and rubber-modified asphalt; (2) noncontact techniques, such as compressed air with an abrasive, high-pressure water jets (with and without abrasives), and microwave technology; and (3) contact techniques, including cutting edge designs and spike-plungers for application of deicing fluid to the ice-pavement interface.

Discussion

It does not seem likely that any of the approaches to Ice-Pavement Disbonding/Surface Modification and Disbonding explored under contract H-204 can be developed into equipment ready for application within the time scope of the SHRP program. Rather than continuing to pursue this project, the Highway Operations Advisory Committee felt that a better use of remaining funds from H-204 would be to evaluate pretreatment approaches for application of chemicals in advance of storms. Coupled with the improved weather forecasting and detection systems that are also being investigated by SHRP, pretreatment could greatly enhance the effectiveness of chemical snow-and-ice-control. The research related to the cutting edge of the snowplow blade, which is ongoing at the University of Iowa as a subcontract to H-204, would continue.

Weather Information and Communications

SHRP is developing recommended specifications for improved weather information and communications systems so that the latest advancements in reporting and forecasting can be made available to highway departments. Such systems will manage weather data from pavement condition sensors and from meteorological forecasts, as well as information from the highway agencies. Intelligent Vehicle Highway Systems (IVHS) will require an even more sophisticated and integrated information and communication system. SHRP is not developing new equipment, but rather is developing standard equipment specifications to maximize the benefits of integrated information systems.

Smart Weather Prediction

SHRP also is developing a local-area integrated weather forecasting and information management system that uses a desktop computer to prepare a 24-hour forecast, ready one hour after data reception. The system forecasts microclimate conditions. Weather information is integrated with terrain and road network information, taking into account such factors as the effects of altitude on temperature, wind, and precipitation. The system will be field tested in Colorado.

Discussion

The overall consensus was that improved weather information and communications have the potential for terrific cost/benefit payoff.

The New Jersey roadway monitoring system currently consists of four stations. Plans call for expansion to eighteen stations. Budget problems delayed the new installations.

Other state agencies, such as the State Police and New Jersey Transit, assist by providing needed communications networks.

A similar system of four stations is now operational in the Seattle, Washington area. Telephone lines are used in Washington for communications links. The big challenge is to obtain acceptance and use of the new information systems by the existing workforce.

New technologies to be initiated during the 1990s by the National Weather Service include new radar measurement of upper air-wind velocity profiles to replace balloon observations; aircraft to transmit weather observations every seven minutes of flight; and replacement of human observations by automatic instruments.

Training and Implementation for Maintenance Workers

"Rough cuts" of two videos describing the SHRP Highway Operations program were shown. The ten-minute videos address two different audiences: Chief Administrative Officers of state highway agencies; and Maintenance Managers (district level to supervisory staff).

Discussion

Information about new developments for control of blowing snow should be incorporated into the videos.

The video scripts should be revised to recognize the contributions of Canada and other cooperating nations.

In response to questions about distribution of the videos, several suggested that the video be made available to individual field crews. It was suggested that SHRP provide each state with a master copy so the states can produce the number they need using their own reproduction facilities.

Public service TV stations may be interested in airing the videos.

The videos might be shown to legislators in Washington, D.C. and in each state.

The H-110 contractor should prepare an index listing products to be delivered from the Highway Operations research contracts.
SHRP should ensure that the FHWA's Technology Transfer Centers are kept informed as implementation products emerge.

Summary Recommendations

- A change of attitude among maintenance organizations regarding research is evident. Strong support for SHRP has developed. Ways to maintain this enthusiasm when SHRP terminates should be explored.

- The importance of implementation was stressed throughout. Without proper attention to this now and later, opportunities for payoff may be missed.

4

Results of the Concrete and Structures Workshops

Key Recommendations: Concrete and Structures

- There is a need to set up close liaison with the American Society for Testing and Materials (ASTM) and the American Concrete Institute (ACI) if the new tests and standards developed by SHRP's Concrete and Structures program are to be adopted rapidly. The highway industry represents only 16 percent of concrete use in the United States. The building industry and other users of concrete must be convinced of the utility of SHRP results.

- Research on electrochemical chloride removal has successfully shown that the process can be carried out without damage to the reinforcing steel or the concrete. A schematic of a chloride removal system was shown by the contractor (C-102A), and six states volunteered to find sites for trials.

- The wrap-up contract for the Structures program (C-104), which provides for development of a methodology and a manual for corrosion-damaged structures, will require strong interaction with the other Structures contracts in order to develop information on life cycle costs for repair systems, and on the effects of repair on the life cycle costs of bridge components. It was emphasized that the production of a manual from C-104 was vital, but that this contractor had been selected for his ability to also produce a computerized version of the manual.

- Work under existing contract C-102B should be replaced by other approaches to production of a user manual for cathodic protection systems.

- Some states expressed an interest in trying out test methods developed by the Concrete and Structures contractors before they are finalized, so that they can adapt them to their own applications and can give feedback to the contractor on their findings and their needs.

- Packing diagrams for optimum concrete mix designs should incorporate the effects of air entrainment (C-201).

- Curing tables should be used to stress the importance of temperature control for proper curing of concrete. Current U.S. practice is mainly concerned with moisture conditions during curing (C-201).

- The Alkali-Silica Reactivity Handbook should be widely available, and training sessions for highway agency personnel should be arranged (C-202 and C-204).

- Aggravation of alkali-silica reactivity by chlorides from deicing salts is a serious concern, and requires thorough study.

- Freeze-thaw durability tests should include the effect of deicing agents (C-203).

- Additional high early strength cement products and/or pozzolans should be considered for evaluation (C-205).

- The assistance and cooperation of the states in providing sites and constructing test sections is critically important to the validation of the products of SHRP's Concrete program.

Proceedings of the Concrete and Structures Workshops

The Concrete and Structures workshops included the following sessions: Nondestructive Testing; Concrete Products from SHRP-IDEAs; Concrete Properties; Concrete Properties and Performance; Electrochemical Protection and Rehabilitation Techniques; and Physical and Chemical Protection and Rehabilitation Techniques.

Each session included presentations by contractors, and, in some cases, by SHRP staff, on the status of the research projects and the expected products. Panel discussions and open discussions followed. The results of each session are highlighted below, followed by a summary of the overall recommendations emerging from the Concrete and Structures workshops.

Nondestructive Testing Workshop

Physical Assessment of Concrete Bridge Components

A range of nondestructive testing equipment for physical assessment of concrete bridge components is being evaluated. Among these are five different devices for corrosion rate measurement. The expected cost for corrosion rate measurement equipment is in the $10,000 to $20,000 range.

Work on remote detection of delaminations on substructures has been discontinued because of the expense and complexity of applying heat to a substructure. Like many other researchers, the SHRP team did not have success with the use of infrared thermography technology for corrosion assessment of asphalt-covered bridge decks. They now are concentrating on radar, and reporting better than 80 percent accuracy with that technology.

The team has not yet been successful in developing a technique for detection of defects in membranes on asphalt-covered bridge decks, but is successfully developing methods for testing the effectiveness of sealers and concrete permeability. The diffusion and permeability tests will be offered for ASTM/AASHTO approval.

Nondestructive Testing for Quality Assessment/Quality Control of Concrete

Nondestructive tests for concrete are being evaluated in this project. There is some overlap with the work described above for assessment of concrete bridge components (C-101). For example, the impact echo device for flaw and void detection is under development under this contract (C-204), but was terminated in the Structures contract (C-101). The effectiveness of AC Impedance, which can be used for corrosion rate measurement, in determination of concrete moisture/resistance, is being evaluated under C-204. Permeability devices are being examined in both contracts.

The contractors expect to develop a much-improved quality control system for fresh and plastic concrete based on a set of nondestructive field techniques. The contractor also will provide a set of techniques for assessment of the condition of in-service concrete.

Discussion

There was discussion of the need for a method for remote detection of delaminations on substructures. Several participants stated the need to minimize access costs on high structures when conducting evaluations. This was of particular concern to New York, Ontario, and Pennsylvania. It was suggested that the laser impact echo and detection

device developed by Harwell Laboratories under SHRP-IDEA Project ID-002 might be better suited to substructure evaluation than to deck evaluation, as it could be rigidly mounted. This has been suggested to the contractor, who has finished the first phase of the research.

There was discussion of the chloride measurement work (under C-101). It was pointed out that chloride located in aggregate will result in a high total chloride measurement, but that chloride in aggregate is not available to promote corrosion.

The work on permeability is important and relevant to several other contracts. Alternative methods for noncontact, nondestructive testing of substructures should be investigated. Even a crude instrument could be useful.

Concrete Products from SHRP IDEAs

Determination of Entrained Air in Plastic Concrete

The fiber-optic air meter developed under SHRP-IDEA project ID-011 is a portable, battery-operated device for use in on-site measurement of air voids in fresh concrete. A small fiber-optic probe is passed through the concrete mix, and detects air-void size and distribution through the reflection or absorption of light. The research team currently is attempting to improve the durability of the probe, and is developing software to allow users instant interpretation of the data.

The first field trials have been completed, and the device is being tested in Pennsylvania and other states. The device has attracted interest, and was one of the earliest products to emerge from SHRP.

Rebar Corrosion Meter

An ultralow-frequency AC impedance device has been developed under the SHRP-IDEA program to detect and measure rebar corrosion. Software has been developed for interpretation of the impedance spectrum to determine the corrosion rate. The device will be field tested by the California Department of Transportation under a Phase II subcontract.

Glass Cements

The hydrogarnet glass cement developed under SHRP-IDEA has potential for cost-effective use as a high-performance patching material for bridges and concrete

pavements. Glass cements bond well to concrete, set rapidly, and exhibit strong strength-gain characteristics. Work is proceeding to determine durability, resistance to freeze-thaw damage, and long-term stability. Field testing is planned as soon as sufficient material is available.

Discussion

The use of the air-void meter and the design of its probe were discussed. The contractor said he is searching for a way to protect the end of the fiber-optic probe from damage by large aggregate. The present design has a guard to deflect large aggregate particles, while allowing the cement paste to pass over the probe end. There was discussion of whether the probe affects the paste, and discussion of the manual movement of the probe, which is simple, but must take place at a steady, defined rate to provide uniformity of measurement.

There was discussion of the cost of the glass cement material, which the producers expect to be comparable to that of other high-performance patching materials.

Electrochemical Protection and Rehabilitation Techniques

Electrochemical Chloride Removal

This innovative technology uses a high-voltage temporary anode system to pull chlorides away from bridge components. A recirculating electrolyte system allows control and monitoring of the process. Results to date indicate that electrochemical chloride removal is technically feasible, and has the potential for economic viability. Post-removal protection is necessary to prevent recurrence of corrosion due to further salt ingress, and remigration of chloride ions, which are not fully removed from the concrete. California, Pennsylvania, New York, Michigan, and Florida have expressed interest in field testing the proposed chloride removal system.

In addition to proving the feasibility of chloride removal, the SHRP project has established the optimum operating parameters, and answered many of the concerns about the process. The major remaining research questions are how long chloride removal will remain effective, and when retreatment will be required.

Cathodic Protection

The goal of this project is to produce a manual on cathodic protection for use by highway engineers. The manual will give guidance regarding when and how to use

cathodic protection, and which types of systems will work best in various circumstances. Preliminary results suggest that intermittent cathodic protection could be feasible. Initial application of impressed current cathodic protection, with a zinc anode--which might then be switched off with the sacrificial galvanic action of the anode left to provide subsequent protection--also was suggested.

The contract was discussed by the Concrete and Structures Advisory Committee, which recommended that the Executive Committee consider nonrenewal of the contract. This project got off to a slow start due to insurance and liability issues. The first phase involved a field survey of existing cathodic protection systems, and the quality of data resulting from the field survey has been judged poor by the Expert Task Group (ETG). Progress in the laboratory work also has not been satisfactory. If the contract is not renewed, SHRP should request proposals for a new contract to finish the work.

Injection of Synergistic Inhibitors

Cationic (positively charged) inhibitors pass through concrete under the influence of an electric field. SHRP has tested various inhibitors to determine their effectiveness and movement through specimens.

The cationic inhibitor work initially was conducted under contract C-102C. It will be continued as a subcontract to C-102A. Under this follow-on subcontract, large-scale testing will be conducted to further assess the technical feasibility and economic viability of the technology. If the process is found to have technical and economic potential, field testing will be conducted as part of the chloride removal field tests already being conducted under contract C-102A. If it works well in field trials, the method could provide a useful post-chloride-removal protection technique.

Discussion

To adequately oversee construction, monitoring, and maintenance of cathodic protection systems, highway agencies may hire or consult with a corrosion engineer.

Specification and control criteria for cathodic protection are needed. Many states report that they have large inventories of corroded bridges, but have not implemented this technology due to lack of necessary information.

SHRP will continue to participate in the AASHTO bridge engineers' meeting.

Paul Virmani of FHWA said that cathodic protection is no longer considered experimental by FHWA. The Demonstration Projects Division will provide help in

installing the first one or two installations, or a new anode system. FHWA training courses also are available.

Cost-effectiveness and durability are key issues to be addressed in the manual that the SHRP contractor is preparing. Selection criteria, specifications and standards, and options for monitoring are other issues that need to be covered. The contractors writing the manual should take an interdisciplinary approach, due to the range of expertise in the state highway agencies.

Because it takes four to six weeks to apply, some suggested that a major application of chloride removal systems may be on substructures rather than decks. One way to reduce the deck closure time may be to imbed the temporary anode in a wearing course, so traffic could use the deck once it is installed, reducing the time a lane would be closed. Others suggested that the four-to-six week closure time for chloride removal on bridge decks is acceptable, since the corrosion repair techniques presently in use require a comparable closure period.

Epoxy coating may make it difficult to connect reinforcement steel for electrochemical measurements, or for electrochemical rehabilitation.

Equipment should be duplicated and sent to the states for trial. This could accelerate ASTM round-robin testing, and would yield better data on reproducibility.

Chemical and Physical Protection and Rehabilitation of Bridges

SHRP is evaluating a range of techniques for chemical and physical protection and rehabilitation of bridges, including patch repairs, concrete removal, impregnation techniques, overlays, sealers, and inhibitors. One goal of the project is to produce a life cycle cost analysis, but the contractor reported that there is a scarcity of good data on costs. A related goal is to develop cost-benefit relationships for doing nothing, versus patching; and for patching versus major rehabilitation and deck replacement. One unresolved issue is how and whether user costs should be included.

One goal of the project is to produce life-cycle cost data for a range of options. One of the difficulties is the range of variables--with nine environments and fourteen rehabilitation methods, a matrix of one hundred twenty-six variables has been generated for choosing trial methods and locations. Historic data are available for only three methods, so estimating service life and costs is difficult. While the contractor recognizes that state agencies need early site selection for trials and field work, he reported that identification of bridges for evaluation of current technology will not be completed until

February 1991. Selection of field test sites for novel systems is scheduled for December 1991, and testing of novel systems will take place in the summer of 1992.

Discussion

It is important to develop techniques that are appropriate for routine use by rehabilitation engineers in the field.

One way to repair existing concrete affected with alkali-silica reactivity is to inject a treatment into the concrete. This might be accomplished with the electrochemical technologies developed under contract C-102. Grooving, partial cover removal, and pressure injection are possible physical and chemical techniques that are being investigated under project C-103.

Guidance is needed regarding the point at which patch repairing is no longer cost-effective.

The problem of inadequate concrete removal must be addressed in the engineering guidance. If damage is left, the repair will fail very quickly.

The definition and measurement of damage, and the definition of the end of the useful life of a deck, will require considerable input from the highway agencies, as an arbitrary definition developed by a researcher could prove unacceptable or unworkable in practice.

The development of payoff curves will be made more difficult by the variation in labor rates among the states. The condition of joints and other parts of the bridge also should be taken into account when doing rehabilitation--and these are areas that SHRP is not investigating presently.

Methodology for Rehabilitation

The objective of the C-104 contract, which is still in negotiation, is to summarize the results of the SHRP Structures research for the practical guidance of highway engineers.

The products of this project will be a textbook manual, and a computerized manual or expert system. The project requires substantial interaction with all the other Structures contractors. Producing a computer system may be difficult due to the lack of accurate data. The manual will guide the user through the process of evaluation, rehabilitation

method selection, and implementation. The manual also is expected to cover life cycle costing, and subsequent maintenance and monitoring of rehabilitated structures.

Discussion

The SHRP work differs from the Bridge Management System being developed by FHWA and the California Department of Transportation, as SHRP will produce a technical manual for treating individual bridges--whereas the Bridge Management System is a tool for decision-making regarding management of a bridge inventory.

The budget for C-104 does not allow for videos or training courses. User costs should not be ignored, but should be used very cautiously.

SHRP will generate an information explosion as it progresses toward its products. The states, both individually and collectively, need to prepare for that explosion. Commitment will be required at all management levels within the state highway agencies, from CAOs and accountants to district engineers, since implementation requires action at all levels within a highway agency. The internal bulletins of the agencies should be used to disseminate the information, and the participation of state highway agency public information divisions should be actively solicited.

The SHRP State Coordinator's Newsletter contains useful technical information, and the state coordinators who are not already doing so may want to consider wider circulation of that publication within their agency. In the future, the State Coordinators Newsletter and Focus should carry more articles on how implementation can occur, using either real case studies or an idealized case.

Some states have been successful in boosting research, and the commitment to the SHRP program within their agencies, by forming a SHRP coordination committee that meets quarterly to discuss progress.

Many states are actively seeking early information on the development of tests and procedures so that they can try them out and modify them for their own needs. Contractors must recognize that, in an applications-oriented research program, time spent training and advising agency engineers on tests under development is an important part of their work.

While early involvement of the state agencies is to be encouraged, it is necessary to proceed with caution in implementing untested procedures and equipment. SHRP must not encourage use of prototypes without making it clear that they are not yet fully developed.

It is essential that the State Coordinators be informed of the SHRP-related activities under way in their states. States also need adequate lead time for field work. Strong interaction with ASTM is required, as ASTM standardization will be necessary for full implementation of many of the concrete tests.

Concrete Properties and Performance

Better Concrete Through Control of Microstructure

SHRP has developed packing diagrams and concrete curing tables. The packing diagrams are based on the physical characteristics of concrete mix components, and are aimed at formulating the concrete mix design for optimum consolidation and workability. The curing tables are based on heat generation and temperature differences between concrete and the surrounding environment, and provide guidelines for proper curing of concrete in the field. Another product, thin section fluorescent microscopy, can be used to evaluate the microstructure and quality of highway concrete. The water and chloride permeabilities of concrete were shown to correlate with its composition and microstructure.

The contractor anticipates some difficulties in the implementation of the research products--in particular, in modifying the specifications and procedures recommended by the standard-setting bodies.

Discussion

The packing diagrams probably will not be used by state highway agencies on a day-to-day basis, but they would certainly be useful to materials engineers in the mix design selection process. The frequency of their use will depend on their complexity (or simplicity), and their applicability when aggregates of various gradations, and other materials and/or admixtures are used in the field concrete. Presenting the information in the form of tables might make it easier to understand and use. It was strongly recommended that the packing diagrams be revised to include the effect of air entrainment. Professor Roy agreed to do so. She stated that including entrained air would not affect the point of maximum packing, although it would affect the absolute value.

Curing tables that are based on the maturity concept, and temperature changes in concrete due to cement hydration will be very useful. This aspect of curing is largely ignored in pavement construction in the United States, where the emphasis is on

moisture loss. There is a need to control temperature changes during curing, especially when extreme temperature conditions are likely to occur after the concrete is placed. Temperature changes can affect the microstructure development, and, hence, the durability of the concrete. Curing tables could provide needed guidance. The work has shown a correlation of slump with the yield stress of concrete, which may be further developed to enhance the simple slump test.

Eliminating or Minimizing Alkali-Silica Reactivity

SHRP sent a questionnaire on alkali-silica reactivity (ASR) problems to the states, and conducted a field survey in a number of states. Based on the field survey, a handbook for identification of ASR in highway structures has been prepared, and will be published by SHRP this year. Measurements of relative humidity have shown that, even in dry desert climates, there is sufficient dampness at pavement depths of about two inches to support ASR, at least on a cyclic basis. Refinement and evaluation of a rapid test for reactive aggregates at elevated temperatures in NaOH solution continues. Work continues on the effect of lithium salts in inhibiting ASR, and that of NaCl in aggravating it. Application of physical restraint was proposed as a way to control ASR expansion in pavement. A laboratory experiment using a miniature pavement to evaluate this concept is under way.

Problems are anticipated in developing a methodology for mitigating ASR in existing concrete, in implementing the research products, and in long-term monitoring beyond SHRP.

Discussion

There is a definite need among the state agencies for information about techniques for evaluation of ASR in highway structures. SHRP's handbook for identification of ASR will address this deficiency.

Users are not familiar with the gel fluorescent method for ASR detection. A training session for highway agency personnel on the use of the SHRP handbook and the gel fluorescent method is needed.

A simple method for the measurement of relative humidity in hardened concrete is needed.

The effect of deicing salt on ASR should be investigated thoroughly.

To mitigate ASR, SHRP should try applying lithium salts to the bottom of a concrete pavement or bridge deck and see if it would migrate upward through the concrete as a result of evaporation at the surface.

Generally, ASR cracking occurs more frequently in lightly reinforced structures, and on the south or west side of structures, where there is more cyclical drying due to sun.

The new tests that are being developed in this project may identify many commercial aggregates as deleterious. There is, therefore, a need to explore whether these aggregates still could be used if special measures to control ASR were applied.

An Australian report mentioned a test for ASR in concrete at 40°C and 100 percent relative humidity, and that the ASR in concrete was successfully controlled by the addition (about 25 percent) of a particular fly ash.

Mechanical Behavior of High-Performance Concretes

The SHRP contractor has developed a tentative definition of high-performance concrete for highway applications: that it should have a 3-hour compressive strength of at least 3000 psi, a 24-hour strength of 5000 psi, and a 28-day strength of 10,000 psi. Further, it should have a water/cement ratio of less than 0.35, and a durability factor of at least 80, after 300 freeze-thaw cycles. So far, this project has produced an annotated bibliography, a state-of-the-art report, and a database on high-performance concretes. Candidate materials for concretes for various applications have been identified, and a comprehensive laboratory testing program is under way.

The goal of the project is to provide specifications and recommendations for the use of high-performance concretes for highway applications. Field trials and long-term monitoring were seen as major potential problems.

Discussion

Both technical and economic factors should be considered in the use of high-performance concretes. Life cycle cost should be a part of the decision-making process.

Some concern was expressed about the selection of a particular proprietary product for high-early-strength applications. Additional materials or special curing procedures also should be considered for achievement of high early strength.

Regarding the work on the bond between concrete and steel, it was suggested that it would be more realistic to use epoxy-coated steel than plain steel for this test.

In field trials, load transfer devices at the joints should be considered carefully.

The relationship between the ultimate and the 28-day strengths of high-performance concretes should be explored.

It was suggested that the Cement and Concrete Reference Laboratory (CCRL) be involved to coordinate tests to facilitate approval or adoption by ASTM or AASHTO.

The state-of-the-art report on high-performance concretes, already published, was very useful to users.

Optimization of Highway Concrete Technology

This project will serve as a wrap-up activity for all Concrete research and development work. The objective of the project is to prepare a comprehensive implementation and training package for the use of highway personnel.

The project will identify and evaluate the most promising products of the SHRP Concrete and Structures research, as well as relevant products developed elsewhere. After thorough field testing and validation, the contractors will develop construction and repair guidelines for highway pavements and structures. The recommendations and guidelines will cover both materials and processes. The project also will develop an expert or advisory system for concrete durability and rehabilitation. The project is in its final stages of negotiation, and is scheduled to start October 1, 1990.

Discussion

The timing of this project is problematic. While this project involves selection of useful products from each of the Concrete and Structures projects for evaluation and validation, the project begins when most of the other Concrete and Structures projects will be at best half-finished. In many cases, products will not yet be developed sufficiently for testing and evaluation. Further, some of the products will require long-term monitoring beyond SHRP's five-year life before their validity can be established. All this poses a great challenge to the contractors, and to those managing and monitoring the project. There is a strong need to maintain very close contact between this project and the rest of Concrete and Structures projects.

This project is essentially a materials project, and should emphasize constructability and durability issues as they relate to materials and processes.

Field Work in Concrete

About sixty field experiments are planned in the concrete area. Of these, forty to forty-five are relatively minor, and involve field survey, sample collection, and equipment trials. However, approximately fifteen to twenty activities are major, and will involve providing sites and constructing test sections for evaluation of the performance and durability of concretes. These activities could be conducted on LTPP Specific Pavement Studies (SPS) test sections, with some adjustments. States participating in the SPS program are requested to give special consideration to participation in concrete field studies.

Resistance of Concrete to Freezing and Thawing

Project C-203 is exploring the relationship of the air-void and pore systems of concrete to its freeze-thaw resistance. The contractor has developed experimental designs and tests for identification of combinations of air-void and pore systems that produce marginal concrete. The contractor also has developed a modification of the ASTM C-666 freeze-thaw test that was designed as a rapid test method for identification of nondurable aggregates. Several aggregates are being tested to validate the procedure.

The contractor described an approach to repair of D-cracked concrete involving removal of damaged concrete at the joint, and sealing the exposed surface with penetrating sealers before repairing the joint with new concrete.

This project will actively collaborate with the project on high-performance concrete (Project C-205). The C-203 project already is collaborating with Project C-204 on the evaluation of the protected paste volume concept.

Problems are anticipated in developing a methodology for mitigation of D-cracking.

Discussion

Existing practice for avoidance of freeze-thaw damage is prescriptive, involving control of water-cement ratio, and amount of admixtures. Highway agencies may have difficulty applying tests for control of air-void and pore structures, unless parameters based on experience are developed.

The sophisticated tests for air-void and pore structures must be simplified for application to field concrete by highway personnel.

The modified freeze-thaw test is an intermediate method between the two ASTM tests, and appears to be a good compromise. It was strongly suggested that the test include deicing agents. The deicers affect moisture content, as well as the freezing temperature and freezing rate of water solutions in concrete.

Regarding mitigation of D-cracking, there was not much optimism for the approach using sealers at the joining surface. There were questions on the use of overlays to decrease the number of freeze-thaw cycles, as it may provide space for water to reside. The aggregate durability test was considered innovative, but it was pointed out that there was a need to do more extensive testing, and to consider the aggregate characteristics. The aggregate pieces produced in the test will be fully characterized.

The possibility of evaluating the durability of glacially deposited gravels by this method also was discussed. Some aggregates may require some pretreatment before testing. However, beneficiation of the aggregates is not a specific objective of this project.

5

Results of the Long-Term Pavement Performance Workshops

Key Recommendations: LTPP

Data Collection

- Establish a program for measurement of the effects of seasonal and environmental factors on the performance of a sample of General Pavement Studies (GPS) test sections.
- Establish guidelines for in situ instrumentation of Specific Pavement Studies (SPS) test sites.
- Consider material tests that include in-situ pavement materials rather than partial material samples--for example, modulus tests on samples that include all aggregate sizes, and not just < 3/4 inch fractions.
- Accelerate, if possible, collection of site-specific traffic and load data.
- Consider additional materials properties tests to include shear values for unbound materials, and characterization of recovered asphalt.

Data Analysis

- Proceed with the evaluation and calibration of current pavement design equations.
- Determine the relative effects of design, materials properties, climatic factors, and traffic factors on performance.
- Develop load equivalence factors as part of the current data analysis activity.
- Be patient in developing pavement rehabilitation models until an adequate supporting data base becomes available. While pavement rehabilitation strategies are badly needed by the highway community, good strategies developed from a strong data set are more important than early, but possibly suspect, strategies.
- Consider an evaluation of the effects of construction variability on pavement performance.
- Consider a plan for evaluation of the effects of seasonal and environmental changes on the characteristics of pavement materials.

Proceedings of the LTPP Workshop

LTPP Data Analysis

The primary objective of the LTPP workshop was to obtain direction in data analysis.

The first goal was the development of consensus among the workshop participants, who represented a cross section of the highway community, on the objectives of the early efforts in data analysis, and on longer-term goals.

Secondly, the SHRP-sponsored research teams required very specific direction on workplan development, so that the workplans would reflect the objectives of the community.

Finally, the SHRP operational team, staff, and contractors needed direction on possible corrections to the data collection plans to support the longer-term objectives identified by the community.

The workshop proceeded through several steps. Initially, the actual status of the LTPP studies, as they exist today, and will exist in the near future, was examined. The LTPP studies, and the data collected through them, represent the raw materials that will be used to construct the products of the data analysis effort. The first workshop session was devoted largely to their examination. For the early analysis activities, the researchers will have to rely on the GPS, which are the studies first pursued and currently best populated.

William MacCreery, Chairman of the SHRP Pavement Performance Advisory Committee, opened the session by reviewing the general goal and objectives for the LTPP effort set by the AASHTO Task Force on the Strategic Highway Research Program.

Goal: "To increase pavement life by investigation of various designs of pavement structures and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soil, and maintenance practices."

The specific objectives are to:

1. Evaluate existing design methods.

2. Develop improved design methods and strategies for pavement rehabilitation.

3. Develop improved design equations for new and reconstructed pavements.

4. Determine the effects of (1) loading, (2) environment, (3) material properties and variability, (4) construction quality, and (5) maintenance levels on pavement distress and performance.

5. Determine the effects of specific design features on pavement performance.

6. Establish a national long-term pavement data base to support SHRP objectives and future needs.

Mr. MacCreery remarked that some evolution in study design and data collection plans had occurred since the initial concepts were first prepared. This evolution was prompted by many factors, including the addition of study parameters overlooked at the first workshops, the distribution of pavement types throughout the United States and Canada, and budget and technological realities. While each of the changes was

recommended and accepted by consultants, expert task groups, and advisory committees, only now has the final shape and content of the GPS become apparent. This final reality, and everything that it contains and does not contain, will define the potential for GPS to carry the LTPP program toward its major goals.

Gary Elkins, a technical manager with the LTPP technical advisory contract team, detailed these changes in his presentation. He also described the nature of data collection for the GPS, the current status of the data base, and its likely status as of December 1991. Even at this early stage, a great deal of data will be available by the end of 1991. Mr. Elkins remarked, "The early analysis of short-term GPS data must anticipate the use of limited, partial data sets of varying quality. The uniformity and completeness of the LTPP data will improve over time. However, the short-term analysis of these data will be constrained. These constraints must be recognized in setting expectations for the results of short-term analyses."

Paul Benson of the California Department of Transportation, and a member of the Expert Task Group on Experimental Design and Analysis, took a critical look at these constraints in his presentation, "Biases and Gaps in the GPS Data Base."

Mr. Benson pointed out features that distinguished the GPS from more controlled "laboratory" experiments. He said, "Designers of the GPS had to deal with many deviations from the ideal laboratory environment. The completed data base inevitably will reflect some effects of the compromises that were made both in the form of hidden bias, and in unbalanced gaps. The significance of the biases and gaps....must be determined. If this is not done, the whole analysis is brought into question." Mr. Benson examined some of the more obvious problems of bias and lack of balance. He suggested analytical activities that should be pursued by any GPS data analyst to determine the degree to which the objectives of the analysis would be limited by this bias and lack of balance.

In his spoken comments, Mr. Benson concluded that even though the GPS has necessary limitations, we should not be discouraged. Those limitations are most dangerous when unrecognized, and the LTPP data will surpass in breadth and quality any similar data available to date.

In his presentation, Mr. Elkins had pointed out that early traffic and load data would be supplied by the state and provincial highway agencies, and would be the most variable and least reliable data available for early analysis. Mark Hallenbeck, a SHRP consultant, examined these data more closely. He described the procedures SHRP will use to identify data reliability, and the plans for improving these data with time.

Initially, the data analysts will be constrained by unidentified variability and unknown reliability, but the constraints will decrease as the data improve.

Paul Irick, another SHRP consultant, looked at GPS data base from yet another perspective. Dr. Irick examined the utility of the GPS data base for evaluation of current design methods--particularly, the current AASHTO flexible and rigid equations. (The evaluation of current design methods is one of the major objectives of the LTPP program.) Dr. Irick concluded that the data necessary to examine these equations, and others in current use, are all available, except for initial serviceability, which can be estimated using other data. Calibration of these models also will be possible using GPS data.

Boris Hryhorczuk, Deputy Minister of the Manitoba Department of Transportation and a member of the SHRP Executive Committee, showed how LTPP-type experiments currently in progress or planned by other nations will supplement the SHRP data base. This first session illustrated that the SHRP GPS data base can provide a starting place for an early attack on the LTPP objectives. The data base is necessarily limited, but many of the limitations will be overcome or ameliorated with time. These limitations, if recognized in the analysis process, will not preclude sound products and progress. The growth of international studies similar to LTPP also will help overcome the limitations inherent in any single national study of this type.

The second session moved from the "what" of studies and data to the "where" of current and future directions. Through a series of five invited papers, the potential for LTPP data analysis to address key issues confronting the highway community was examined. The speakers examined both the near-term and longer-term potential for LTPP to shed light on these issues.

Joe Mahoney of the University of Washington suggested that load equivalency factors currently included in the AASHTO Guide for the Design of Pavement Structures will evolve, but the need for such factors will not disappear, and they should not be ignored in LTPP data analyses. Dr. Mahoney also stressed that it is important to understand the nature of vehicle/pavement interactions when developing revised factors.

Matthew Witczak of the University of Maryland stated that the current GPS data base could not be used to accurately evaluate the impact of environmental factors on long-term pavement performance, and that changes to the current data collection schemes would be necessary in order to provide adequate data. He stressed the need for much more frequent collection of response data, such as deflection, on a subset, at least, of GPS test sections.

Marshall Thompson of the University of Illinois offered a conclusion that LTPP data, in concert with other SHRP research, can be used to develop new mechanistic-empirical design models that will improve design methods currently in use. He suggested, however, that early efforts using the current GPS data base may be limited, because a knowledge of the distress history is lacking, and distress may not accumulate rapidly enough to allow short-term conclusions. The collection of some additional data types that are not currently collected for GPS also may be necessary. Thus, the development of totally new design methods is unlikely in the near-term, and collection of different types of data may be necessary in future rounds of GPS data collection, or for the Specific Pavement Studies. Dr. Thompson pointed out that LTPP data also will permit development of performance prediction models suitable for pavement management systems.

Michael Darter, of the University of Illinois, discussed the potential of GPS data analyses to improve rehabilitation strategies. He stated that the shortage of "multiple point" data in the first five-year period of SHRP would severely limit the utility of the data base. By combining the available data with experience and other available data, however, it will be possible to make some progress in improvement of rehabilitation strategies even in the first five-year period. Dr. Darter also asked for improvements in the LTPP experiments for rehabilitation and maintenance. He voiced the strong opinion that the GPS studies of overlays of rigid and flexible pavement, particularly those where "condition prior to overlay" is known, need more test sections.

Michael Markow of Cambridge Systematics, Inc. addressed the issues of pavement type selection and life cycle costing. Dr. Markow pointed out that U.S. highway agencies were under pressure to develop rationally based pavement type selection procedures and life cycle cost bases by 1993. The GPS data can contribute to achievement of that goal. If the GPS data is to be used for this purpose, performance prediction equations rather than design equations must be developed, and the effects of maintenance histories must be integrated into these equations.

Longer-term analyses should permit a better understanding of the causes of observed pavement performance and deterioration and thus strengthen models used for prediction of the performance of new construction, and for prediction of the benefits of maintenance and rehabilitation.

John Olds of the Illinois Department of Transportation chaired a panel discussion among representatives of different segments of the highway community. The panel discussed the issues confronting the highway community that could be addressed through analyses of LTPP data.

Richard Lill, representing the American Trucking Association, cited as high priorities:

- Determination of lowest life cycle costs.
- Effect of materials variation and environmental factors on performance.
- Development of performance equations, rather than design equations.

Richard Morgan of the National Asphalt Pavement Association offered as high priorities:

- Development of high-performance, low-maintenance designs.
- Performance-related specifications for materials.
- An improved understanding of the impacts of traffic and environment.
- The introduction of innovative design.

Charles Marek of Vulcan Materials suggested as key priorities for his industry:

- Evaluation of the contribution of total base course strength to determination of thickness in pavement design.
- Replacement of "layer coefficients" with true design values.

Byron Blaschke of the Texas Department of Transportation offered priority needs from the view of state highway agencies:

- Major Improvements to the current AASHTO Guide, including:
    1. Primary emphasis on rehabilitation strategies
    2. Guidance for pavement management
    3. Development of mechanistic-empirical design methods
- Analysis of LTPP data to promote sound pavement practices.

Marlin Knutson of the American Concrete Pavement Association cited the following high-priority needs:

- Evaluation of key design factors for concrete pavements, such as joint spacing, and drainage.

- Innovation in construction, such as fast-track techniques.

Paul Teng represented the Federal Highway Administration. The FHWA high-priority objectives were:

- Replace the current AASHTO design procedures with a mechanistically based system that accommodates a larger variety of performance factors.

- Develop transfer functions for performance prediction equations.

- Provide the basis for improved pavement management systems.

- Use data in the LTPP data base to address locally developed issues.

- Develop rehabilitation strategies and extend the studies to address second rehabilitation cycles.

The Expert Task Group on Experimental Design and Data Analysis was charged with evaluating the workplans and capabilities of contractors who had proposed to undertake LTPP data analysis for SHRP. At the third session of the LTPP Workshop, the objectives of the ETG and the workshop as a whole coincided, as both groups heard presentations by selected researchers on potential approaches to LTPP data analysis.

Thursday night the Expert Task Group and the Advisory Committee met in joint session to discuss the content of the workshop. They developed a list of recommendations regarding direction to researchers currently pursuing SHRP-sponsored data analysis, directions for future analysis activities, and recommendations for possible changes in direction for data collection and study design to support these future directions. These were listed above as the "Data Analysis" recommendations.

Specific Pavement Studies

Amir Hanna of the SHRP staff presented an overview of the Specific Pavement Studies (SPS). He described the process involved in selecting the areas for investigation in the SPS program. The role of state and provincial highway agencies in developing the experimental design, research plans, and construction guidelines for these experiments was described. The need for participation of highway agencies by constructing test sites

for these experiments was emphasized, and regarded as essential for the success of the LTPP program and achievement of its objectives. SPS will address many of the issues that GPS cannot. It also will be more firmly controlled, overcoming the deficiencies of the largely uncontrolled GPS.

Thomas White of Purdue University described the results of the workshop on instrumentation, which involved demonstration projects in four states, with assistance from several universities and consultants. He emphasized the need for a broad-based pavement instrumentation data set to define the response variable distribution, and to help with the calibration and validation of mechanistic models.

Jerome Maddock, Manager of Information Services for the Transportation Research Board, outlined the different report formats available from the National Pavement Performance Data Base, and public access to the system.

David Newcomb of the University of Minnesota described typical instrumentation plans for selected test sites to measure in situ material properties, pavement response, and environmental conditions. The use of existing data to supplement SHRP data was recommended. For example, MN/Road data are collected in the same format as LTPP data to facilitate use.

William Hadley, a technical manager with the LTPP technical advisory contract team, summarized the potential impact of LTPP data analysis on the AASHTO Guide for Design of Permanent Structures. He explained that LTPP results will impact the design equations, the PSI concept, material characterization, the reliability concept, and rehabilitation strategies.

Lynne Irwin of Cornell University addressed long-term opportunities in the study of pavement performance. Certain material properties change with time. It is important to consider these properties in design and evaluation procedures. Potential long-term goals for LTPP might include: broadening research objectives to include recycled asphalt, modified asphalt, and other materials or features; as well as enhancing the quality of collected data.

Neil Hawks, LTPP Program Manager, concluded the session by discussing the implementation of SHRP products. Mr. Hawks pointed out that design methods and strategies would be the major, long-term LTPP products. However, short-term products such as specifications for equipment, and standardized procedures, already have been developed. He emphasized that some of these products were especially designed for SHRP, and may need to be modified for state use. He solicited the participation of the states in the implementation of such products.

Mr. Hawks cited the SHRP proficiency sample program as an example of an activity that addresses standardized procedures and control of materials variability. This program is being conducted with the assistance of fourteen state highway agencies, four field agencies, seven universities, two industries, and six SHRP testing laboratories. Mr. Hawks stressed the importance of the involvement of state highway agencies and users in the development of effective implementation.

6

Closing Plenary Session

The closing plenary session at SHRP's Denver meeting included wrap-up presentations by the chairmen of SHRP's four technical area Advisory Committees and by three members of the SHRP Executive Committee representing government, university, industry, and user backgrounds. Their remarks, based on participation in the three-day workshop, are highlighted below.

Asphalt Advisory Committee Chairman Tom Moreland said, "Considerable progress has been made in the asphalt program--so much, that if we stopped today, we could produce the binder specification."

Moreland said, "the tug-of-war continues between physical versus chemical characteristics" for evaluation of asphalt performance. "A balance of the best of both is desired. Physical properties must exhibit strong correlations with performance.

"Adoption of the binder specifications will have a significant economic impact on the asphalt industry," Moreland continued. "We need to interact with industry in anticipation of this."

Concrete and Structures Advisory Committee Chairman Howard Newlon said that program had produced "a few eurekas" already. The goal is to produce "an arsenal of procedures" to improve the quality and durability of concrete pavements and structures, from "the relatively simple to the comparatively complex."

Newlon noted that field trials of a promising new technology for electrochemical chloride removal are beginning. He noted that SHRP's corrosion research is somewhat unique in addressing substructures as well as decks.

One of the early deliverables in the concrete program will be a photographic handbook for identification of alkali-silica reactivity. That project also is expected to produce a rapid field method for identification of alkali-silica reactivity. Both products will warrant widespread distribution, Newlon said.

An array of products for nondestructive testing of concrete are under development and evaluation--some old, and some new. The fiber-optic air-void meter is the result of a successful SHRP-IDEA project, and will be field tested in several states later this year.

Newlon said that one of the major problems in the Concrete and Structures program is timing: wrap-up contracts in both areas are running concurrently with the research. "We foresee the need for a significant post-SHRP education effort directed to all levels of industry," Newlon said. "Liaison with other organizations will be crucial. A substantial presence of state highway people will be needed both in ACI and ASTM."

Highway Operations Advisory Committee Chairman Dean Testa said one result of the workshop was a recommendation that two prototype variable moldboard snowplows--instead of just one--be developed for testing next winter. Testa noted that the snow fence work was substantially complete, and that the result would be near-term availability of snow fence design guidance. He said the storm monitoring and communication project is progressing well. In the area of snow and ice control, Testa noted that a decision had been made to add a project that would evaluate the effectiveness of pretreatment.

In the worker safety area, Newlon said a decision had been made to develop a remote-controlled shadow vehicle rather than a totally automated intelligent vehicle, because of the high cost and risk involved in the latter.

"SHRP has changed the attitude of those in the maintenance area," Testa said. "In the past many had thought research was for the more glamorous areas, like construction. But now there's lots of enthusiasm for research in the maintenance community."

Long-Term Pavement Performance Advisory Committee William MacCreery said the workshop participants had taken a close look at data analysis techniques.

"Over time, we will be able to produce good mechanistic models for pavement design," MacCreery said. "We do need to keep open minds to other applications of the data, and to develop better life cycle costing models." In the course of the workshop, MacCreery said, "We learned there are a lot of concerns out there, but there is tremendous potential to improve knowledge, understanding, and application of highway engineering and to move it closer to science than the art that it is now."

AASHTO Executive Director Frank Francois said continuing and increasing state involvement in the SHRP program poses a major challenge. He noted that governorships are up for election in the coming year, and "all of us have the job of talking to the new CAOs to education them about SHRP, and to find the necessary state funding."

SHRP's implementation effort will require the full support of highway agency management, Francois said. He noted that rewriting AASHTO guidelines and standards "will take time," and that "money will be a problem."

Francois said "there is no question that LTPP must continue for another fifteen years," but said "the debate is not over" regarding the best organizational home for the effort. "The challenge will be to sustain the enthusiasm for pavement research ten years from now," Francois said.

Francois called for caution in "overselling" the SHRP program because "much more research needs to be done. In many areas we will just start the ball rolling. There needs to be an additional 'P' in 'LTPP,' (Long Term Pavement Performance)," Francois said, for 'Permanent.' The bottom line is funding."

Ray Decker of University Science Partners, who is chairman of SHRP's Implementation Subcommittee, called for immediate implementation of the early products of the SHRP program that are beginning to come on line. He called for "friendly competition" among the states for the opportunity to serve as test sites for emerging products.

Decker also called for continuation of the SHRP-IDEA program after SHRP closes out. SHRP-IDEA awards small contracts to study the feasibility of highly innovative concepts.

"SHRP has boosted the science base for concrete and asphalt, which was depleted," Decker said. "There is a need for a longer train of studies, however," Decker added.

Decker said he is "astonished by the consortium established by SHRP," and said, "we must find a way to perpetuate and enhance this."

Purdue Department of Civil Engineering Chairman Harold Michael, chairman of SHRP's Report Review Subcommittee, said SHRP had elicited more cooperation among state highway departments than he had seen "in forty years in the highway transportation field."

Michael said he would "Like to see the federal-state professional relationship continue, and expand to include city and local groups through technology transfer activities."

Michael said he would "Like to see the federal-state professional relationship continue, and expand to include city and local groups through technology transfer activities."

Michael said a key reason that cooperation had developed so well in the SHRP program was that "SHRP has no power to require that the results are implemented. That has to be done in the real way that things are sold in the real world," Michael said.

FHWA Executive Director Dean Carlson said FHWA is "gearing up for deployment of SHRP results through organizational change."

Roger Yarbrough, President of Apcon Corporation, a construction contracting firm, said "it is important that everybody understand that the products are not finished; that they are products in development." He particularly encouraged states to participate in the round-robin testing in the asphalt program. "Buy in. Be supportive and helpful," Yarbrough urged.

Industry is "well aware of what's going on in SHRP," Yarbrough said, "but there will be a need for further involvement in the implementation phase, for example to explore ways for rapid field testing."

Highway Users Federation Executive Director Les Lamm said that SHRP's meaning to the nation's 190 million road users "has to be something that ends up on the road system making things better."

Lamm said, "One hundred-fifty million dollars is equal to 1.5 billion gallons of gas tax. It's significant, especially in a tight budget atmosphere. It is incumbent upon us to make it cost-effective. We have to be producing a noticeable improvement.

"This has been a heck of a workshop," Lamm said. "We had great turnout and everywhere people were speaking their minds. There's been no apple-polishing. The contractors are very capable--some of the sharpest people talking about these issues that I've heard in thirty-five years in the business. I think we've seen that the management concept of advisory committees supplemented by expert task groups is working. And the process has begun to produce results that we are all going to be proud of."

Appendix

SHRP MIDCOURSE ASSESSMENT MEETING
DENVER, COLORADO
AUGUST 1-3, 1990

Agenda

Opening Plenary Session (Wednesday, August 1, 9:00 a.m.-12:00 p.m.)

(Session Moderator: John R. Tabb)

SHRP: Origin and Purpose: A review of the factors that led to the creation of SHRP and recapitulation of the key products that define SHRP's scope (Thomas B. Deen, Transportation Research Board)

Keeping Highway Research Focused and Responsive (Phil Smith, National Research Council)

AASHTO's Involvement in and Expectation from SHRP (Kermit Justice, Delaware Department of Transportation)

SHRP at the Midpoint: An Overview of Key Developments and Findings (Damian J. Kulash, SHRP)

From Research to Innovation: The Challenge of SHRP's Second Half (Thomas D. Larson, Federal Highway Administration)

Objectives of this Workshop: Making Sure We Fully Refine and Test the Most Promising Products (John R. Tabb)

Afternoon Session

Asphalt (Wednesday, August 1, 1990, 1:00 p.m.-5:00 p.m.)

Program Goals and Development (Session Chair: Thomas D. Moreland)

- Products of the Asphalt Program: Performance-Based Specifications (Edward T. Harrigan)
- Strategy to Achieve Key Products (Thomas Kennedy)
- Program Changes Since Inception (Rita Leahy)

Key Product Prospects: Asphalt Binder Specification (Session Chair: Ronald Cominsky)

Relationships and Test Methods Employed in the Asphalt Binder Specification:

- Compositional Factors, Aging, and Physical Structuring and Their Effect on Asphalt Performance (Raymond Robertson, Contract A-002A)
- Tests to Measure Asphalt Physical and Chemical Properties Related to Performance (David Anderson, Contract A-002A)
- Using Acoustic Emission to Evaluate Adhesion and Cracking Behavior (Wenji Chang, Contract A-002B)
- Functional Group Analysis and Heteroatom Content Related to Asphalt Performance (Wynn Jennings, Contract A-002C)

Validation Techniques to Establish Property-Performance Relationships for Specification Development (Session Chairman: Thomas Kennedy)

- Validation of Relationships Between Asphalt Binder Properties and Pavement Performance with Simulative Laboratory Tests of Asphalt-Aggregate Mixtures (Carl Monismith, Contract A-003A)
- Validation of Relationships Between Asphalt Binder Properties and Pavement Performance with Field Pavement Data (Robert Lytton, Contract A-005)

Concrete and Structures-NDT (Wednesday, August 1, 1:00 p.m.-5:00 p.m.)

Quality and Condition of Concrete and Structures (Session Chair: Howard H. Newlon)

- Assessment of Physical Condition of Concrete Bridge Components (Philip Cady, Contract C-101)
- Nondestructive Testing for Quality Control/Condition Analysis of Concrete (Paul Read, Contract C-204)
- Application of Products from C-101 and C-204 (Richard Gaynor, with discussion by industry and state highway agency representatives

Concrete Products from SHRP-IDEAS (Session Chairman: Mark Yancey)

- Fiber Optic Air meter (Farhad Ansari)
- Rebar Corrosion Meter (Digby Macdonald)
- Glass Cements (Thomas Gardner)

Highway Operations (Wednesday, August 1, 1:00 p.m.-5:00 p.m.)

Maintenance Effectiveness-Part 1 (Session Chair: Dean M. Testa)

- SHRP's Maintenance Effectiveness Program: Overview and Update (S. C. Shah, SHRP Staff)

- Innovative Worker Safety Devices (Jerry Graham, Contract H-108)
- Human Factors and Testing of Worker Safety Devices (Rodney Pletan, Minnesota Department of Transportation, with discussion by industry and TRB representatives)

Pavement Performance (Wednesday, August 1, 1:00 p.m.-5:00 p.m.)

LTPP Data Analysis: The GPS Experiments and Data (Session Chair: William J. MacCreery, Michigan Department of Transportation)

- The GPS Experiments as Implemented (Gary Elkins, Texas Research and Development Foundation)
- Biases and Gaps in the Data Base (Paul Benson, California Department of Transportation)
- LTPP Traffic Data--What it Really Is (Mark Hallenbeck, Washington State Transportation Center)
- Using LTPP to Evaluate Current Design Methods (Paul Irick, Texas Research and Development Foundation)
- International Experiments: A Prime Example (Boris Hryhorczuk, Manitoba Department of Transportation and SHRP Executive Committee)

Conference Dinner (Wednesday, August 1, 6:30 p.m.)

(Dinner Speaker: Dennis VanPatter, Colorado Tourism Board)

Morning Session

Asphalt (Thursday, August 2, 8:00 a.m.-12:00 p.m.)

Key Product Prospects: Asphalt Mixture Specification (Session Chair: Ronald Cominsky)

Test Methods and Evaluation Systems Employed in the Asphalt-Aggregate Mixture Specification:

- Standardized, Accelerated Laboratory Tests to Measure the Performance Characteristics of Asphalt-Aggregate Mixtures (Carl Monismith, Contract A-003A)
- Important Aspects of Asphalt-Aggregate Bonding: Adhesion, Moisture Sensitivity and Adsorption (Christine Curtis, Contract A-003A)
- Test Methods and Protocols for Selection of Modifier Systems to Enhance Asphalt-Aggregate Mixture Performance (David Rowlett, Contract A-004)
- Using Axial Tomography to Characterize Distress Development in Asphalt-Aggregate Mixtures (Costas Synolakis, Contract A-002B)

Current Draft Performance-Based Specifications for Asphalt Binder and Asphalt-Aggregate Mixtures (Including an Asphalt-Aggregate Mixture Analysis System) (Thomas Kennedy, Contracts A-001 and A-006)

Strategic Plan for 1990-1993 (Session Chair: Gale Page)

- Possible Economic Ramifications of the Performance-Based Specifications (Ronald Cominsky)
- Routes to Product Implementation (Thomas Kennedy)
- Recommended Changes in Program Strategy and Research Components to Successfully Produce the Performance-Based Specifications by March 31, 1993 (Edward T. Harrigan)

Concrete (Thursday, August 2, 8:00 a.m.-11:20 a.m.)

Concrete Properties (Session Chair: Howard H. Newlon)

- Resistance of Concrete to Freezing and Thawing (Don Janssen, Contract C-203)
- Advances in Freeze-Thaw Durability (Paul Klieger, with discussion by industry and state highway agency representatives)
- Eliminating or Minimizing Alkali-Silica Reactivity (David Stark, Contract C-202)
- Measures for Mitigating ASR (Bryant Mather, with discussion by industry and state highway representatives)

Structures (Thursday, August 2, 8:00 a.m.-11:20 a.m.)

Electrochemical Protection and Rehabilitation Techniques (Session Chair: James Murphy)

- Electrochemical Chloride Removal and Protection of Concrete Bridge Components (Jack Bennett, Contract C-102A)
- Cathodic Protection of Concrete Bridge Components (Jack Tinnea, Contract C-102B)
- Injection of Synergistic Corrosion Inhibitors (Sam Hettiarachchi, Contract C-102C)
- Adapting Electrochemical Protection and Rehab Procedures by Highway Agencies (David Manning, with discussion by highway agency representatives)

Highway Operations (Thursday, August 2, 8:00 a.m.-12:00 p.m.)

Winter Maintenance Considerations (Session Chair: Clayton Sullivan)

- SHRP's Attack on Ice-Pavement Bonding (David Minsk, SHRP Staff)

- Evaluation of Deicing Materials (Cecil Chappelow, Contract H-205)
- Perspectives on SHRP's Evaluation Criteria (Wallace Rippie, with discussion by users and producers)

Preparing Highways for Winter (Session Chair: Gerald M. Miner)

- Improved Snow Fences (Ron Tabler, Contract H-206)
- Sensors for Monitoring Highway Conditions (Ed Boselley III, Contract H-207)
- Highway Agency Perspectives on Winter Preparations (Gordon Bell, with discussion by highway agency representatives)

Pavement Performance (Thursday, August 2, 8:00 a.m.-12:00 p.m.)

LTPP Data Analysis: Perspectives on Impacts (Session Chair: Robert Clevenger, Colorado Department of Highways)

- The Future of Load Equivalency Factors (Joe Mahoney, University of Washington)
- Environmental Factors in Long-Term Performance (Matthew Witczak, University of Maryland)
- Impact on Pavement Design (Marshall Thompson, University of Illinois)
- Pavement Rehabilitation: Selection and Design (Michael Darter, University of Illinois)
- Pavement Type Selection and Life Cycle Costs (Michael Markow, Cambridge Systematics, Inc.)

LTPP Data Analysis: Strategic Objectives (John Olds, Illinois Department of Transportation)

A Panel Representing Key Constituencies of the Highway Community Discussed Prime Objectives in the Analysis of LTPP Data

Richard A. Lill, representing the American Trucking Association
Richard Morgan, National Asphalt Paving Association
Marlin Knutson, American Concrete Pavement Association
Charles Marek, Vulcan Materials, Inc.
Byron Blaschke, AASHTO Subcommittee on Design
Louis Papet, Federal Highway Administration

Concrete and Structures (Thursday, August 2, 11:30 a.m.-1:20 p.m.)

Products and Issues Working Lunch - Closed Executive Session of the Concrete and Structures Advisory Committee and Expert Task Groups

- Primary Goals and Products of the Concrete and Structures Projects

Asphalt (Thursday, August 2, 1:00 p.m.-5:00 p.m.)

Two Concurrent Workshops on the Draft Binder Specification and the Draft Mixture Specification (Session Chairs: Joseph Goodrich and Charles Potts)

- Appraise the "Hard" Products under Development to Support Specification Development
- Identify Gaps in the Product Development
- Select Top Priority Research Areas for Effective Product Development
- Assess Potential Economic and Operational Impacts of the Specifications and Other Products of the Highway Paving Industry
- Identify Routes and Barriers to Successful Implementation of the Products

Concrete (Thursday, August 2, 1:30 p.m.-5:00 p.m.)

Concrete Properties and Performance (Session Chair: James Murphy)

- Concrete Consolidation and Curing (Della Roy, Contract C-201)
- Better Concrete with Control of Microstructure and Curing (Stephen Forster, with discussion by industry and university representatives)
- Mechanical Behavior of High Performance Concrete (Paul Zia, Contract C-205)
- Using High Performance Concrete (Tom Pasko, with discussion by industry and highway agency representatives)
- Field Trials in Concrete Research (Inam Jawed, SHRP)
- Optimization of Highway Concrete Technology (Jim Murphy with the C-206 Contractor, with discussion by industry and state highway agency representatives)

Structures (Thursday, August 2, 1:30 p.m.-5:00 p.m.)

Physical and Chemical Protection and Rehabilitation Techniques (Session Chair: Howard Newlon)

- Concrete Bridge Protection and Rehabilitation (Richard Weyers, Contract C-103)
- Use of Products from C-103 by Highway Agencies (James E. Roberts, with discussion by highway agency representatives)
- Methodology for the Protection and Rehab of Existing Structures (Arun Shirole and the C-104 Contractor)
- Field Trials in Structures Research (John Broomfield)

Highway Operations (Thursday, August 2, 1:00 p.m.-5:00 p.m.)

Snow and Ice Disbonding and Removal (Session Chair: Don Orne)

- Improved Snowplows (Kynric Pell, Contract H-206)
- New Techniques for Ice Removal (Al Wuori, Contract H-204)
- Putting SHRP's Products into Use (Michael Ryan, with discussion by state highway agency representatives)

Weather Information and Communications (Session Chair: Dorothy Andres)

- Communications Networks for Pavement and Weather Monitoring Systems (Ed Boselly III, Contract H-207)
- Smart Weather Prediction (Elmar Reiter, SHRP-IDEA 018)
- Implementing Road Weather Information Systems (RWIS) (Richard Balgowan, with discussion by representatives from state highway and government agencies)

Pavement Performance (Thursday, August 2, 1:00 p.m.-5:00 p.m.)

LTPP Data Analysis: Workshop on Approaches (Session Chair: Newton Jackson, Washington State Department of Transportation)

- There are many potential approaches, both traditional and innovative, to the analysis of LTPP data. There must be a match between the strategic objectives of near-term analysis and the analytic approach adopted. In this session, several approaches to data analysis, including those of the SHRP contractor for data analysis (Contracts P-020), will be examined by the Expert Task Group on LTPP Experiment Design and Data Analysis. The objective of this examination will be the formulation of recommendations to the LTPP Advisory Committee on a strategic plan for analysis of LTPP data.

- Presentations:
  1. A Proposal to Learn from What We Already Know (James Brown, Texas Department of Highways and Public Transportation)
  2. The Contract P-020 Workplans:
     a. J. Brent Rauhut (Principal Investigator, Contract P-020A) BRE, Inc.
     b. Leon Talbert (Principal Investigator, Contract P-020B) CTL, Inc.
     c. Gilbert Baladi (Principal Investigator, Contract P-020C) Michigan State University
  3. C-SHRP Analysis of LTPP Data - One Approach (Gordon Sparks, C-SHRP)
  4. Henry Kerali (Principal Investigator, SERC (UK) Project) University of Birmingham

The presentations will be followed by a discussion among the Expert Task Group members and workshop attendees on near-term objectives.

Evening Session

Closed Executive Sessions

Asphalt (Thursday, August 2, 7:30 p.m.-9:30 p.m.)

Concrete and Structures (Thursday, August 2, 7:30 p.m.-9:30 p.m.)

Highway Operations (Thursday, August 2, 7:30 p.m.-9:30 p.m.)

Pavement Performance (Thursday, August 2, 7:30 p.m.-9:30 p.m.)

Morning Session

Asphalt (Friday, August 3, 8:00 a.m.-12:00 p.m.)

Workshop on Validation Techniques (Workshop Chair: Gale Page)

Presentation of Consensus Finding and Recommendations from the Workshops (Session Chair: Edward T. Harrigan)

- Reports on the Outcome of each Workshop by the Chairs
- Panel Discussion on:
  1. Future Program Strategy
  2. Product Scope and Definition at this Juncture
  3. Program Changes Recommended to Enhance the Successful Development and Implementation of the Key Products

  4.Potential Effects of Key Product Adoption on the Highway Paving Industry

Concrete and Structures (Friday, August 3, 8:00 a.m.-12:00 p.m.)

Expert Task Group Recommendations (Session Chair: Howard H. Newlon)

- Reports from Structures Expert Task Groups (Charles Arnold, David Manning, and Arun Shirole)
- Reports from Concrete Expert Task Groups (Stephen Forster, Richard Meininger, and Richard Gaynor)
- Panel Discussion of State Involvement, State Coordination, and State Implementation (Jim Murphy, with discussion by state highway agency representatives)
- Identification of Action Items from Concrete and Structures Workshop

Sessions to be Reported to Closing Plenary Session

Highway Operations (Friday, August 3, 8:00 a.m.-12:00 p.m.)

Maintenance Effectiveness - Part II (Session Chair: Dean Testa)

- Pavement Maintenance Effectiveness (Roger Smith, Contract H-101)
- Technologies to be used in Maintenance Measuring Equipment (Ken Maser)
- Training and Implementation for Maintenance Workers (John McCullough, Contract H-110)
- SHRP Highway Operations - Workshop Conclusions and Recommendations

Pavement Performance (Friday, August 3, 8:00 a.m.-12:00 p.m.)

LTPP: Progress, Products, and the Future (Session Chair: William Moyer, Pennsylvania Department of Transportation)

- The Specific Pavement Studies (Amir Hanna, SHRP)
- Application of Instrumentation in SHRP SPS Research (Thomas White, Purdue University)
- Accessing the Data Base: Policy and Procedures (Jerome Maddock, Transportation Research Board)
- Correlating LTPP Research (Dave Newcomb, University of Minnesota)
- Impact on the AASHTO Guide for Design of Pavement Structures (William Hadley, Texas Research and Development Foundation)
- Long-Run Opportunities in LTPP (Lynne Irwin, Cornell University)
- Implementing the Results (Neil F. Hawks, SHRP)

Closing Plenary Session (Friday, August 3, 1:00 p.m.-3:00 p.m.)

(Session Moderator: Lester P. Lamm)

Program Priorities and Implementation Plans-- Key Recommendations of this Workshop:

Asphalt	Thomas D. Moreland
Concrete and Structures	Howard H. Newlon
Highway Operations	Dean M. Testa
Pavement Performance	William J. MacCreery

Panel Discussion: Implications for the Next Two and One-Half Years--Technical Targets, Prototype Testing, Training Needs, Contractual Opportunities, Implementation Actions

Panel Members:

Francis B. Francois
Raymond F. Decker
Harold L. Michael
Thomas D. Larson
Roger L. Yarbrough

Closing Remarks (Lester P. Lamm)

BIBLIOGRAPHY OF ADVANCE PAPERS

ADVANCE PAPERS FOR ASPHALT
Contact Juliet Narsiah at (202) 334-1425 for copies.

Kennedy, Thomas W. and Ronald J. Cominsky. "The SHRP Asphalt Research Program: 1990 Strategic Plan (Part II)." 1990. SHRP-A/UWP-90-012.

Kennedy, Thomas W. and Ronald J. Cominsky. "Hypotheses and Models Employed in SHRP Asphalt Research Program." 1990. SHRP-A/WP-90-008.

ADVANCE PAPERS FOR CONCRETE AND STRUCTURES
These abstracts are presented in the Concrete and Structures Workshop Proceedings. Contact Ann Saccomano at (202) 334-1410 for copies.

Ansari, Farhad. "Air Content of Fresh Concrete Via an Optical Sensor." New Jersey Institute of Technology. Presented August 1, 1990.

Bennett, Jack. "Electrochemical Chloride Removal and Protection of Concrete Bridge Components." ELTECH Research Corp. Presented August 2, 1990.

Broomfield, John. "SHRP Structures Field Work." SHRP. Presented August 2, 1990.

Cady, Philip. "Assessment of Physical Condition of Concrete Bridge Components." Pennsylvania State University. Presented August 1, 1990.

Hettiarachchi, Sam. "Injection of Synergistic Corrosion Inhibitors into Choride-Contaminated Concrete." SRI International. Presented August 2, 1990.

Janssen, Don. "Resistance of Concrete to Freezing and Thawing." University of Washington. Presented August 2, 1990.

Jawed, Inam. "Field Trials in Concrete Research." SHRP. Presented August 2, 1990.

Macdonald, Digby D., M. Urquidi-Macdonald, R.C. Rocha-Filho, and Y.A. El-Tantawy. "The Application of Electrochemical Impedance Spectroscopy for Calculating the Corrosion Rate of Rebar in Reinforced Concrete." SRI International. Presented August 1, 1990.

MacDowell, John F., and Thomas N. Gardner. "Glass Cements: Evaluation of Stratlingite-Hydrogarnet Cement as a Quick-Setting Patching Material." Corning Inc. Presented August 1, 1990.

Read, Paul. "Nondestructive Testing for Quality Control/Condition Analysis of Concrete." Trow, Inc. Presented August 1, 1990.

Roy, Della. "Concrete Microstructure." The Pennsylvania State University. Presented August 2, 1990.

Stark, David. "Eliminating or Minimizing Alkali-Silica Reactivity." Construction Technology Laboratories(?). Presented August 2, 1990.

Tinnea, Jack. "Cathodic Protection of Concrete Bridge Components." Battelle. Presented August 2, 1990.

Weyers, Richard. "Concrete Bridge Protection and Rehabilitation: Chemical and Physical Techniques." Virginia Polytechnic Institute and State University. Presented August 2, 1990.

Zia, Paul. "Mechanical Behavior of High Peformance Concretes." North Carolina State University. Presented August 2, 1990.

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The Highway Operations Program Agenda contains all the abstracts listed below. Contact Lisa McNeil at (202) 334-1450 for a copy.

Boselly, S. Edward. "Communications Networks for Pavement and Weather Monitoring Systems." Matrix Management Group. Presented August 2, 1990.

Boselly, S. Edward. "Sensors for Monitoring Road Conditions." Matrix Management Group. Presented August 2, 1990.

Boyd, Patrick. "Human Factors and Testing of Worker Safety Devices." ENSCO, Inc. Presented August 1, 1990.

Chappelow, Cecil. "Evaluation of Deicing Materials." Midwest Research Institute. Presented August 2, 1990.

Graham, Jerry L. "Innovative Worker Safety Devices." ENSCO, Inc. Presented August 1, 1990.

Maser, Kenneth R. "Technologies to be Used in Maintenance Measurement Equipment." INFRASENSE, Inc. Presented August 3, 1990.

McCullough, John. "Contract H-110 Maintenance Worker Training." Roy Jorgensen Associates. Presented August 3, 1990.

Minsk, L. David. "SHRP's Attack on Ice-Pavement Bonding." SHRP. Presented August 2, 1990.

Reiter, Elmar R., and Luiz Teixeira. "Smart Weather Prediction: An Information Management System for Snow and Ice Control on Highways." Wels Research. Presented August 2, 1990.

Shah, Shashikant. "SHRP Maintenance Cost-Effectiveness Research Review and Update." SHRP. Presented August 1, 1990.

Smith, Roger E. "Pavement Preventive Maintenance Effectiveness." Texas A&M University, College Station. Presented August 3, 1990.

Tabler, Ronald D. "Engineering the Control of Blowing Snow." Tabler & Associates. Presented August 2, 1990.

Pell, Kynric. "Improved Displacement Plow and Blowing Snow Control." University of Wyoming Center for Information Technology. Presented August 2, 1990.

Wuori, Albert F. "New Techniques for Ice Removal." Michigan Technological University. Presented August 2, 1990.

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Benson, Paul. "Biases and Gaps in the GPS Database." California Department of Transportation. Presented August 1, 1990.

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