BUILDING FOR THE FUTURE:

A TECHNOLOGY PROGRAM FOR PORTLAND CEMENT CONCRETE PAVEMENTS

U.S. Department of Transportation
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FOREWORD

The Federal Highway Administration's Pavement Technology Program is a managed suite of research, development, delivery, and deployment initiatives focused on the improvement of pavement performance. The goal of the program is to achieve deployment of improved technologies that will lead to more durable, user-responsive, cost-effective pavement systems. The program's effectiveness relies on the greatly expanded participation of the FHWA field offices in the delivery and deployment of pavement technology.

Key features of the program include the following:

- The program is based on the formation of working partnerships, thus reflecting the input and buy-in of State departments of transportation, the American Association of State Highway and Transportation Officials (AASHTO), academia, and the pavement industry.
- Accomplishment of the program is a collaborative effort by all FHWA headquarters and field offices.

The Pavement Technology Program has two major focus areas: asset management and better performing pavements.

The asset management area includes research, development, delivery, and deployment of tools and methods to forecast conditions and costs, assign values to assets, measure returns on investments, measure resource capacity and user costs, quantify benefits and opportunity costs, and evaluate investment tradeoffs.

Although asset management is a fundamental element of all of FHWA's pavement programs, it is specifically addressed in the pavement management program and is thus not addressed in this report.

The better performing pavements area includes research, development, delivery, and deployment of technology and training activities associated with new and recycled materials; the design system and selection of design features; and construction processes. The goal is to develop pavements that will have a longer service life, provide a smoother, quieter ride, and require less maintenance.

The focus areas of better performing pavements and asset management are composed of four technology programs:

- Portland cement concrete (PCC) pavement
- Asphalt concrete pavement
- Pavement management
- Long-term pavement performance (LTPP) studies

This report focuses on the PCC pavement technology program.

PORTLAND CEMENT CONCRETE PAVEMENT TECHNOLOGY PROGRAM

OBJECTIVES

The portland cement concrete pavement technology program is composed of three elements:

- Materials characterization and mixture design
- Pavement evaluation and structural design
- Performance specifications and construction procedures

Those three elements comprise 13 key objectives:

◆ *Materials Characterization and Mixture Design*

1. Improved testing methods for materials characterization and selection
2. Procedures for predicting and preventing materials-related distress
3. Models and procedures to achieve high-performance concrete for pavements
4. Use of advanced concrete materials

◆ *Pavement Evaluation and Structural Design*

5. Pavement response and performance data for design and analysis
6. Approaches for prevention of structural distress and deterioration
7. New design concepts for PCC construction and rapid repair
8. Performance-based rehabilitation strategies

◆ *Performance Specifications and Construction Procedures*

9. Effect of construction equipment and procedures
10. Nondestructive testing (NDT) and other innovative techniques for concrete pavement evaluation
11. Performance-related specifications (PRS) for rigid pavements
12. Advanced traffic management and construction strategies
13. Pavement smoothness

Each objective is addressed by multiple projects that encompass the research, development, delivery, and deployment of the technology; together, these projects will bring the concept of high-performance concrete pavement (HPCP) into the state of the practice. In many cases, projects are already underway to accomplish these objectives; in other cases, additional effort or new projects will likely be needed to achieve the objective (see Table 1).

Table 2 summarizes the funding needed by fiscal year 1998–2003 for these projects. Many segments of the 13 specific objectives will be completed in the next 5 to 7 years (see Table 3 for timeline and products).

Advanced research—Acquires or increases fundamental knowledge. May be technology-specific or problem-specific. Typically long-term and high-risk, but with potential for significant improvements in the state of the art.

Applied research—Applies knowledge to solve specific highway problems. Addresses specific user needs or problems. May be short-term or long-term and is typically lower risk than advanced research.

Development—Converts research results to market-ready products. Involves prototyping, testing and evaluation, and packaging for delivery. Requires close interaction with a select group of product users and the use of market research techniques to evaluate the size and characteristics of the potential user base. Also includes consideration of delivery strategies and mechanisms.

Delivery—Introduces and brings new, market-ready products to the user. Delivery requires a detailed understanding of user needs and constraints and the use of a wide variety of delivery mechanisms and distribution approaches.

Deployment—Enables routine product usage through ongoing technical assistance. Involves continuous technical assistance. Requires a close involvement between the user and technically competent individuals with access to technical experts.

MATERIALS CHARACTERIZATION AND MIXTURE DESIGN

1. *Improved testing methods for materials characterization and selection*

The ever-increasing complexity of concrete mixtures has made recipe specifications and empirical rules of mixture design less reliable for obtaining concretes with the desired performance for HPCP. The use of a range of chemical and mineral admixtures, and the potential for compatibility problems, have added to this complexity. Improved tests are needed that better characterize the materials involved in terms of their impact on the performance of the concrete produced. This is particularly true in the case of aggregates, whose potential influence on concrete performance has not been sufficiently investigated or categorized. The suite of tests developed must also be able to evaluate any waste, byproduct, or recycled material with the potential for use in paving concrete.

2. *Procedures for predicting and preventing materials-related distress*

Premature materials-related distress in concrete pavements appears to be becoming more widespread. Investigation to date indicates a variety of potential causes for this problem. Work is currently in progress to develop guidelines for the evaluation of materials-related distress in existing pavements. Using these guidelines, the distresses must be evaluated to determine the causative mechanisms. Then, procedures for predicting and preventing the distress must be developed for inclusion in the mix design process for HPCP. To be successful, these evaluation procedures must be applicable to job-specific materials and proportions.

3. *Models and procedures to achieve high-performance concrete for pavements*

The complexity of portland cement concrete mixes, as indicated by objectives 1 and 2, above, will make the trial-and-error process of mix design in the laboratory even more time consuming and labor intensive than it already is. Means are therefore needed to model the behaviors of concrete mixes without actually having to mix all of the possible combinations and cast specimens in the laboratory. Work has begun on computer simulation of concrete in order to optimize proportions and properties. This work needs to be continued so that most of the details of mix design can be worked out through such simulations, with only small-scale laboratory follow-up testing needed to verify predictions. These models must be capable of designing concrete mixes incorporating recycled materials, as well as special mixes for maintenance or rehabilitation activities.

4. *Use of advanced concrete materials*

Concrete mixes are becoming more and more complex. Research is needed to determine the effect of admixtures, and their interaction, on the long-term performance of PCC. In addition, evaluation of other advanced materials, such as fiber of various types, and a range of cementitious and pozzolanic materials will be conducted in order to determine their effect on performance of the concrete in both the plastic and hardened conditions.

PAVEMENT EVALUATION AND STRUCTURAL DESIGN

5. *Pavement response and performance data for design and analysis*

Most design and analysis procedures for rigid pavements are based on assumptions as to the behavior of concrete pavements under a range of environmental conditions and loading. The lack of agreement, even among experts in the area, as to the magnitude and prevalence of the effect of these factors indicates the need for further study and clarification. Current studies are systematically evaluating the effects of curling and warping of jointed pavements and these effects in combination with loads. This information, along with performance data, needs to be formatted so that it can be used in design, analysis, and evaluation processes leading to HPCP. This information would feed into the AASHTO 2002 design guide, as well as later design guides.

6. *Approaches for prevention of structural distress and deterioration*

The performance of in-service pavements needs to be evaluated for possible deficiencies in the currently used rigid pavement design procedures. Use of LTPP data will be an integral part of this evaluation, and the results will be used in support of the development of the AASHTO 2002 design guide. Design procedures for reinforcing steel will be evaluated, and an optimized procedure will be developed for jointed reinforced concrete pavement (JRCP) and continuously reinforced concrete pavement (CRCP). Also, optimized design procedures for lean concrete bases will be developed based on LTPP data and data collected through FHWA's test and evaluation project 30.

7. *New design concepts for PCC construction and rapid repair*

The three currently used new pavement types (in order of use) are: jointed plain concrete pavement (JPCP), continuous reinforced concrete pavement (CRCP), and jointed reinforced concrete pavement (JRCP). They have all been around for some time, and all can have performance problems. Because JPCP and CRCP have the greatest potential for HPCP, they are the focus of future design improvements. New design concepts for construction and/or rapid repairs may also need to be developed to help deliver the HPCP concept. These might include such approaches as precast/prestressed concrete slabs or post-tensioned pavements. The merits of two-lift construction, as practiced in Europe and demonstrated in Detroit, must also be explored.

8. *Performance-based rehabilitation strategies*

In order to be successful, an ongoing rehabilitation program must have a series of key elements. Rehabilitation trigger values must be defined for each performance element of concern so that rehabilitation is scheduled and performed in a timely manner. Performance models must be developed to predict the performance of various rehabilitation treatments. Guidelines for selection of the appropriate rehabilitation options must be developed and provided in an easy-to-use format.

PERFORMANCE SPECIFICATIONS AND CONSTRUCTION PROCEDURES

9. *Effect of construction equipment and procedures*

The size and sophistication of concrete paving equipment has greatly increased over the past several years. The effect of these changes on the performance of pavements constructed with this equipment should be carefully evaluated so that it can be optimized. This needs to be coordinated with the investigations of materials and mix design to ensure that the construction equipment and the mixes being developed are compatible with each other and that HPCP is the result. Pavement texturing and curing must be investigated and optimized as a part of this effort. Close cooperation with the paving and ready-mixed concrete industries and equipment manufacturers is a necessity to meet this objective.

10. *Nondestructive testing (NDT) and other innovative techniques for concrete pavement evaluation*

A number of NDT techniques and other available technologies have the potential to improve our ability to evaluate the characteristics and properties of concrete mixes and concrete pavements. One pressing example is the need for a quality control procedure for determining the placement of dowel bars at joints. This problem will be addressed in partnership with the concrete paving industry. A workshop of viable NDT techniques for concrete will be developed and delivered. This workshop will address a wide range of concrete and concrete pavement properties and characteristics, as well as the techniques to measure them.

11. *Performance-related specifications (PRS) for rigid pavements*

FHWA has had an ongoing program of research in the area of PRS for rigid pavements to help ensure the construction of HPCP. States are advancing through the continuum of cookbook specifications to quality control/quality assurance (QC/QA) specifications to PRS-based specifications. Determination and setting of limits on performance parameters are part of the development process. In order for this program to succeed, advanced nondestructive tests must be developed, validated, and implemented as necessary to measure the performance parameters. This test development will be coordinated with nondestructive testing techniques. PRS delivery depends on buy-in to the concept and then cooperation by the States and industry.

12. *Advanced traffic management and construction strategies*

Under certain situations, user costs and delays can outweigh all other considerations for pavement construction, reconstruction, or rehabilitation. In these cases, special steps must be taken to minimize lane closures and reduced traffic access. Examples of strategies currently used in fast-track paving are nighttime paving and high early strength concrete, which allow pavements to be opened earlier to traffic. These and other logistical and construction options need further evaluation in order to develop a set of guidelines for delivery to the States.

13. *Pavement smoothness*

Initial (as-constructed) smoothness of concrete pavements has long been an important issue in the construction of concrete pavements. Advances in concrete materials and paving equipment have enabled the construction of ever-smoother pavements. Currently there is no definitive guideline as to what level of smoothness is appropriate for concrete pavements. Initial smoothness will be investigated to determine its impact on long-term pavement performance, as well as on ride quality, as perceived by the traveling public.

Table 1. PORTLAND CEMENT CONCRETE PAVEMENT PROJECTS

Materials Characterization and Mixture Design

To extend concrete pavement life through enhanced equipment and procedures for materials selection, distress potential prediction, and mixture design optimization.

Topic Areas:

(1) Improved testing methods for materials characterization and selection
(2) Procedures for predicting and preventing materials-related distress
(3) Models and procedures to achieve high-performance concrete (HPC) for pavements
(4) Use of advanced concrete materials

(1) Improved testing methods for materials characterization and selection

Project Title	Project Description	Project Type
DP-75 Field Management of Concrete Mixes	Demonstrate state-of-the-art testing equipment using the mobile concrete laboratory	Delivery/Deployment Contract
TE-34 SHRP Showcase Contracts	Deliver information on SHRP products; conduct equipment loan program; and provide technical assistance	Delivery/Deployment Contract
Petrographic Manual	Reprint manual and deliver to field	Delivery Staff
Petrographic Techniques	Develop and deliver workshop based on Petrographic Manual	Development/Deployment Contract
Petrographic Examination	Develop expert system for petrographic examination	Development Contract
PCC Rheology and Workability	Develop a simple and workable test for the determination of PCC workability	Research/Development Contract
Freeze-Thaw Durability	Investigate modifications to the freeze-thaw test developed under SHRP	Research Staff
Thermal Coefficient of Expansion	Develop test procedures and equipment to measure the thermal coefficient of expansion of concrete	Development Staff
PCC Permeability	Evaluate various permeability test methods in relation to concrete durability	Research Staff
Shrinkage Potential	Evaluate shrinkage potential of PCC	Research Staff
Micro-Cracking	Investigate the field occurrence and the impact of micro-cracking on long-term performance	Research Contract
Guidelines for Optimizing Materials and Mix Design for HPC	Develop synthesis of various topics related to materials and mix design for HPC	Development Contract
Effect of Cementitious Compounds	Investigate effect of cementitious compounds on concrete performance	Research NCHRP
Aggregate Characterization	Aggregate tests related to field performance	Development NCHRP
NHI Course 13119 - Portland Cement Concrete Materials	Training course to provide introduction or refresher for inspectors & engineers working in PCC construction	Delivery Staff

Table 1. PORTLAND CEMENT CONCRETE PAVEMENT PROJECTS (CONTINUED)

Project Title	Project Description	Project Type
(2) Procedures for predicting and preventing materials-related distress		
Early Distress in Concrete Pavements	Deliver report to field	Delivery Staff
Automated Image Analysis System for PCC Air Voids Analysis	Develop procedure to analyze air voids in PCC using automated linear traverse systems and semi-automated point count systems	Development Staff
Materials-Related Distress	Develop guidelines for detection, analysis, and treatment of materials-related distress in PCC	Development Contract
Mix-Specific ASR Potential	Evaluate existing tests to determine reaction of aggregate sources and concrete mixes	Development Staff
Remaining ASR Distress Potential	Develop procedure to evaluate remaining ASR distress potential in existing concrete pavement	Development Contract
Guidelines on PCCP Evaluation and Repair/Rehabilitation/Recyling Options	Synthesis of research/development projects	Development Contract
(3) Models and procedures to achieve HPC for pavements		
DP-119 Quality Concrete	Demonstrate quality concrete mix design, batching, and construction procedures	Development Contract
Evaluation of PCC Strength and Associated Properties	Develop guidelines on optimized strength concrete for pavement	Development Contract
Statistical Approach to Mix Optimization	Investigate feasibility of using statistical experimental design to optimize concrete mixtures	Development Staff
Link Materials Databases	Evaluate linking materials databases from different sources and agencies into integrated system	Development Contract
Recycled PCC Aggregate	Develop guidelines for recycled PCC in pavements	Development Contract
(4) Use of advanced concrete materials		
Effect and Interaction of Admixtures	Determine effect and interaction of concrete admixtures on long-term performance of PCC	Research Contract
Advanced Materials Evaluation	Evaluate advanced materials as part of TE-30, such as fiber reinforcing and GGBF slag	Research/Development Work Order

Table 1. PORTLAND CEMENT CONCRETE PAVEMENT PROJECTS (CONTINUED)

Pavement Evaluation and Structural Design

To achieve HPCP by extending the service life and minimizing the life-cycle costs of concrete pavements, through enhanced design procedures based on a better understanding of the relationships among pavement design, response, and performance.

Topic Areas:

(5) Pavement response and performance data for design and analysis
(6) Approaches for prevention of structural distress and deterioration
(7) New design concepts for PCC construction and rapid repair
(8) Performance-based rehabilitation strategies

(5) Pavement response and performance data for design and analysis

Project Title	Project Description	Project Type
Workshop on Portland Cement Concrete Pavement Design	Develop workshop on PCC pavement design and construction based upon recently completed research	Development/Delivery Contract/Staff
Interactive CD-ROM on PCC Pavement Design and Construction	Develop and deliver interactive CD-ROM of recommended practices for PCC design & construction	Development/Delivery Contract
Curling and Warping	Conduct research on the effect of curling and warping on the performance of PCC pavement	Research/Development Research/Development Contract
Development of Roughness in PCCP	Time sequence longitudinal profile data and analysis to explore the development of roughness	Research/Development Contract
LTPP Product Development and Delivery (I)	Develop/deliver LTPP products from research and analysis from LTPP for implementation team	Development/Delivery/Deployment Contract/Staff
LTPP Product Development and Delivery (II)	Develop/deliver LTPP products from research and analysis from LTPP for HNG-453	Development/Delivery/Deployment Contract/Staff

(6) Approaches for prevention of structural distress and deterioration

Optimized Steel Design for JRCP and CRCP	Develop an optimized steel design procedure for JRCP and CRCP	Development/Delivery Contract
Pavement Structural Design (SPS-2)	Utilize LTPP SPS-2 project to refine PCC structural design process in support of AASHTO 2002 guide	Development/Delivery Contract/Staff
Optimized LCB Design	Develop a procedure to design an optimized LCB for PCC using results from TE-30 and SPS-2 projects	Development/Delivery Contract

Table 1. PORTLAND CEMENT CONCRETE PAVEMENT PROJECTS (CONTINUED)

Project Title	Project Description	Project Type
(7) New design concepts for PCC construction and rapid repair		
Accelerated Testing of UTW	Test and evaluate ultra-thin whitetopping (UTW) in ALF, in partnership with ACPA	Development Partnership
Guidelines for Whitetopping	Develop/deliver guidelines for whitetopping existing asphalt pavements including UTW	Development/Delivery Contract
Precast PCC Panels for Pavements	Investigate feasibility of using precast PCC for new pavement and rapid repair of existing pavements	Research/Development/Delivery Contract
Advanced Design Features from TE-30 Projects	Test and evaluate advanced design features from TE-30 projects	Development/Delivery Contract
Alternative Load Transfer Devices	Develop guidance for cost-effective use of load devices based on TE-30 projects	Development/Delivery Contract
Thin-Bonded Overlay Guidelines	Develop guidelines based upon ISTEA 6005 TBO projects	Development/Delivery Contract
Guidance on Two-Lift Construction	Develop/deliver guidance on cost-effective use of two-lift construction using evaluations from TE-30 projects	Development/Delivery Contract/Staff
High-Performance Concrete Pavements	Test and evaluate high-performance concrete pavement projects features	Development Coop Agreement
(8) Performance-based rehabilitation strategies		
Unbonded PCC Overlays	Deliver NCHRP report and develop guidance based upon report	Development/Delivery Staff/Contract
NHI 13108 - Techniques for Pavement Rehabilitation	Develop updated material for course relative to concrete rehab based upon SP-205 & other projects	Development Staff
SP 205 - Quality Concrete Pavement Rehabilitation and Preservation	Test & evaluate existing effective techniques for PCC rehab and repair; develop & deliver guidelines	Research/Development/Delivery Staff
Guidance on Patch Quality	Develop guidance on PCC patch quality; extension of H-106	Development/Delivery Contract/Staff
Repair and Rehabilitation Materials and Techniques for PCC	Research on cost-effective rehabilitation materials and techniques	Research/Development Contract
SPS-7 Bonded Concrete Overlay	Develop guidance on design and construction of bonded concrete overlays, based on SPS-7 & other projects	Development/Delivery Contract
Performance of Alternate Rehabilitation Treatments	Evaluation of data on performance of alternate rehabilitation treatments (GPS/SPS-6)	Development/Delivery Contract

Table 1. PORTLAND CEMENT CONCRETE PAVEMENT PROJECTS (CONTINUED)

Performance Specification and Construction Procedures

To consistently build HPCP that can be opened to traffic sooner, through enhanced equipment and procedures; performance-related specifications; advanced traffic management; and construction planning strategies.

Topic Areas:

(9) Effect of construction equipment and procedures
(10) NDT and other innovative techniques to evaluate concrete pavement
(11) Performance-related specifications for rigid pavements
(12) Advanced traffic management and construction strategies
(13) Pavement smoothness

(9) Effect of construction equipment and procedures

Project Title	Project Description	Project Type
Guidelines for Joint Sealant Use	Develop guidelines on when and how to seal jointed concrete pavement based on TE-30 and other projects	Development/Delivery Contract
Guidance on Corrosion Resistant Dowels	Develop guidance on corrosion resistant dowels, based upon TE-30 projects and other sources	Development/Delivery Contract
Guidelines for Joint Design	Develop/deliver guidance on joint design	Development/Delivery Contract
HIPERPAV	Develop/validate HIPERPAV	Development/Delivery Contract
Performance of PCCP Curing Materials and Techniques	Investigate the effectiveness of current curing materials and practices	Research/Development Contract
Guidelines for Quality Concrete	Develop guidelines for joint sawing, proper consolidation and curing through DP119 projects	Development/Delivery Contract/Staff
NHI Course 13133 - Construction of PCC Pavements	Training course to provide overview of the entire portland cement concrete paving process	Delivery Partnership
Managing Physical, Chemical & Mechanical Development of PCC during Construction	Develop guidelines/workshop based upon synthesis of six research/development projects	Development Contract
Texturing Guidelines	Develop field-validated texturing guidelines based on TE-30 projects	Development/Delivery Contract
Friction and PCC Texture	Collect and analyze data to explore/validate relationships between friction and PCC texture	Research/Development Contract

Table 1. PORTLAND CEMENT CONCRETE PAVEMENT PROJECTS (CONTINUED)

Project Title	Project Description	Project Type
(10) NDT and other innovative techniques for concrete pavement evaluation		
Quality Control Procedures for Dowel Bar Placement	Develop QC procedure for dowel bar placement (ACPA)	Development/Delivery Partnership
NDT Equipment Workshop	Provide for national effort to showcase and promote NDT products for concrete pavements	Development/Delivery Contract
Determination of In Situ Concrete Strength	Investigate method of determining concrete strength nondestructively during and after curing	Research/Development Contract
(11) Performance-related specifications for rigid pavements		
Lab/Field Investigation of Performance-Related PCC Pavement Construction Variables	Establish relationships between PCC pavement construction quality characteristics and pavement performance	Research/Development Contract
Validation of Performance Models for PCC Pavement Construction	Validate improvements to distress prediction models used in prototype PRS for PCC paving	Research/Development Contract
Evaluation of Initial PRS Systems	Develop a conference to inform SHAs and contractors about PRS concepts, benefits, and specifications	Development Contract
Optimization of Acceptance Criteria and Establishment of Cost-Effective PRS	Collect and summarize information on costs, and establish measures of specification effectiveness	Research/Development Contract
Effectiveness of Construction Specifications	Conduct an investigation on the effectiveness of quality assurance specifications	Research Staff Study
Development of PRS for Overall Pavement Structure	Extend PRS guidelines and concepts for pavement surfaces to the entire pavement structure	Research/Development Contract
Development of PRS for PCC Pavement Rehabilitation	Extend PRS guidelines and concepts for new pavement construction to PCC rehabilitation	Research/Development Contract
PRS Training Courses	Conduct executive-level and working-level courses to educate SHAs and industry on PRS concepts	Development/Delivery/Deployment Contract
Test and Evaluation Project for PRS	Construct T+E projects for PRS	Development/Delivery Contract

Table 1. PORTLAND CEMENT CONCRETE PAVEMENT PROJECTS (CONTINUED)

Project Title	Project Description	Project Type
(12) Advanced traffic management and construction strategies		
High-Volume, High-Speed Corridor Reconstruction	Develop and deliver workshop on high-volume, high-speed corridor reconstruction using PCC	Development/Delivery Cooperative Agreement
(13) Pavement smoothness		
Effect of Initial Smoothness on Long-Term Performance	Determine the effect of initial smoothness on long-term performance of PCCP	Research/Development Contract
Other		
Management Consultant	Provide management support for the Concrete Pavement R&T program	Various Contract
Partnership Agreement with ACPA	Conduct research/development/delivery/ deployment services as specified	Various Partnership
International HPCP Technology Assessment	Conduct scanning trip to other countries to assess innovative technology for application in US	Delivery/Deployment Contract
National/International Conferences on HPCP	Sponsorship of national and international conferences to showcase HPCP accomplishments	Delivery/Deployment Contract
Laboratory Support Services	Additional support services, not included in individual staff studies	Various Staff

Table 2. FUNDING SUMMARY FOR PORTLAND CEMENT CONCRETE PAVEMENT PROGRAM

Program Elements	Funding Need by Fiscal Year ($1000)					
	1998	1999	2000	2001	2002	2003
Materials Characterization and Mixture Design						
(1) Improved testing methods for materials characterization and selection	496	1480	1070	1450	1350	1000
(2) Procedures for predicting and preventing materials-related distress	0	50	0	0	250	250
(3) Models and procedures to achieve HPC for pavement	1045	2000	2000	1000	1000	50
(4) Use of advanced concrete materials	20	50	200	250	20	20
Subtotals	**1561**	**3580**	**3270**	**2700**	**2620**	**1320**
Pavement Evaluation and Structural Design						
(5) Pavement response and performance data for design and analysis	106	250	250	200	200	110
(6) Approaches for prevention of structural distress and deterioration	0	100	100	170	150	20
(7) New design concepts for PCC construction and rapid repair	1000	2925	2415	2270	2250	2250
(8) Performance-based rehabilitation strategies	450	260	400	400	50	0
Subtotals	**1556**	**3535**	**3165**	**3040**	**2650**	**2380**
Performance Specifications and Construction Procedures						
(9) Effect of construction equipment and procedures	560	345	265	525	425	75
(10) NDT and other innovative techniques for concrete pavement evaluation	2500	100	300	300	300	0
(11) Performance-related specifications for rigid pavements	305	1965	1100	200	200	200
(12) Advanced traffic management and construction strategies	0	0	0	0	0	0
(13) Pavement smoothness	0	0	0	200	200	0
Subtotals	**3365**	**2410**	**1665**	**1225**	**1125**	**275**
Other	**235**	**890**	**900**	**1020**	**920**	**970**
Totals for Portland Cement Concrete Pavement	**6717**	**10415**	**9000**	**7985**	**7315**	**4945**

Table 3. CONCRETE PAVEMENT RESEARCH AND TECHNOLOGY ACTIVITIES TIMELINE AND PRODUCTS

Technical Topics	Timeline						Comments
	1998	1999	2000	2001	2002	2003	
1 Improved methods for materials characterization and selection	Deliver DP-75 - Field Mgt of Concrete Mixes						
	Deliver TE-34 Concrete Durability Showcase						
	Deliver Petrographic Manual reprint	Develop workshop on petrographic techniques for non-experts	Deliver 5 or more workshops				
			Research on Expert System for Petrographic Examination				
	Research on PCC Rheology and Workability		Develop/Deliver/Deploy Guidelines for Optimizing Materials and Mix Design for PC [sym]				**Product:** Guidelines for Optimizing Materials and Mix Design for High-Performance Concrete for Highway Use
	Research on Freeze Thaw Durability						
	Research on Thermal Coefficient of Expansion						
	Research on PCC Permeability						
		Research on Evaluation of Shrinkage Potential					
		Microcracking: Field Occurrence and Impact on Performance					
	Research on Effects of Cementitious Compounds - NCHRP						
	NCHRP 4-20 Aggregate Characterization						
	NHI-13119 Portland Cement Concrete Materials course						

Table 3. CONCRETE PAVEMENT RESEARCH AND TECHNOLOGY ACTIVITIES TIMELINE AND PRODUCTS (CONTINUED)

Technical Topics	Timeline						Comments
	1998	1999	2000	2001	2002	2003	
2 Procedures for predicting and preventing materials-related distress	Deliver Report on Early Distress of Concrete Pavement						
	Research on Materials Related Distress			Develop/Deliver/Deploy Guideline & Repair, Rehabilitation		PCCP Evaluation	**Product:** Guidelines for PCCP Evaluation & Repair, Rehabilitation, or Recycling Options
		Research on Mix-Specific ASP Potential		Develop Procedure to Evaluate Mix-specific ASP Potential			
		Research on Evaluating Remaining ASR Potential in existing concrete		Develop Procedure to Evaluate Remaining ASR Distress Potential in existing pavement			
3 Models and procedures to achieve HPC for pavements		Research on Air Void Analysis System					Component of Optimizing Materials and Mix Design for HPC
	Develop Guidelines for Optimized Strength Concrete						
	DP-119 Develop Workshop on Quality Concrete		Deliver DP-119 Workshop to 10 states				
	Research on Statistical Approach to Mix Optimization						
						Develop Linking Materials Databases	
4 Use of advanced concrete materials	Research on Recycled PCC Aggregate	Develop Guidelines for mix/str design of Recycled PCC	Deliver Guidelines for Recycled PCC in Pavements				Component of Guidelines for PCCP Evaluation & Repair, Rehabilitation, or Recycling Options
			Research on Effect and Interaction of Admixtures				Component of Guidelines for PCCP Evaluation & Repair, Rehabilitation, or Recycling Options
	Advanced Materials Evaluation (TE 30)						

Table 3. CONCRETE PAVEMENT RESEARCH AND TECHNOLOGY ACTIVITIES TIMELINE AND PRODUCTS (CONTINUED)

Technical Topics	Timeline						Comments
	1998	1999	2000	2001	2002	2003	
5 Pavement response and performance data for design and analysis	Develop Workshop and Guidelines on "Rigid Pavement Design and Construction"			Deliver 6 or more Workshops			
		Develop Interactive CD-ROM on Rigid Pavement Design and Construction					
	Research on Effect of Curling and Warping of JPCP						Component of Construction Guidelines for Managing Physical, Chemical, & Mechanical Development of PCC
				Explore Development of Roughness in PCCP			
	LTPP Product Development, Delivery and Deployment -LTPP Implementation Team						
	LTPP Product Development, Delivery and Deployment - HNG-45						
6 Approaches for prevention of structural distress and deterioration		Develop optimized steel design of JRCP and CRCP		Deliver Guidelines to Field			
				Research on pavement structural design (SPS-2)			
				Develop Optimized LCB Design			
7 New design concepts for PCC construction and rapid repair	Research on Accelerated Testing of UTW						
		Develop guidelines for Whitetopping including UTW		Deliver Demo on Whitetopping/UTW			
		Research on Design/Construction of Pre-cast PCC Panels for Pavement					
			TE-30 Test and Evaluation Projects				
	Develop guidance on Alternative Load Transfer Devices						
		Develop TBO guidelines based on 6005 projects					
			Advanced Design Features (TE-30)				
		Deliver guidance on 2 lift Construction TE-30					
8 Performance-based rehabilitation strategies		Deliver NCHRP Report on Evaluation of Unbonded Overlays	Develop/Deliver Workshop on Unbonded Overlays based upon NCHRP Report				
	Develop update to NHI Course "Techniques for Pavement Rehab"			Delivery of updated course			
	Develop SP-205 Workshop/Guidelines		Deliver SP-205 Workshop				Component of Guidelines for PCCP Evaluation & Repair, Rehabilitation, or Recycling Options
		Develop guidance on patch quality - ext of H-106					
			Research on Evaluation of Repair and Rehabilitation Methods and Techniques				
		Research on SPS-7 Bonded Concrete Overlay		Deliver guidelines on BCO			
				Research on performance of alternate rehabilitation treatments (GPS/SPS-6)			

Table 3. CONCRETE PAVEMENT RESEARCH AND TECHNOLOGY ACTIVITIES TIMELINE AND PRODUCTS (CONTINUED)

Technical Topics	Timeline						Comments
	1998	1999	2000	2001	2002	2003	
9 Effect of construction equipment and procedures		Develop guidelines for joint sealant use	Deliver Guidelines				
		Develop guidance on corrosion resistant dowels	Deliver Guidelines				
			Develop Guidance on Joint Design		Deliver Guidance on Joint Design		
	Develop/Validate HIPERPAV	Deliver HIPERPAV through workshop		Develop/Deliver/Dep Chemical & Mech	Guid s on Managing Physical t Development Construction Cost	PCC during	Project Guidelines for Managing Physical, Chemical & Mechanical Development of PCC during Construction
	Research on Curing Materials and Procedures						
		Develop guidelines for joint sawing, proper consolidation and curing of PCC pvt (DP119)		Deliver Guidelines			
	Deliver NHI course on Concrete Pavement Construction						
				Develop Field Validated Texturing Guidelines - TE-30	Deliver Guidelines		
			Develop Guidelines on PCC Friction and Texture		Deliver Guidelines		
10 NDT and other innovative techniques for concrete pavement evaluation	Develop/Deliver Quality Control Procedures for Dowel bar placement (ACPA)						
	Develop NDT Equipment Workshop (DP-75)		Deliver NDT Equipment Workshop				
			Develop test to determine in situ strength of concrete				

Table 3. CONCRETE PAVEMENT RESEARCH AND TECHNOLOGY ACTIVITIES TIMELINE AND PRODUCTS (CONTINUED)

Technical Topics	Timeline						Comments
	1998	1999	2000	2001	2002	2003	
11 Performance-related specifications for rigid pavements	Develop Validation of Performance Models for PCC Pavement Construction						Product: Viable Performance-Related Specification for PCCP
	Develop Evaluation of Initial PRS			Test and Evaluation Project for Initial PRS			
		Develop Optimized Acceptance Criteria and Establishment of Effective PRS					
	Research on Effectiveness of Construction Specifications						
			Develop PRS for Overall Pavement Structure				
			Develop PRS for PCC Rehabilitation				
				Develop PRS Training Course			
					Test and Evaluation Project for Final PRS (OTA)		
12 Advanced traffic management and construction strategies	Develop Workshop on High-Volume, High-Speed Corridor Reconstruction	Deliver Workshop					
13 Pavement smoothness				Research on Effect of Initial Smoothness on Long-term Performance			

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