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SPECIFIC PAVEMENT STUDIES EXPERIMENTAL DESIGN AND RESEARCH PLAN FOR EXPERIMENT SPS-6 REHABILITATION OF JOINTED PORTLAND CEMENT CONCRETE PAVEMENTS

STRATEGIC HIGHWAY RESEARCH PROGRAM
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Specific Pavement Studies
Experimental Design and Research Plan
for Experiment SPS-6
Rehabilitation of Jointed Portland Cement Concrete Pavements

INTRODUCTION

The studies of rehabilitation and overlay techniques were the strongest contenders for inclusion in Specific Pavement Studies (SPS) as determined by previous balloting of highway agencies. Participation in and support of the research plans by the state and provincial highway agencies indicates enthusiasm for early implementation of the plan. Successful completion of the research project SPS-5 "Rehabilitation of Asphalt Concrete Pavements" and the research project SPS-6 "Rehabilitation of Jointed Portland Cement Concrete Pavements" will make major contributions to our ability to increase the life of the existing primary highway system of the United States and Canada through proper use of rehabilitation and overlay techniques.

The experimental designs and research plans presented here for SPS-6 were adapted from the Specific Pavement Studies on restoration of jointed concrete pavements (JCP) and pretreated JCP with AC overlay originally described in the May 1986 Strategic Highway Research Program Research Plans issued by the Transportation Research Board. Some of the original experimental design factors have been revised based on state and province desires and budget limitations. The plan has been prepared by the SHRP in cooperation with state and provincial highway agency personnel participating in various meetings including an SPS-6 workshop held in Washington, D.C., February 28 - March 1, 1989. The recommendations of the participants from 25 states and provinces and FHWA are incorporated into the experimental design and research plan described in this report. This research plan will be used by highway agencies and SHRP as a guide for selecting candidate projects to be considered for inclusion in the SPS-6 experiment and for design and construction of the test sections.

PROBLEM STATEMENT

Many United States and Canadian highway agencies are faced with the difficult task of determining the best way to treat existing aging and deteriorating jointed concrete pavements. Not only must they determine which rehabilitation procedures work best under which circumstances, but they must also determine the most appropriate time to apply such rehabilitation treatments. The problem is further complicated by the need to address an entire network of pavements at various levels of condition and age with limited funding resources.

There are a variety of rehabilitation techniques that can be applied to jointed concrete pavements (JCP) to restore condition and extend service life. These techniques involve a combination of levels and types of pavement preparation with and without the application of asphalt concrete (AC) overlays.

Pavement preparation approaches range from minimal treatment of the original PCC pavement to full "Concrete Pavement Restoration" (CPR) as well as cracking/breaking and seating. Pavement preparation can include diamond grinding, subsealing, full-depth repair, partial-depth spall repair, restoration of load transfer, resealing of transverse joints, resealing of longitudinal lane/shoulder joints, pressure relief joints, retrofit tied PCC concrete shoulders, and longitudinal subdrains. Depending on the extent and type of pavement preparation, asphalt concrete overlays of appropriate thicknesses may or may not be applied.

The long term performance of such rehabilitated pavements has not been systematically monitored and evaluated. There are no analytical design procedures for PCC rehabilitation and there are many unanswered questions regarding the appropriate rehabilitation techniques to use for a given pavement condition, traffic level, and climate as well as the proper timing of rehabilitation treatments.

One of the major LTPP objectives is "To Develop Improved Design Methodologies and Strategies for the Rehabilitation of Existing Pavements." A generally accepted approach for making cost effective decisions on pavement maintenance and rehabilitation is the use of pavement management concepts including life-cycle cost analyses of construction and rehabilitation activities. The ability to predict the performance and life expectancy of various rehabilitation strategies, with and without overlays, is essential to pavement management and life-cycle cost analyses. Consequently, the development of improved performance predictions models for various rehabilitation strategies is essential to achieving the LTPP objectives and should be one of the early products of research.

OBJECTIVE

The objective of this study is to develop improved performance prediction models to be used for determining the additional pavement life that can be expected from the application of a variety of JPC and JRC pavement rehabilitation methods and strategies ranging from minimal to maximum investment in the rehabilitation treatment. The treatments being studied include combinations of surface preparations, with and without AC overlay, as well as crack and seat preparation with AC overlay. The study objective includes a determination of the influence of environmental region and initial pavement condition on the effectiveness of rehabilitation methods. Accomplishing this objective will provide substantially improved "tools" for use in pavement management and life-cycle cost analysis activities.

PRODUCTS

One of the primary specific products of this portion of SHRP LTPP research will be to evaluate and improve portions of the AASHTO Guide for Design of Pavement Structures that pertain to pavement rehabilitation design methods, life-cycle cost analysis, and pavement management. The SPS-5 and SPS-6 experiments will provide uniform and structured field performance data upon which "Part III - Pavement Design Procedures for Rehabilitation of Existing Pavements" and sections on pavement management and life-cycle cost analysis of the AASHTO Guide can be evaluated and improved. These products are a direct response to the first two objectives of the LTPP program, which are 1) to evaluate existing pavement design procedures and 2) develop improved pavement rehabilitation design methods and strategies.

The structural overlay method for rehabilitation of existing pavements that is included in the AASHTO Guide is based on a thickness or structural deficient approach that presumes the existing pavement is structurally inadequate for anticipated future traffic and climactic conditions. This experiment will provide means for the field verification of this design approach. In addition, these AASHTO design procedures are not applicable to non-structural deficiencies and other functional rehabilitation needs. However, these factors will be considered in this experiment.

This study will produce data concerning JPC and JRC pavement performance and extended life predictions, including the relative cost effectiveness of various rehabilitation methods and strategies, ranging from minimum restoration to extensive concrete pavement restoration with and without AC overlays plus crack/break and seat with AC overlay.

The key products from the proposed study will include the following:

1. Comparisons and development of empirical prediction models for performance of JPC and JRC pavements with different methods of surface preparation, with and without AC overlays, with sawed and sealed joints, and with crack/break and seat preparation and different AC overlay thickness.

2. Evaluation and field verification of the AASHTO Guide design procedures for rehabilitation of existing JPC and JRC pavements with and without AC overlay, and other analytical overlay design procedures for JPC and JRC pavements.

3. Determination of appropriate timing to rehabilitate JPC and JRC pavement in relation to existing condition and type of rehabilitation procedures.

4. Development of procedures to verify and update the pavement management and life-cycle cost concepts in the AASHTO Guide using the performance prediction models developed for rehabilitated JPC and JRC pavements.

5. Development of a comprehensive data base on the performance of rehabilitated jointed concrete pavements for used by state and provincial engineers and other researchers.

BENEFITS TO PARTICIPATING HIGHWAY AGENCIES

This experiment will provide the states and provinces with actual data on the cost and performance of alternative methods for portland cement concrete pavement rehabilitation. These data are necessary for the accurate use of pavement management systems including life-cycle cost analysis and predictions. In addition to these direct benefits, participating highway agencies will receive ancillary benefits as a result of direct involvement in the experiment. For example, the interactions between agency's personnel are the SHRP staff, contract researchers, and highway personnel from other agencies will produce valuable insights and exchange of ideas.

To evaluate innovative rehabilitation designs and local practices, sponsoring states and provinces can construct additional test sections on or near the SPS experiment projects containing factors of special interest. For example, an agency interested in evaluating the performance of a proprietary product such as geo-fabric to reduce reflective cracking, could construct additional test sections along with the SPS experiment test sections. SHRP will assist with the design, data collection, and performance evaluation of such experiments and will provide coordination for desired regional or partial experiments.

Another primary benefit to participating highway agencies is that a portion of the research will be conducted on the specific pavements and construction practices employed by the participating highway agency, allowing direct use of the results. Having test sections within a jurisdiction provides the opportunity to link performance measurements based on the local pavement evaluation techniques directly to the national pavement data base being developed by SHRP. For example, highway agencies using a Dynaflect or Roadrater deflection measurement device can develop correlations with the falling weight deflectometer measurements performed using SHRP equipment.

EXPERIMENTAL DESIGN

The recommended experimental design is shown in Table 1. It identifies the primary experimental factors and their relationships with each other. Table 1 identifies site related factors across the top and rehabilitation treatments down the side. Each column in this arrangement represents either one or two project locations each of which incorporates several test sections. Each row represents a series of test sections with specific features to be constructed at each project location.

This experimental design is a coordinated research plan intended to produce data and performance information for a variety of rehabilitation and overlay procedures constructed to extend the life of existing jointed PCC pavements. The primary factors being studied are: (1) the extent of preparation and restoration of the existing pavement, (2) thickness of AC overlay, and (3) environmental (climatic) factors. Other considerations are: (1) existing condition of pavement, (2) pavement type, (3) subgrade soil, and (4) traffic volume and load. In addition, the experiment will include other test sections desired by the highway agency to evaluate local practices or innovative features.

SHRP fully recognizes that no agency is able to continue in service any test section, even for research purposes, that becomes unsafe or disruptive to traffic flow. When in the judgment of the highway agency, a test section reaches such a condition, it should be treated as considered appropriate by the state or provincial highway agency. Such sections will be removed from the study and SHRP will endeavor to obtain final condition data prior to their treatments by the highway agency.

Site Related Factors

Site related factors include two pavement types (jointed plain concrete and jointed reinforced concrete) in both fair and poor conditions in three climatic regions (wet-freeze, wet-no freeze, and dry-freeze), and one pavement type (jointed plain concrete) in both fair and poor condition in the fourth climatic region (dry-no freeze). Jointed Reinforced Concrete pavement type is not a

Table 1. Experimental design for SPS-6, rehabilitation of jointed portland cement concrete pavements.

Rehabilitation Procedures / Factors for Moisture, Temperature, Pavement Type, and Pavement Condition		WET FREEZE				WET, NO FREEZE				DRY FREEZE				DRY, NO FREEZE	
		JPCP		JRCP		JPCP		JRCP		JPCP		JRCP		JPCP	
		FAIR	POOR	FAIR	POOR	FAIR	POOR	FAIR	POOR	FAIR	POOR	FAIR	POOR	FAIR	POOR
PREPARATION	OVERLAY THICKNESS														
Routine Maintenance (Control)	0	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	x	x	x	x
Minimum Restoration	0	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	x	x	x	x
	4"	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	x	x	x	x
	4" *	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	x	x	x	x
Maximum Restoration (CPR)	0	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	x	x	x	x
	4"	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	x	x	x	x
Crack/Break and Seat	4"	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	x	x	x	x
	8"	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	x	x	x	x

* with saw AC overlay joints above JCP joints and seal

Subgrade Soil: Fine
Traffic: >200 KESAL/Year

Each "x" designates a test section.

study factor in the dry-no freeze region because it is not frequently built in this region.

These levels of climatic regions, pavement types, and pavement condition study factors will result in fourteen different study combinations. In addition, each test section, with the exception of JRC pavements in the dry-freeze and JPC pavements in the dry-no freeze climatic regions will be replicated. Thus, twenty-four project sites are needed for this experiment. Where ever possible, replication will take place in different jurisdictions to allow a greater range of practices to be studied.

Climatic Factors

The climatic regions are, for the most part the same as the environmental zones used in the General Pavement Studies (GPS) except they are not modified to correspond with state boundaries. Climatological factors at specific locations will be used for selection of SPS projects. For example, in this experiment a project in the south east portion of Kansas could fall in the wet-freeze climatic zone rather than in the dry-freeze zone as indicated on the GPS environmental zone map.

Wet climatic regions are considered to have a high potential for moisture presence in the entire pavement structure throughout most of the year. Dry climatic regions are considered to have very little and low seasonal fluctuation of moisture in the pavement structure. Freeze regions include locations with severe winters that result in long-term freezing of the subgrade. No freeze climatic regions are considered to have no long-term freezing of subgrade.

Pavement Type Factors

The two pavement types considered in this experiment are JPCP and JRCP. Although there are a wide range of joint spacings in existing pavements, no specific criteria has been established in this regard for the selection of projects to be included in this experiment. This factor will be given further consideration when candidate projects are being reviewed for final selection.

Pavement Condition Factors

The classification of existing pavement condition as fair or poor will be used primarily to screen candidate projects to provide a range of existing distress conditions. Distress condition surveys of all test sections will be made prior to rehabilitation to provide information for the data base. However, it is desirable to have some type of composite distress index be used by highway agencies to classify pavement condition when selecting projects for submittal to SHRP as candidates for the study. In view of the desire to immediately identify candidate projects for the 1989 construction season, agencies are urged to select projects that they classify as in fair or poor condition and provide details on the procedures used for such classification. This information will be used by the SHRP to further develop distress index classification procedures for use in selecting the remaining candidate projects for the 1990 construction season.

A structural based classification of present pavement condition will be used rather than roughness, ride quality, or skid resistance because these conditions are normally corrected by placement of thin overlays. The rehabilitation procedures being studied are intended to overcome structural inadequacy. The types of distress to be included in the classification include faulting, patching, spalling, pumping, joint deterioration, and slab cracking. The distress index will consider the extent and severity of each distress type. Although several types and degrees of distress may occur in a project, all test sections in a project are to be either in fair or poor condition and as the result of the same type of distress.

Other Site Factors

Other factors that contribute to pavement performance which are not included as study factors, will be considered in the test site selection process to keep the experiment within a practical implementable size.

This experimental design is intended for projects built on fine grained subgrade types and for traffic levels above 200 KESAL per year (per outside lane) because they represent the situation of greatest concern and provide a sterner test of rehabilitation strategies. If project sites meeting these criteria cannot be found, lower traffic levels and/or coarse grained subgrade types will be considered. However, all test sections in a site should have the same type of subgrade soil and traffic.

The proposed experimental design further constrains other factors through the site selection process as follows:

1. Performance period - Because quantification of the existing pavement condition is not possible for previously overlayed pavements, all test sections are to be located on pavements in their first performance period (i.e. no prior overlay). A section can be considered if a thin overlay or maintenance surface patch has been placed but will be removed prior to the rehabilitation and the current condition of the JCP can be determined. Existing open graded friction courses should be removed by milling if the pavement is to be considered as a candidate project. The addition of an open graded friction course to the new overlay for safety and/or agency policy requirements is allowed, but should not be considered part of the structural overlay thickness.

2. Pavement age - All projects should have been completed between 1965 and 1978 to avoid excessively young or old pavements and unusual performance.

3. Pavement thickness - All pavements shall be 8" to 10" thickness over a minimum of 3" stabilized or unstabilized subbase.

4. Project uniformity - All test sections in a project should have the same design details, materials, construction quality and should experience uniform traffic movement.

Pavement Preparation

Three levels of pavement preparation plus routine maintenance as a control section will be applied to the test sections prior to AC overlay. They are minimal restoration, intensive CPR, and crack/break and seat. Routine maintenance will consist of joint and crack sealing and limited patching.

The minimal restoration level will consist of routine maintenance including limited patching (filling pot holes), crack repair and sealing, and stabilization of joints. This level is typical of the current practice of many highway agencies prior to overlay.

The intensive CPR level will consist of several activities that will be done depending on pavement distress and condition. This intensive level represents a premium level of pavement preparation addressing grinding, subsealing, subdrainage, joint repair and sealing, full depth patching with restoration of load transfer, and shoulder rehabilitation. Surface grinding and joint and crack sealing will not be performed on test sections that will receive an AC overlay.

Due to the possible variation in existing pavement condition, 1,000 foot long test sections are recommended for the study of the minimum restoration and intensive CPR sections without an AC overlay.

Crack/break and seat is the process of using mechanical means to reduce slab size to minimize or eliminate reflective cracking in the asphalt concrete overlay. Crack and seat is the process used with plain (unreinforced) concrete pavement and break and seat is the process used with jointed reinforced concrete pavements. The cracking and breaking procedures need to be uniformly applied to their respective pavement types. The seating procedures also need to be controlled to ensure seating of the cracked or broken slabs.

If desired by the participating highway agency, additional sections incorporating other types of pavement preparation will be evaluated. These sections may include crack and seat with different crack spacing, rubblized pavements, or other features.

Overlay Factors

The study design includes three overlay thicknesses, (0, 4, and 8 inches). No overlay will be used on the control section and one each of the test sections that will receive minimum restoration and intensive CPR pavement preparation. The 4-inch thick overlays will be used on the test sections receiving the minimal restoration level of pavement preparation, the intensive CPR level of pavement preparation, and the crack/break and seat pavement preparation. The 8-inch thick overlay will be used on a test section that will involve crack/break and seat. In addition, a 4-inch overlay in which joints are sawed above the existing joints and then sealed will be applied to test sections receiving the minimum restoration treatment.

The overlays allowed for use on the test sections will be further constrained to insure a reasonable level of consistency as follows:

1. All overlays use virgin materials.
2. The application will not incorporate SAMI or any type of reinforcement (fibers, geotextiles, etc.).

If desired by the participating highway agency, additional sections incorporating other types of overlay design will be evaluated. These sections may include AC overlays with different thickness, portland cement concrete overlays, use of fabrics or fibers, or other features.

AC Mix Design

Problems will likely to develop if an agency or a contractor is required to design or build test sections that vary substantially from the normal practice and experience. For this reason, a standard AC overlay mix design is not required. However, to produce reasonably consistent mixes for the AC overlays using local materials and design procedures, the FHWA Technical Advisory T5040.27, "Asphalt Concrete Mix Design and Field Control" dated March 10, 1988 shall be used as a guide by the state and provincial highway agencies. This Advisory contains detailed recommendations for material selection, mix design, plant operation, and compaction.

TEST SECTION SEQUENCE

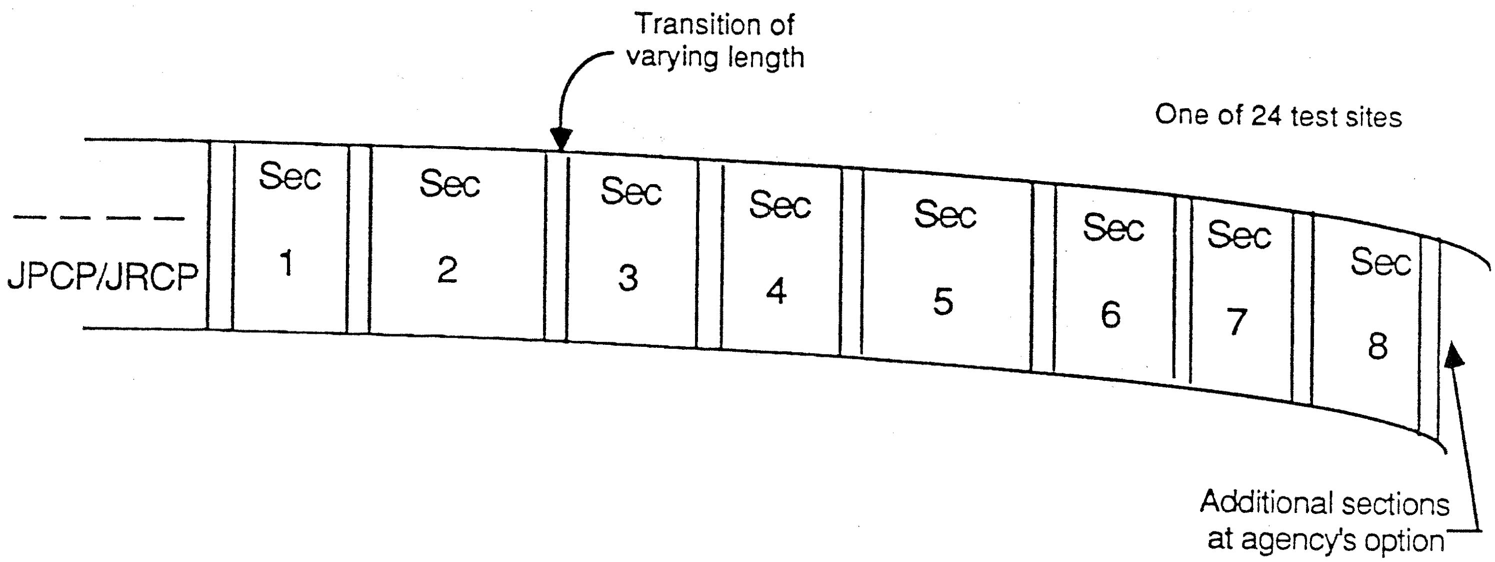
The sequence of sections depicted in Figure 1 are not random. They are organized based on construction considerations. It places test sections with similar pavement preparation levels adjacent to each other and minimizes abrupt changes in asphalt concrete overlay thicknesses. Under this approach the overlay thickness can be gradually modified over the transition area.

The sequence shown in Figure 1 is not fixed and may be varied to accommodate local construction conditions. Each test section will be 500 feet in length with the exception of the test sections that receive minimum restoration and full CPR preparation and no asphalt concrete overlay. These test sections will be 1,000 feet long. The sections will be separated by an appropriate transition length to meet practical construction considerations. Transition section length will vary based on site condition to assure cohesive test sections.

To help reduce the effort in identifying potential test sites for this experiment, several sources can be used. These include the agency's list of projects scheduled for rehabilitation, projects identified as candidates for GPS-7B, "New AC Overlay on Portland Cement Concrete Pavements", and projects in GPS-3, "Jointed Plain Concrete Pavement", and GPS-4, "Jointed Reinforced Concrete Pavement" that warrant rehabilitation. The use of GPS candidate projects will result in a reduced data collection effort.

CONSTRUCTION CONSIDERATIONS

Construction problems and variations as well as environmental conditions during construction could influence the performance of test sections to a greater extent than the design factors. Because construction procedures and control will be the responsibility of the many participating agencies, accurate records of actual construction procedures must be obtained (references to construction



SPS-6 SECTION	JC PAVEMENT PREPARATION	OTHER TREATMENTS	OVERLAY THICKNESS
1	Routine Maintenance		0
2	Minimum Restoration		0
3	Minimum Restoration		4-inch
4	Minimum Restoration	Saw and seal joints in AC	4-inch
5	Maximum Restoration (CPR)		0
6	Maximum Restoration (CPR)		4-inch
7	Crack/Break and Seat		4-inch
8	Crack/Break and Seat		8-inch

Figure 1. Illustrative Test Section Layout for SPS-6, Rehabilitation of Jointed Portland Cement Concrete Pavements.

specifications will not be adequate). In addition, records must be maintained of weather conditions and events such as equipment breakdowns and material contamination during the test section construction. Testing during construction of the AC overlays will be required to encourage as much uniformity as possible. Guidelines will be developed to cover such items as compaction and air voids content, profile or roughness specifications for the finished overlay, and minimum sampling and testing for quality assurance and control. Field experience gained during the initial projects completed in 1989 will be used to develop these guidelines.

Breaking the JRCP requires a considerably higher effort than cracking JPCP. For uniformity during cracking and breaking, guillotine hammer or pile driver equipment should be used. Crack spacing should be 3 feet by 6 feet for JPCP and 18 inches for JRCP. Tests should be performed to ensure full depth cracking. A minimum 30 ton roller should be used for seating, and field tests should be performed to determine the rolling pattern required to achieve proposed crack pattern and pavement seating. Test sections should receive the AC overlay as soon as possible after seating.

Although the test sections to be monitored are limited to the outside lane in one direction, it is desirable that all rehabilitation preparation activities and overlays be extended the full width of the pavement. Also to ensure uniformity, it is required that all test sections in each site be completed in one construction season.

Arrangements will be made for the collection of AC overlay samples for later testing by SHRP.

PARTICIPATING AGENCY RESPONSIBILITIES

Participating highway agencies will play the major role in the development and conduct of the Specific Pavement Studies, including the following activities:

- Participation in experimental design and implementation plans.
- Nomination of test sites.
- Preparation of plans and specifications.

- Selection of construction contractor.
- Construction of the test pavements.
- Construction inspection and management.
- Provision of traffic control for all test site data collection.
- Routine material sampling.
- Collection and reporting of pavement inventory data.
- Collecting periodic skid resistance measurements.
- Conducting and reporting maintenance activities.
- Collection and reporting of traffic and load data.

SHRP RESPONSIBILITIES

SHRP responsibilities will include the following:

- Development of the experimental design.
- Coordination among participating highway agencies.
- Final acceptance of test sites.
- Development of standard data collection forms.
- Assistance with special sampling requirements.
- Coordination of materials sampling and testing.
- Monitoring of pavement performance.
- Development of a comprehensive data base and data entry.
- Control of data quality.
- Data analysis and reporting.

IMPLEMENTATION AND SCHEDULE

This SPS-6 research plan and experimental design is ready for implementation. However, development was an evolutionary process and change is likely to continue with detailed adjustments as experience is gained from early projects.

Step one of implementation is the identification and submission by highway agencies of candidate projects for possible inclusion in the study. A total of 24 projects will be required to complete the experiment as planned. SHRP desires to select and construct test sections in at least 2 or 3 projects during the

1989 construction season. The remaining sections will be selected from the identified candidates and constructed in 1990. SHRP will assist the highway agencies in identifying candidate projects.

The existing condition of the test sections; in terms of distress, profile, deflections, and material characteristics; must be assessed prior to the rehabilitation and overlay activities. This will require extensive coordination between SHRP staff and regional offices, and the highway agencies. Traffic data must be collected at each site using WIM equipment. It will be desirable to install the WIM equipment at the time of rehabilitation work but, if this is not possible, it should be installed within a year of construction.

The proposed schedule of activities for this experiment is as follows:

Nomination of Candidate Projects:	
- For 1989 Construction Season	April 30, 1989
- For 1990 Construction Season	May 30, 1989
Review and Screening of Candidate Projects	As received
Notification of State/Provinces of Accepted Projects	
- For 1989 Construction Season	June 1, 1989
- For 1990 Construction Season	July 15, 1989
Supplementary Recruitment Activities (with individual agencies)	As needed
Implementation Workshop with Participating Agencies	
- For 1989 Construction Season (with individual agencies)	As required by Participating Agency
- For 1990 Construction Season	Mid-August 1989