Strategic Plan for Partnered Pavement Research Program (PPRC) for 2003/2004

Prepared for:
California Department of Transportation

University of California, Berkeley;
University of California, Davis
California Department of Transportation
Dynatest Consulting, Inc.
Council for Scientific and Industrial Research, South Africa
EXECUTIVE SUMMARY

This document is the Strategic Plan for Partnered Pavement Research for 2003/2004. This document was prepared by the University of California Pavement Research Center and the California Department of Transportation, Division of Research and Innovation, Office of Pavement Research. The goals and projects included in this plan were prioritized and approved by the Pavement Standards Team and approved by the Pavement Steering Committee. This document describes a plan for work to be completed by the University of California Pavement Research Center and its subcontractors (UC Contract Team) and partners under the direction of the California Department of Transportation (Caltrans). This work is primarily funded by Caltrans through Research Contract # 65A0077, which is in effect from 29 June 2000 through 30 June 2004. The total cost of the contracted work to be performed under the agreement is $20,000,000.

The contract and program organization allow for leveraging of Caltrans and UC Contract Team resources and research results to obtain results and assistance from their partners. Partners or potential partners are listed in the description of each implementation project and research goal in this strategic plan.

A background document has been prepared describing the long-term vision for development of Caltrans pavement technology through partnered pavement research (downloadable at www.its.berkeley.edu/pavementresearch). The long-term vision of the Partnered Pavement Research Program is to improve Caltrans pavement technology so that Caltrans can more efficiently complete its mission and meet the needs of the public.

The work included in this Strategic Plan is designed to meet the following needs of Caltrans:

• provide Caltrans with an ongoing and improving technical resource for pavements,
• address immediate needs Caltrans is facing with regards to pavement technology policy decisions, and needs for new solutions to immediate problems,

• continue to develop new technology that has the potential for large payoffs in the longer-term period of three to ten years, and

• facilitate implementation of new pavement technology, and to aid in the evaluation of existing technology through forensic studies.

All work performed to address the immediate needs of Caltrans is intended to also provide information and technology to complete longer term research goals that will have large payoffs for Caltrans in the future. Two key principles in the Mission for Partnered Pavement Research are to avoid duplicating work done by other researchers, and to incorporate useful results, methods, and skills from outside the UC Contract Team wherever possible.

The work described in this Strategic Plan includes Research Services (including Implementation Projects), Research Goals for which work is already underway, and proposed new Research Goals and Implementation Projects. Summary descriptions of all Research Services and Research Goals are included in this document, and a progress report on work included in the previous December 2000 version of this Strategic Plan. Detailed work plans have been developed for many of the Research Goals and Implementation Projects, as noted in the summary descriptions included in this strategic plan.

Research Services in this Strategic Plan include:

• Development of a Program for Partnered Pavement Research,

• Continued development of the Pavement Research Database,

• Provision of pavement technology advice to Caltrans, as needed,
• Special Forensic Investigations of pavement performance, through sampling, laboratory testing, instrumentation, monitoring, and analysis of results. Special forensic studies currently underway include:
  · Longitudinal joint compaction
  · Deep in-situ recycling (DISR) using recycled AC as unbound base: field and laboratory testing
  · Deep in-situ recycling (DISR) using foamed asphalt: laboratory testing (SR20)
  · Maintenance surface treatments for noise and performance: test section layout and performance monitoring (SR138)

• Implementation Projects for technologies under evaluation by Caltrans. This work includes help with experiment design, specification development, construction, sampling, laboratory testing, instrumentation, monitoring, and analysis of results. Implementation Projects currently underway are:
  · Calibration of HIPERPAV for California Conditions
  · Evaluation of Concrete Maturity Meters
  · Use of the Dynamic Cone Penetrometer (DCP) for maintenance, rehabilitation and reconstruction site evaluation
  · Quality Assurance Laboratory Testing for AC Long-life pavement mix designs (I710)
  · Development of new asphalt concrete QC/QA pay factor tables

Prioritized Implementation Projects to be started as part of this strategic plan are:
• Calibration Sites for Falling Weight Deflectometers (FWD), Profilers, and Skid Resistance Devices

• Evaluation of Profilers and Automated Distress Data Collection Equipment

• Process for Evaluating Recycling Strategies for Pavement Materials, with first case study “Recycling of PCC Grindings Slurry”

• Development of Integrated Databases to Make Pavement Preservation Decisions (FPP 3.5)

• Documentation of pavement performance data for pavement preservation strategies and evaluation of cost-effectiveness of such strategies. (FPP 3.2 and 6.6)

• Development of Improved Patching Procedures for OGAC Overlays

• Pilot Projects for Compaction Specifications for Aggregate Base and Aggregate Subbase/Use of the Rapid Compaction Control Device (RCCD)

• Pilot Projects for Chip Seal Specifications based on South African Design Practice (FPP Statement 2.1),

• Development of guidelines for effective maintenance treatment evaluation test sections (FPP 4.1)

• Mix design procedure for asphalt concrete base for rigid pavements

Work is currently underway on the following Research Goals:

• Development of the First Version of a Mechanistic-Empirical Pavement Rehabilitation, Reconstruction and New Pavement Design Procedure for Rigid and Flexible Pavements (pre-Calibration of AASHTO 2002), including

  • Evaluation of AASHTO 2002 procedures for Caltrans implementation
· Seasonal deflection monitoring sites
· Climate database
· Truck traffic database (WIM)
· Typical Caltrans materials properties for mechanistic-empirical design input
· Design algorithms
· Customize FHWA Life Cycle Cost Analysis software
· Verification/calibration of design systems

- Evaluation of Rigid Pavement Long-Life Pavement Rehabilitation Strategies (LLPRS-Rigid) (HVS Goal 4)
- Performance of Drained and Undrained Flexible Structures Under Wet Conditions (HVS Goal 5)
- Development of Asphalt Concrete Rutting Performance Tests and Analysis Procedures
- Calibration of Mechanistic-Empirical Design Models
- Development of Rehabilitation Construction Productivity Analysis Products, including:
  - Construction productivity analysis
  - Construction closure traffic delay estimation
  - Inclusion of Life Cycle Cost Analysis
- Verification of Asphalt Concrete Long-Life Pavement Strategies (HVS Goal 6), including:
  - Crack, seat and overlay
• Full-depth reconstruction

• Dowel Bar Retrofit of Rigid Pavements (HVS Goal 7)

• Investigation of Asphalt Concrete Moisture Damage (HVS Goal 8)

• Development of Improved Rehabilitation Designs for Reflection Cracking (HVS Goal 9)

• Evaluation of Hydraulic Cement Concrete Mix Design for Pavements

Proposed new Research Goals, or additional tasks for Research Goals currently underway are:

• Additional task to be added to “Investigation of Asphalt Concrete Moisture Damage (HVS Goal 8)”:
  
  · HVS tests on AC mixes to verify field performance data base analysis on relative contribution to moisture damage of aggregate source, mix design, construction compaction, traffic repetitions, anti-stripping additives.

• Additional task to be added to “Development of Improved Rehabilitation Designs for Reflection Cracking (HVS Goal 9)”:
  
  · Laboratory asphalt binder testing and mix fatigue beam testing to evaluate performance-related parameters (including SSV and SSD) for AC binder specification for cracking.

• Development of Improved Mix and Structural Design and Construction Guidelines for Deep In-Situ Recycling (DISR) of Cracked Asphalt Concrete as Stabilized or Unstabilized Bases (HVS Goal *)
• Validation of Asphalt Concrete QC/QA Pay Factors (HVS Goal *)

• A Framework for Implementing Innovative Contracting Methods For Transportation Infrastructure Rehabilitation/Reconstruction

• Development of Integrated Pavement Strategy Decision Support System

This Strategic Plan is intended to provide a basic description of the work to be performed by the UC Contract Team for the Partnered Pavement Research Program over the next two to three years. This Strategic Plan includes work past the end of the current termination of the Partnered Pavement Research Contract in June 2004, which will be continued if there is a subsequent contract. This Strategic Plan will need to be updated in approximately two years (winter, 2004).

Detailed test plans have been, or will be, prepared for each Research Goal. Each Research Goal may change somewhat when the test plans are developed, based on additional information, changes in available resources, and any changes in the needs of Caltrans and the partners for that Research Goal. The objectives of each Research Goal should not change without a review process by Caltrans.

* HVS Goal Number to be assigned if/when research goal prioritized for commencement and detailed test plan developed.
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<th>Description</th>
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<td>AB</td>
<td>Aggregate base</td>
<td>Material or pavement layer used in flexible and rigid pavements</td>
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<tr>
<td>AC</td>
<td>Asphalt concrete</td>
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<td>AC Long-life</td>
<td>AC Long-life</td>
<td>LLPRS strategies involving the use of asphalt concrete</td>
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<td>ADT</td>
<td>Average Daily Traffic</td>
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<td>ARHM-GG</td>
<td>Asphalt Rubber Hot Mix Gap Graded</td>
<td>Previous name for RAC Type G</td>
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<td>ATPB</td>
<td>Asphalt Treated Permeable Base</td>
<td>Drainage material or pavement layer used in flexible and rigid pavements</td>
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<tr>
<td>ADT</td>
<td>Average Daily Traffic</td>
<td></td>
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<td>BMP</td>
<td>Best management practice</td>
<td>Practices established to minimize environmental damage from highway construction and maintenance activities</td>
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<td>CAL/APT</td>
<td>Caltrans Accelerated Pavement Testing Program</td>
<td>Pavement research program performed by UC Berkeley and sub-contractors under Caltrans Research, from 1994 to 2000</td>
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<td>Caltrans</td>
<td>California Department of Transportation</td>
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<td>Concrete pavement</td>
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<td>Pavements with a portland cement concrete or hydraulic cement concrete layer as the primary structural layer</td>
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<td>Construction</td>
<td>Construction program of Caltrans</td>
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<tr>
<td>CSIR</td>
<td>Formerly Council for Scientific and Industrial Research (only acronym used now)</td>
<td>Sub-contractor in UC Contract Team, located in South Africa</td>
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<td>DBR</td>
<td>Dowel bar retrofit</td>
<td>Pavement rehabilitation strategy for restoring joint load transfer in concrete pavements</td>
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<td>Design</td>
<td>Caltrans Project Development program</td>
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<tr>
<td>Detailed test plan</td>
<td></td>
<td>A formal document prepared by the UC Contract Team that includes the detailed scope, tasks, and schedule for an implementation project or research goal</td>
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<td>DGAC</td>
<td>Dense graded asphalt concrete</td>
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<td>DISR</td>
<td>Deep In-Situ Recycling</td>
<td>In place strategy for grinding up of existing asphalt concrete and aggregate base materials and using them as a new base material, may include stabilization with asphalt and/or cement</td>
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<td>Districts</td>
<td>Caltrans districts</td>
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<td>Department of Transportation</td>
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<td>DPW</td>
<td>Department of Public Works</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<td>Flexible pavement</td>
<td>Pavements with an asphalt concrete layer as the primary structural layer</td>
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<td>FPP</td>
<td>Foundation for Pavement Preservation</td>
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<td>FWD</td>
<td>Falling Weight Deflectometer</td>
<td>Mobile equipment used to measure deflections on flexible and rigid pavements</td>
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<tr>
<td>Goal</td>
<td>A large comprehensive research goal of the Partnered Pavement Research Program</td>
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<tr>
<td>HVS</td>
<td>Heavy Vehicle Simulator</td>
<td>A large, mobile load frame and wheel loading system owned by Caltrans, used to perform accelerated pavement testing on full-scale pavement test sections</td>
</tr>
<tr>
<td>Implementation project</td>
<td>A limited research project of the Partnered Pavement Research Program to facilitate evaluation and potential implementation of a product, strategy, technique, etc.</td>
<td></td>
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<tr>
<td>LCCA and LCC</td>
<td>Life Cycle Cost Analysis and Life Cycle Cost</td>
<td>Analysis of the costs associated with a pavement strategy over a time period greater than the design life, accounting for time value of money</td>
</tr>
<tr>
<td>LLPRS</td>
<td>Long-life Pavement Rehabilitation Strategies</td>
<td>Strategies for rehabilitation/reconstruction of urban freeways meeting criteria for traffic/trucks and pavement condition, intended to provide 30 or more years design life and minimum maintenance</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Caltrans Maintenance program</td>
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<tr>
<td>MB</td>
<td>Modified Binder</td>
<td>Binders meeting the Caltrans MB specification</td>
</tr>
<tr>
<td>METS</td>
<td>Materials and Engineering Testing Service</td>
<td>Branch of Caltrans responsible for Bituminous Materials, Concrete Materials and Structural Section Design</td>
</tr>
<tr>
<td><strong>OPR</strong></td>
<td>Office of Pavement Rehabilitation</td>
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</tr>
<tr>
<td><strong>PPRC</strong></td>
<td>Partnered Pavement Research Center</td>
<td>The center established at the University of California (Berkeley and Davis) for performing the work under the Caltrans Research Partnered Pavement Research contract</td>
</tr>
<tr>
<td><strong>PSC</strong></td>
<td>Pavement Steering Committee</td>
<td>Organization in Caltrans consisting of program chiefs from METS, Construction, Design, Maintenance and District Directors.</td>
</tr>
<tr>
<td><strong>PST</strong></td>
<td>Pavement Standards Team</td>
<td>Organization in Caltrans with representatives from METS, Construction, Design, Maintenance, and District Materials Engineers. Formerly known as Office of Pavement Standards. Reports to the Pavement Steering Committee. Responsible for decisions regarding pavements in Caltrans.</td>
</tr>
<tr>
<td><strong>RAC Type G</strong></td>
<td>Rubber Asphalt Concrete Type G</td>
<td>A material or pavement layer that has an asphaltic binder containing recycled tires and a gap graded aggregate</td>
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<tr>
<td><strong>RACTAG</strong></td>
<td>Rubber Asphalt Concrete Technical Advisory Group</td>
<td>Caltrans/Industry group to study and make recommendations regarding rubber asphalt concrete products</td>
</tr>
<tr>
<td><strong>RAP</strong></td>
<td>Recycled Asphalt Pavement Research</td>
<td>Caltrans Division of Research, within Office of Research and Innovation (ORI)</td>
</tr>
<tr>
<td><strong>Rigid pavement</strong></td>
<td>Pavements with portland cement concrete or hydraulic cement concrete layer as the primary structural layer</td>
<td></td>
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<tr>
<td><strong>SPTC</strong></td>
<td>State Pavement Technology Consortium</td>
<td>Pooled fund group established to share pavement research, includes Departments of Transportation of California, Minnesota, Texas, and Washington</td>
</tr>
<tr>
<td><strong>TMP</strong></td>
<td>Traffic management plan</td>
<td>Plans developed by Traffic Operations to minimize traffic delay during pavement construction activities</td>
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<tr>
<td><strong>Traffic Operations</strong></td>
<td>Caltrans Traffic Operations program</td>
<td></td>
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<tr>
<td><strong>UC Contract Team</strong></td>
<td>University of California, Berkeley Contract Team</td>
<td>The prime contractor for the Partnered Pavement Research Center</td>
</tr>
<tr>
<td>Vision Document</td>
<td>Document prepared by the UC Contract Team in 2000 outlining a 10-15 year roadmap for the improvement of Caltrans pavement technology</td>
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<tr>
<td>WIM</td>
<td>Weigh-In Motion</td>
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<tr>
<td>WSDOT</td>
<td>Washington State Department of Transportation</td>
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1.0 INTRODUCTION AND SCOPE

This document is the Strategic Plan for Partnered Pavement Research, as of 15 April, 2003. This document describes a plan for work to be completed by the University of California, Berkeley Pavement Research Center and its subcontractors (UC Contract Team) and partners under the direction of the California Department of Transportation (Caltrans). This work is primarily funded by Caltrans through Research Contract # 65A0077 through 30 June, 2004. Some of the work included in this strategic plan cannot be completed before the completion of that agreement, as is noted in the estimated schedule for work included in this document.

Additional resources for some of the work may be obtained from other research partners and other sources within Caltrans.

1.1 Current Research Agreement between Caltrans and UC Contract Team

On 29 June, 2000, an agreement was signed between the California Department of Transportation (Caltrans) and the Regents of the University of California to perform “Partnered Pavement Research.” The title of the contract is Western Pavement Research Center. The Caltrans Contract Number is 65A0077.

The agreement expires on 30 June, 2004. The total cost of the contracted work to be performed under the agreement is $20,000,000. The annual limits of total expenditures for contracted work under the agreement are as follows:

- 1 June through 30 June, 2000: $100,000
- 1 July, 2000 through 30 June, 2001: $4,900,000
- 1 July, 2001 through 30 June, 2002: $5,000,000
- 1 July, 2002 through 30 June, 2003: $5,000,000
- 1 July, 2003 through 30 June, 2004: $5,000,000
Current subcontractors and major purchase agreement providers included under this research agreement include Dynatest Consulting, Inc. (Ventura, California), CSIR (South Africa), the University of California, Davis (UCD), the University of Illinois (Urbana-Champaign, Illinois), Symplectic Engineering Corporation (Berkeley, California), the Technical University of Vienna (Austria), the University of Maine, the University of Washington, and the US Army Corps of Engineers Cold Regions Laboratory. Each subcontractor has tasks in the work described in this Strategic Plan. The agreement contains provisions for short-term employment of technical specialists outside of the staff of the UC Contract Team to perform tasks within the research plan, and this has been very successfully applied to date. Technical specialists from the Technical University of Denmark, San Jose State University, ERES Consultants, and several pavement and materials consultants have recently contributed to specific goals and projects in the program.

The contract and program organization also allow for leveraging of Caltrans and UC Contract Team resources and research results to obtain results and assistance from their partners. Partners or potential partners are listed in the description of each implementation project and research goal in this strategic plan.

1.2 Long Term Vision for Caltrans Pavement Technology

A background document has been prepared describing the long-term vision for development of Caltrans pavement technology through partnered pavement research (downloadable at www.its.berkeley.edu/pavementresearch). The work included in this Strategic Plan meets the Mission and Vision statements included in that document. The long-term vision is to improve Caltrans pavement technology so that Caltrans can more efficiently complete its mission and meet the needs of the public. The “Vision” document provides an overview of the
long-term vision for Caltrans Pavement Technology, as well as details regarding specific elements envisioned for future Caltrans pavement technology.

The work included in this Strategic Plan is designed to meet the following needs of Caltrans:

- provide Caltrans with an ongoing and improving technical resource for pavements,
- address immediate needs Caltrans is facing with regards to pavement technology policy decisions, and needs for new solutions to immediate problems,
- continue to develop new technology that has the potential for large payoffs in the longer-term period of three to ten years, and
- facilitate implementation of new pavement technology, and to aid in the evaluation of existing technology through forensic studies.

All work performed to address the immediate needs that Caltrans faces are intended to also provide necessary information and technology to complete longer term research goals that will have large payoffs for Caltrans in the future.

Two key principles in the Mission for Partnered Pavement Research are to avoid duplicating work done by other researchers, and to incorporate useful results, methods, and skills from outside the UC Contract Team wherever possible, which is stated as follows:

“The [state-of-the-art] technology [provided to Caltrans] may be developed by the UC Contract Team, taken from other sources and verified and calibrated for use in California, developed in partnership with other entities through leveraging of Caltrans and UC Contract Team resources, or gathered directly from other sources, depending upon which method is most efficient.”
The work described in this Strategic Plan is designed to maximize the application of these principles.

Some of the proposed new work addresses problems identified at a Research Problem Statement Workshop held in Sacramento, June 21-22, 2001 by Caltrans, FHWA, and the Foundation for Pavement Preservation (FPP). Where appropriate, the relevant FPP research problem statement number from the workshop document “Pavement Preservation Research Problem Statements” will be noted in this Strategic Plan.

1.3 What is Partnered Pavement Research?

Implementation of research results produced by the PPRC has no value to its sponsors unless it is implemented. Implementation is greatly facilitated by identifying the departments and individuals within Caltrans who will ultimately implement the research and by their participation in the research activity from the beginning. Also, it is vital that Caltrans and external partners be found for each research goal to maximize the use of Caltrans pavement research funding and the resources of the Partnered Pavement Research Center (PPRC).

Potential external partners must be identified based on two criteria:

1) they have pavement needs that are covered partly or fully in the Caltrans research goal, and

2) they have an ability to provide resources that contribute towards completion of the research goal or increase the benefits obtained from the research goal.

Resources provided by external partners can include funding to augment Caltrans funding, results from research they are funding, materials, data, staff, pavement test sections, equipment, instrumentation, testing services, knowledge, or implementation. The mechanisms that permit partnering will vary. In many cases, it will be desirable to partner without contractual
agreements. In other cases, risk and financial and legal obligations will require a contract. Contractual agreements can be set up through direct contracts with the University of California (UC), with UC as contractor or contracting organization.

All research performed as part of the Partnered Pavement Research Program must have partners within Caltrans to interact with the researchers during the research work, such as Materials, Design, Maintenance, Construction, Traffic, Districts, or line functions (for example, Materials Engineers, or Maintenance Engineers), to facilitate implementation of the research. All research will be communicated to the Pavement Standards Team (PST), and, primarily through PST, to the Pavement Steering Committee (PSC). Coordination and communication across all Caltrans groups is needed. Partners will also be sought from organizations outside of Caltrans, including local agencies, contracting and materials industry groups, individual contractors and producers, other state DOTs, other universities in and out of California, and other national and international organizations.

1.4 Selection Process for New Goals and Implementation Studies

The Caltrans Pavement Steering Committee (PSC) holds the ultimate authority for setting Research work to be performed by the Partnered Pavement Research Program.

The selection process for the New Research Goals and Implementation Projects included in this strategic plan consisted of the following tasks:

Summarize and synthesize feedback from interaction Pavement Standards Team (PST), and other Caltrans headquarters and district staff regarding the most important pavement issues requiring new research. Wherever possible, include disparate problems identified by different sources into comprehensive experimental objectives and plans. Relate research needs identified through this process to the overall goals of Caltrans:
· Reliability
· Performance
· Flexibility
· Efficiency
· Safety

Review:

a. national pavement research programs such as those of the National Cooperative
   Highway Research Program, US Army Corps of Engineers, Federal Aviation
   Administration and Federal Highways Administration,

b. international programs such as those of the European Community, the South African
   national and provincial programs, and the Australian Road Research Board, and

c. state programs, particularly those of the partner states in the State Pavement
   Technology Consortium (SPTC).

To avoid duplication, identify where calibration or verification was required for
California, and to identify potential partners. Identify how short-term research needs fit into the
long-term vision for Caltrans pavement technology.

Develop a preliminary scope, schedule and resource requirements needed for each new Research
Goal, and identify available resources within the research agreement with Caltrans. Identify
potential partnerships and additional resources that can be obtained from partners.

Obtain prioritization from meetings with members of the Pavement Standards Team, and where
possible members of the Pavement Steering Committee.
Take the priorities identified by the PST and the PSC and summarize them into a coordinated, logistically feasible research Strategic Plan, including schedule, scope and expected research products.

Submit the prioritized Strategic Plan to the PST and PSC for review and approval.

The research program described in this Strategic Plan may be amended, or changed by Caltrans Research, depending upon Caltrans needs, as identified by the PST and the PSC.

1.5 Scope of this Strategic Plan

This Strategic Plan is intended to provide a basic description of the work to be performed by the UC Contract Team for the Partnered Pavement Research Program over the next two to three years. This Strategic Plan includes work past the end of the current termination of the Partnered Pavement Research Contract in June 2004, which will be continued if there is a subsequent contract. This Strategic Plan will need to be updated in approximately two years (Winter, 2004).

Detailed test plans have been, or will be, prepared for each Research Goal. Each Research Goal may change somewhat when the test plans are developed, based on additional information, changes in available resources, and any adaptations to changes in the needs of Caltrans and the partners for that Research Goal. The objectives of each Research Goal should not change without a review process by Caltrans.

1.6 Outline of Work Included in this Strategic Plan

The work described in this Strategic Plan includes Research Services (including Implementation Projects), Research Goals on which work is already underway, and proposed new Research Goals and Implementation Projects. Summary descriptions of all Research
Services and Research Goals are included in Section 2 (basic Research Services and Special Forensic Investigations), Section 3 (Implementation Projects), and Section 4 (Research Goals) of this document. Detailed work plans have been developed for many of the Research Goals and Implementation Projects, as noted in the summary descriptions included in this strategic plan.

1.6.1 Research Services

Research Services include:

- Development of a Program for Partnered Pavement Research,

- Continued development of the Pavement Research Database,

- Provision of pavement technology advice to Caltrans, as needed, (described in Section 2)

- Special Forensic Investigations of pavement performance, through sampling, laboratory testing, instrumentation, monitoring, and analysis of results. Current Special Forensic Investigations are listed in Section 1.3.1.1 and summarized in Section 2 of this strategic plan, and

- Implementation Projects for technologies under evaluation by Caltrans. This work includes help with experiment design, specification development, construction, sampling, laboratory testing, instrumentation, monitoring, and analysis of results. Current and new Implementation Projects are listed in Section 1.3.1.2 and summarized in Section 3 of this strategic plan.
1.6.1.1 Special Forensic Investigations

Specific forensic investigations currently underway are:

- Longitudinal joint compaction

- Deep In-Situ Recycling (DISR) using recycled AC as unbound base: field and laboratory testing (US395)

- Deep In-Situ Recycling (DISR) using foamed asphalt: laboratory testing (SR20)

- Maintenance surface treatments for noise and performance: test section layout and performance monitoring (SR138)

1.6.1.2 Implementation Projects

Implementation Projects currently underway that should be completed in 2003/2004 are:

- Calibration of HIPERPAV for California Conditions

- Evaluation of Concrete Maturity Meters

- Use of the Dynamic Cone Penetrometer (DCP) for maintenance, rehabilitation and reconstruction site evaluation

- Quality Assurance Laboratory Testing for AC Long-life pavement mix designs (I710)

- Development of new asphalt concrete QC/QA pay factor tables

Implementation Projects to be started in 2003/2004 are listed in the order of their ranking by the Pavement Standards Team, from highest priority to lowest:

- Calibration Sites for Falling Weight Deflectometers (FWD), Profilers, and Skid Resistance Devices

- Evaluation of Profilers and Automated Distress Data Collection Equipment
• Process for Evaluating Recycling Strategies for Pavement Materials, with first case study “Recycling of PCC Grindings Slurry”

• Development of Integrated Databases to Make Pavement Preservation Decisions, Tasks A, B, and C to identify databases and develop procedures for integrating and populating them (FPP 3.5), the remaining tasks in this project, to populate the databases, cannot be started in this strategic planning cycle

• Documentation of pavement performance data for pavement preservation strategies and evaluation of cost-effectiveness of such strategies (preliminary study) (FPP 3.2 and 6.6)

• Development of Improved Patching Procedures for OGAC Overlays

• Pilot Projects for Compaction Specifications for Aggregate Base and Aggregate Subbase/Use of the Rapid Compaction Control Device (RCCD)

• Pilot Projects for Chip Seal Specifications based on South African Design Practice (FPP Statement 2.1),

• Development of Guidelines for Effective Maintenance Treatment Evaluation Test Sections (FPP 4.1)

• Mix design Procedure for Asphalt Concrete Base for Rigid Pavements

1.6.2 Research Goals

Research Goals currently underway are listed in Section 1.3.2.1; summaries are provided in Section 4 of this document. New Research goals to be started in 2003/2004 are listed in Section 1.3.2.2; summaries are provided in Section 4.
1.6.2.1 Research Goals Currently Underway

Work is currently underway on the following Research Goals:

- Development of the First Version of a Mechanistic-Empirical Pavement Rehabilitation, Reconstruction and New Pavement Design Procedure for Rigid and Flexible Pavements (pre-Calibration of AASHTO 2002), including:
  - Evaluation of AASHTO 2002 procedures for Caltrans implementation
  - Seasonal deflection monitoring sites
  - Climate database
  - Truck traffic database (WIM)
  - Typical Caltrans materials properties for mechanistic-empirical design input
  - Design algorithms
  - Customize FHWA Life Cycle Cost Analysis software
  - Verification/calibration of design systems

- Evaluation of Rigid Pavement Long-Life Pavement Rehabilitation Strategies (LLPRS-Rigid) (HVS Goal 4)

- Performance of Drained and Undrained Flexible Structures Under Wet Conditions (HVS Goal 5)

- Development of Asphalt Concrete Rutting Performance Tests and Analysis Procedures

- Calibration of Mechanistic-Empirical Design Models

- Development of Rehabilitation Construction Productivity Analysis Products, including:
Construction productivity analysis
Conconstruction closure traffic delay estimation
Inclusion of Life Cycle Cost Analysis

- Verification of Asphalt Concrete Long-Life Pavement Strategies (HVS Goal 6), including:
  - Crack, seat and overlay
  - Full-depth reconstruction

- Dowel Bar Retrofit of Rigid Pavements (HVS Goal 7)

- Investigation of Asphalt Concrete Moisture Damage (HVS Goal 8)

- Development of Improved Rehabilitation Designs for Reflection Cracking (HVS Goal 9), including:

- Evaluation of Hydraulic Cement Concrete Mix Design for Pavements

1.6.2.2 New Research Goals

New Research Goals to be started in 2003/2004 are listed in the order of their ranking by the Pavement Standards Team, from highest priority to lowest:

- Development of Mix and Structural Design and Construction Guidelines for Deep In-Situ Recycling (DISR) of Cracked Asphalt Concrete as Stabilized or Unstabilized Bases (HVS Goal 10)

- Additional task added to “Investigation of Asphalt Concrete Moisture Damage (HVS Goal 8)”: HVS tests on AC mixes to verify field performance data base analysis on relative contribution to moisture damage of aggregate source, mix design,
construction compaction, traffic repetitions, anti-stripping additives. Validation of Asphalt Concrete QC/QA Pay Factors (HVS Goal 11).

- Additional task added to “Development of Improved Rehabilitation Designs for Reflection Cracking (HVS Goal 9)”: Laboratory asphalt binder testing and mix fatigue beam testing to evaluate performance-related parameters (including SSV and SSD) for AC binder specification for cracking.

- A Framework for Implementing Innovative Contracting Methods For Transportation Infrastructure Rehabilitation/Reconstruction

- Development of Integrated Pavement Strategy Decision Support System

1.7 Obtaining Reports, Technical Memorandums, and Technology Transfer

Conclusions and recommendations from results obtained to date on past and current Research Goals and Implementation Projects of the Partnered Pavement Research Program and its predecessor, the CAL/APT program, are summarized in a document titled “Overview of Caltrans Accelerated Pavement Testing (CAL/APT) and Partnered Pavement Research (PPR) Programs (1994-present).” This document is downloadable at www.its.berkeley.edu/pavementresearch. The document includes tables summarizing research work to date, and references to reports and technical memorandums.

All reports and technical memorandums produced by the PPRC and its CAL/APT predecessor are downloadable at the same web site in PDF format. Hard copies and CDs of reports and technical memorandums can be obtained from the Office of Roadway Research, Division of Research and Innovation.
Briefings on research results are also regularly provided to members of the Caltrans Pavement Standards Team (PST) and functional groups within Caltrans working on specific problems, and information and status of research implementation is available from them as well as from the Office of Roadway Research. Many of the implementation projects and research goals support deliverables of the PST. Regular communication of progress on results supporting the PST work plan, and participation of the researchers and inclusion of the research results in the work of the PST is vital for effective implementation. Similar communication and participation is necessary for the implementation projects and research goals that do not directly support PST deliverables with the Caltrans teams and functional groups working on those problems.

Many research results are also included in technology transfer classes funded by Caltrans and produced by the Technology Transfer Program of the Institute of Transportation Studies at UC Berkeley. Special briefings on research results and the status of specific research projects and goals described in this document can be arranged through the Office of Roadway Research.
2.0 RESEARCH SERVICES

2.1 Development of Partnered Pavement Research Program

The UC Contract Team will perform this work through monitoring of the technical literature, attendance at technical conferences and meetings, service on technical and conference committees, and visits to potential partner institutions. Contacts will be maintained or initiated with other State DOTs, leading DOTs and governmental pavement research institutes in Europe, Australia/Asia, Africa, and South America, state and national pavement industry groups, and leading universities and consultants performing pavement research around the world. This task will also require participation on pavement research technical committees, institutions, and associations.

Once partners for research are identified, detailed experimental plans must be developed. The guiding principle will be to meet the needs of Caltrans, which is providing the anchor funding, and then to augment the experiment plan to cover some or all of the objectives of the research partner(s) depending upon their contribution to the research goal.

As work on partnered research goals is underway, the UC Contract Team will need to manage the contributions of the partners, communicate with them, update them on the results, and provide them with the final results.

At the same time that partners for Research Goals are being identified, a scanning process will be performed to identify the results of the work of others that could be of benefit to Caltrans. These results can include ideas, methods, procedures, data, software, equipment, specifications, materials, and other forms of pavement technology. The scanning process will also include evaluation of research being performed outside of the Partnered Pavement Research Program, and assessment of the benefits of participation to Caltrans.
The expected benefits to Caltrans from this task include the following:

- Leveraging of Caltrans research funding to the PPRC to obtain better results for Caltrans than would be obtainable with only the Caltrans funding;

- Development of strong relationships with other organizations performing, funding, and using pavement research, which will minimize duplication of efforts and lead to greater sharing of results and ideas. This will help Caltrans and the UC Contract Team avoid the “not invented here syndrome”;

- Experimental plans that incorporate a wide range of ideas, from interaction of Caltrans, the UC Contract Team, and research partners;

- Input from leaders in various specialties of pavement research and technology from around the world to that can be incorporated into Caltrans research goals being performed by the Partnered Pavement Research Program;

- Provision to Caltrans of current pavement technology and research results developed around the world, already evaluated and screened in terms of Caltrans needs; and

- Evaluation of pavement research to be performed or currently underway outside of the Partnered Pavement Research Program from which Caltrans may benefit from taking part, either financially or through resource sharing.

2.2 **Pavement Research Database**

2.2.1 Background

The production of reports and other research products at the completion of a research goal captures the immediate results of the research. However, data produced from later research
goals can be combined with those results to produce better results in the future. Ideas may be
developed that can be tested against the data, and models can be developed from the data, that
were not included in the original research.

However, data quickly becomes difficult to access and understand at the completion of a
research goal if it is not organized and stored in a database. This occurs because the human
memories of data location and meaning are lost with time, and storage media deteriorate with
age. The UC Contract Team has a Pavement Research Database, originally developed as part of
the CAL/APT contract completed in 2000.

2.2.2 Objectives

This work continues development of database structures for new types of data that will be
collected, and the organization of all data produced during the contract into the database. It also
includes the development of improved access and analysis procedures to make better use of the
data, including the development of query procedures, downloading, and reporting features.

Work in this research service also includes improving access to the pavement research
database by Caltrans, the UC Contract Team, and Partnered Pavement Research partners.
During the first two years of the PPRC contract (2000 – 2002) all past data has been loaded into
Microsoft Access format, and new routines have been written to automatically reduce raw data
into desired variables and upload it into the database. Loading of the Microsoft Access database
into Oracle, which provides greater querying functions and the ability to handle larger volumes
of data, has been started. The next steps are to:

• complete loading of the database into Oracle,

• upgrade the data queries in Oracle, and
• develop a system to provide web access by Caltrans to the database

• Once access is improved, provide technology transfer to inform potential users of the contents of the database and how to access them.

2.2.3 Expected Benefits

The expected benefits of Continued Building of the Pavement Research Database include:

• Preservation of results, and raw and processed data, which Caltrans has invested considerable funds in obtaining.

• Continued facile access to data by Caltrans, the UC Contract Team, and research partners.

• Ability to perform systematic searches of the database for results relevant to later projects and problems.

• Support for users of the database.

• Incorporation of all new data developed as part of the PPRC contract, through development of new data structures, and organization of the new data into the database.

• Technology transfer to Caltrans regarding the contents and use of the database.

2.2.4 Potential Partners

Potential partners for this work include organizations performing research of interest to Caltrans, and organizations that are interested in the work being performed by the Partnered
Pavement Research Program. Current potential partners include the State Pavement Consortium [SPTC, includes Caltrans, Washington State, Minnesota and Texas DOTs (including the Mn/Road and Texas MLS Projects), CSIR (South Africa), the Danish Road Institute, and the Army Corps of Engineers Waterways Experiment Station and the Army Corps of Engineers Cold Regions Laboratory]. The Florida DOT, the University of Nottingham, and the Australia Road Research Board have contacted the UC Contract Team regarding sharing of data and data structures. An NCHRP project regarding accelerated pavement testing (APT) data base structures has recently been completed and results are being evaluated for incorporation in the database structure.

2.3 Provision of Pavement Technology Advice to Caltrans, As Needed

Benefits from the development of improved pavement technology can only be obtained if it is widely distributed and implemented. Three primary means of dissemination of pavement technology information have been identified, in addition to the implementation projects and special forensic investigations: participation in meetings, discussions, and presentations; technology scanning; and technology transfer.

2.3.1 Meetings, Discussions and Presentations

This work consists of:

- Participation in meetings at the request of Caltrans by UC Contract Team members and other experts whose travel expenses and fees can be paid through the research contract,
• preparation of presentations on specific items, or overviews of recent results from the partnered pavement research program at Caltrans and industry meetings, symposiums, conferences and workshops, and

• Telephone consultation with Caltrans regarding pavement technology research.

Any information provided by the UC Contract Team will include referral to the appropriate Caltrans staff members in PST and the District (if a district call), and any information provided will be forwarded to PST.

2.3.2 Technology Scanning

This work consists of attending conferences, workshops, symposiums, and other meetings to obtain information needed by Caltrans to improve pavement technology in California. This work requires development of a clear and comprehensive understanding of Caltrans, so that technology in use outside of California can be evaluated for its applicability to California problems and conditions, and synthesized into usable recommendations. This work also includes incorporation of technology scanning results into the research being performed for California and/or direct distribution to Caltrans.

2.3.3 Technology Transfer

This work consists of development of technology transfer materials and their transmission to Caltrans, contractors, and others. The objective is to transfer the results of research in a usable form to pavement technologists and managers. The traditional means of technology transfer include production of reports, presentations, classes, symposiums, conferences and workshops. In addition to these means of technology transfer, the UC Contract
Team, Caltrans Research, and their partners will investigate new technology transfer formats, including:

- Short memorandums, called Roadway Research Notes, that provide brief descriptions and summaries of results of PPRC work, condensed from one or more reports,
- Web-based self paced learning (distance learning),
- Internet distribution of results, and
- Distribution of results in non-paper media such as CDs.

The primary partners identified for this work at this time are the UC Berkeley ITS Technology Transfer Program and the University of Washington.

As new software is developed as part of the research program, a strategy for its maintenance, support, and distribution will need to be developed. It is anticipated that this work will be investigated as part of the Partnered Pavement Research Program, but the funding for the actual maintenance, support, and distribution of the software will need to come from other sources.

2.4 Special Forensic Investigations

Special forensic investigations are short-term research oriented investigations of pavement condition or performance. PST members acting on behalf of their functional group or on district requests may request Caltrans Research to have the UC Contract Team assist in forensic investigations where some special expertise or equipment will aid in successful identification of the failure mechanism or evaluation of pavement condition or performance. The number of Special Forensic Studies that can be performed by the PPRC is limited.
The results of these Special Forensic Investigations will also provide case histories that will provide validation and calibration data for new pavement technology being developed as part of the research program. Only those investigations that are currently underway are shown in this Strategic Plan. Other Special Forensic Investigations can be performed as needed.

2.4.1 Longitudinal Joint Compaction

Longitudinal joints in asphalt concrete paving have been identified as problem areas for compaction, resulting in high air-void contents, high permeability, and low stiffness and fatigue resistance. This results in flexible pavements often failing at the longitudinal joints long before the rest of the pavement experiences significant damage.

The State Pavement Technology Consortium (SPTC) funded this as a project for partnered research, with the Texas DOT and Texas A&M University as the leaders. The work on this project for the UC Contract Team consisted of sampling density at longitudinal joints in California to complete portions of the project’s experiment design. Construction projects are being identified by the UC Contract Team contacting each of the districts. To date, coring has been completed on three projects with the materials shipped to Texas A&M. The project is underway and results will be reported to the SPTC, including Caltrans, by Texas A&M.

2.4.1.1 Expected Benefits

The study is intended to assess the difference in compaction at the longitudinal joints compared to the rest of the asphalt concrete mat, and to provide recommendations for improved construction of longitudinal joints.
2.4.1.2  Partners

The partners in this study are Caltrans, the districts where the cores will be taken, and the other three states in the four-state State Pavement Technology Consortium (Texas, Minnesota and Washington State). It is possible that this may lead to pilot projects using the recommended joint construction techniques, in which case the Asphalt Paving Associations would become partners.

2.4.2  Deep In-Situ Recycling (DISR) Using Recycled AC as Unbound Base: Field and Laboratory Testing (US395)

Assistance in performing a forensic evaluation was provided to District 2 personnel for an unbound recycled asphalt pavement (RAP) base project on Route 395 near Alturas. Approximately 6 km of pavement was ground, recompacted, and then paved with 150 mm DGAC. The UC Contract Team provided deflection testing using a Dynatest HWD for comparison with METS deflection testing using the Dynaflect and a JILS FWD. Dynamic Cone Penetrometer (DCP) tests were also performed in the field on the previous aggregate base material, and the new recycled material. Extensive assistance with laboratory testing was also provided, including triaxial testing of stiffness. The material was compared with typical virgin Class AB from District 2 and District 4. Lime treatment of the materials was also evaluated in the laboratory. A draft report on the work has been submitted to METS and District 2. It is not known at this point if there will be any follow up work requested beyond periodic evaluation of the section.
2.4.2.1  *Expected Benefits*

PST has designated this use of RAP as an experimental strategy and is currently evaluating it before deciding whether or not to make it a standard strategy. It offers the potential for eliminating reflection cracking in the new asphalt concrete layer placed. These results will help PST determine whether this will become a standard strategy.

2.4.2.2  *Partners*

District 2 and Office of Pavement Rehabilitation (OPR).

2.4.3  Deep In-Situ Recycling (DISR) Using Foamed Asphalt: Laboratory Testing (SR20)

Material was collected from a District 3 Deep In-Situ Recycling (DISR) project on SR20 where the resulting RAP material was stabilized with foamed asphalt. This material will be tested in the PPRC laboratory for stiffness and permanent deformation using a triaxial testing device.

Meetings were facilitated by PPRC between District 3 and personnel from the Gauteng Department of Transportation (Gautrans) and CSIR, both of South Africa, who are currently performing research on this type of material. Common objectives identified included the need for a more robust structured design process, consistent construction specifications and QC/QA procedures. The result is that these objectives have become the basis of a new Research Goal (HVS Goal 10) in this Strategic Plan.

2.4.3.1  *Expected Benefits*

PST has designated this use of RAP as an experimental strategy and is currently evaluating it before deciding whether or not to make it a standard strategy. It offers the potential
for eliminating reflection cracking in the new asphalt concrete layer placed. These results will help PST determine whether this will become a standard strategy.

2.4.3.2 Partners

Partners for this work include District 3, METS Office of Pavement Rehabilitation and Office of Bituminous Materials, Gautrans, and CSIR.

2.4.4 Maintenance Surface Treatments for Noise and Performance: Test Section Layout and Performance Monitoring (SR138)

Caltrans Maintenance has built test sections on SR138 in Los Angeles County between Castaic and Lancaster to evaluate the noise reducing properties and relative performance of different maintenance treatments. The UC Contract Team evaluated the section of SR138 to determine uniform and consistent locations for applying the maintenance treatments. The procedures used by the PPRC for identifying these locations are based on typical project level evaluation procedures and included deflection measurements, visual condition surveys, coring, and DCP measurements to determine existing layer thicknesses, properties, and condition. Some materials testing to evaluate the quality of the maintenance materials used will likely be performed in the near future.

2.4.4.1 Expected Benefits

The relative performance of the maintenance treatments can only be determined if they are placed on similar test sections. The work performed by the UC Contract Team helps create an unbiased evaluation of the performance, which will aid Caltrans in selecting the most cost-effective treatments. This work also serves as the basis for the proposed new implementation
project “Development of Guidelines for Effective Maintenance Treatment Evaluation Test Sections (FPP 4.1).”

2.4.4.2 Partners

The partners for this work are Caltrans HQ Maintenance and District 7.
3.0 IMPLEMENTATION PROJECTS

3.1 Implementation Projects Currently Underway

Implementation projects are used to evaluate new pavement technologies. The new technologies may be those developed by the Caltrans Partnered Pavement Research Program and its partners, technologies adopted “as-is” from other locations, or technologies adopted from other locations and calibrated and verified for Caltrans.

Expertise must be provided to accurately assess new technologies for the development of appropriate specifications and construction practices. Implementation sections should be instrumented and monitored so that the pavement behavior can be measured and understood. Materials should be sampled for laboratory testing to quantify their properties and the effects of construction and materials selection. Mechanistic models of the pavement behavior and performance must be developed, and calibrated for the project site climate, traffic, and subgrade conditions so that the results can be extrapolated to other locations in the state. The work of the UC Contract Team will be performed as partners in implementation teams that will also include Caltrans Research staff, industry representatives, the hosts and patrons of the implementation projects (typically Caltrans headquarters and district staff), and some other partners identified for each task.

3.1.1 Calibration of HIPERPAV for California Conditions

3.1.1.1 Background

The combination of differential shrinkage and thermal stresses (curling) has been identified by PPRC researchers as the cause of cracking of all the long concrete slabs at the
Palmdale HVS test sections, prior to any HVS loading. Condition surveys have identified transverse cracking in most long concrete slabs on Caltrans pavement in the desert regions. Longitudinal cracking has been tied to the combination of shrinkage, thermal, and loading stresses in concrete pavement in the valley and desert by UC researchers as well. Recently constructed expensive concrete pavements in District 8 have also cracked due to early age cracking within weeks or months of construction.

A computer program has been developed by TransTech, Inc. under FHWA contract. The software, called HIPERPAV, predicts early age behavior of jointed concrete pavements. It is intended to provide the pavement and concrete mix designer with a prediction regarding whether a pavement will crack under combined temperature and moisture stresses in the first 72 hours after construction. The experience in District 8 is that for the desert region, HIPERPAV can erroneously predict cracking that doesn’t appear in the field. District 8 is building approximately 150 lane-km of concrete pavement in the next few years.

3.1.1.2 Objectives

This project consists of two parts. In the first part, the UC Contract Team performed a sensitivity study with HIPERPAV using input data that has been developed for a variety of California concrete mixes, environmental data, and pavement design geometry and features used in California. The results of the sensitivity study indicate which California variables are most important for early age cracking, according to HIPERPAV. The models included in HIPERPAV and their interaction have been evaluated to the extent possible from the literature, and compared with other models that are available. These results have been compared with past field experience. A report has been completed covering this objective of the project.
The second part of the project consists of instrumenting new District 8 pavements to monitor the factors that cause early age cracking, including weather, slab temperatures and slab deformations caused by temperature and shrinkage gradients. This information will be used to evaluate the HIPERPAV results for those pavements. Four locations have been selected in District 8 for instrumentation and field evaluation of the HIPERPAV results and the maturity meter. The first project was instrumented in April, 2002 and the second in February, 2003. The remaining two projects are scheduled for completion by early 2004. The field results will be compared with HIPERPAV calculations using data from the weather station placed at the instrumentation locations.

The expected outcomes of this work are:

- A comprehensive evaluation of how to use HIPERPAV for design and construction evaluation in California,
- An assessment of the risk of early age cracking in different climate regions, construction scenarios and for different designs in California,
- Creation of a database for shrinkage and temperature changes in concrete pavements in the California desert and Inland Empire, including doweled and undoweled pavements, and pavements built using Type I/II cement, Type III cement, and Fast Setting Hydraulic Cement (FSHC),
- Recommendations for construction and design changes to minimize the risk of early age cracking in different climate regions in California,

The results of the study may indicate that a better computer model can be developed for Caltrans that will be available at no cost to Caltrans.

A detailed test plan has been developed for this Implementation Project.
3.1.1.3 Expected Benefits

The results of this project will provide Caltrans with an understanding of the sensitivity of HIPERPAV predictions to typical California conditions. It will also provide information to help Caltrans determine whether HIPERPAV is useful for routine analysis of early age cracking potential for California. If the results indicate that HIPERPAV does not reasonably predict field results, the field studies will provide valuable data for calibration of HIPERPAV. Alternative models may be recommended if the HIPERPAV models do not work well for California pavements.

3.1.1.4 Partners

The primary partners for this project are Caltrans METS Concrete, District 8, and the concrete paving contractors operating in California and on the District 8 sites.

3.1.2 Evaluation of Concrete Maturity Meters

3.1.2.1 Background

In many cases, Caltrans uses a strategy of replacing cracked individual slabs instead of replacing an entire concrete pavement lane. Much of this construction is performed at night under 7- or 10-hour traffic closures, particularly in urban areas. The minimum flexural strength that concrete must have to avoid using most of its fatigue life when traffic is put on it is about 2.8 GPa (400 psi). Breaking of flexural beams to check this strength is difficult with these time constraints on a crowded night closure construction site. Breaking of beams is time consuming and difficult even on construction projects that do not have severe time constraints, which limits the number of samples that can be taken. There are also some questions as to the ability of
beams to represent flexural strength in the slab as they are currently prepared, cured, and tested by Caltrans.

Maturity meters are a non-destructive means of monitoring concrete strength. Maturity meters essentially measure mix temperature, which when previously calibrated against concrete flexural strength for a particular mix, can provide a quick and easy estimate of flexural strength.

Maturity has been calibrated primarily for splitting tensile and compressive strength test results and under standard laboratory conditions. The application to flexural strength and to conditions other than standard laboratory conditions has not been investigated in depth by any previous researchers. A specific protocol for measurement and calculation of maturity and estimation of flexural strength has not yet been developed for Caltrans pavements.

3.1.2.2 Objectives

The objective of this project is to investigate and calibrate a nondestructive test method (maturity) used to estimate the strength development in concrete pavement under field conditions. This project will investigate the relations between maturity measured in beams and beam strength in the field, and between maturity measured in slabs and measured in beams. The project will include:

- Laboratory work to investigate the relation between maturity measured in beams and beam strength under different curing conditions. This work will also be performed for cylinders and compressive strength;

- Field work to measure and investigate the relations between maturity in slabs, maturity in field cured beams (per current Caltrans specification), and beam strength in beams cured under field conditions and standard laboratory conditions. This work
will also be performed for cylinders and compressive strength. Four sites in District 8 (the same as for HIPERPAV evaluation) and two sites in Northern California to be identified by METS Concrete will be included in the study; and

- Development of protocols and test methods for the implementation of maturity in Caltrans standard practice.

A detailed test plan has been developed and includes field evaluation of maturity meters on the District 8 HIPERPAV evaluation projects described above, as well as laboratory evaluation.

3.1.2.3 Expected Benefits

The work being performed in this project will aid Caltrans METS Concrete in the development of efficient and sound practices for implementing maturity concepts into standard practice. This implementation is expected to increase the efficiency of Caltrans construction inspection, and provide better information regarding opening strengths of slabs, and the potential for early age cracking on construction projects. These results will also aid in the development of new methods of designing concrete mixes, which is a Research Goal described elsewhere in this Strategic Plan as “Evaluation of Hydraulic Cement Concrete Mix Design for Pavements”.

3.1.2.4 Partners

The partners for this project are the Caltrans METS Concrete and District 8, and the concrete paving contractors on the six sites to be evaluated. Eventual partners will be the concrete paving industry in California.
3.1.3 Use of the Dynamic Cone Penetrometer (DCP) for Maintenance, Rehabilitation and Reconstruction Site Evaluation

3.1.3.1 Background

This technology was presented at the Workshop on South African Pavement Technology produced by the UC Contract Team and the State Pavement Technology Consortium in March, 2000, and was identified by Caltrans attendees as a key technology that should be implemented. The Dynamic Cone Penetrometer (DCP) is a simple device that consists of a rod with a cone at the end, similar to the cone penetrometers used by geotechnical engineers, and a drop hammer that slides on the rod and drives the cone through the pavement layers. The cone cannot be driven through thick asphalt concrete or through portland cement concrete. Although it is a very simple device for use in the field, it can provide sophisticated information to pavement engineers, particularly for evaluating existing pavements for rehabilitation:

- the rate of cone penetration (blows per centimeter of penetration) provides a measurement of layer thickness,

- the rate of cone penetration can be calibrated in the laboratory for typical Caltrans materials and provide an indication of the stiffness and shear strength of unbound layers for use in mechanistic-empirical pavement design, or the R-value for Caltrans empirical design,

- small core holes (38 mm diameter) can be made in thick asphalt concrete layers or portland cement concrete layers, and the DCP can be used to assess layers beneath the surface. This information is often unavailable for rehabilitation projects if construction as-builts cannot be found, and actual construction may not match records that are available, or layers may have deteriorated.
Caltrans District 3 has begun implementation of this technology and METS Office of Pavement Rehabilitation and District 2 Maintenance have been given the equipment. A training session was given at the Southern California District Maintenance Engineers meeting in early 2003.

3.1.3.2 Objectives

The work involved in this task includes:

- loaning of the two DCPs available at the UC Contract Team to Caltrans districts and HQ units to try out,
- help in training personnel to use the DCP,
- collection of DCP data (penetration rates) and samples from district pavements to provide local calibration of stiffness and potentially R-value versus penetration rate. This work is ongoing with collection of DCP penetration rates in typical Caltrans material and calibrating these rates against triaxial test results for these materials. Calibration with R-values is scheduled to be carried out shortly.
- in the longer term, development of calibrated relations between laboratory or backcalculated stiffness and R-value and penetration rate for statewide use. The work already performed by CSIR in calibrating stiffness versus penetration rate will be valuable for this task. Calibration information will also be developed as part of Goal 5 “Performance of Drained and Undrained Flexible Structures Under Wet Conditions” and other research goals will be used for the Research Goal “Development of the First Version of a Mechanistic-Empirical Pavement Rehabilitation, Reconstruction, and New Pavement Design Procedure for Rigid and
Flexible Pavements (pre-Calibration of AASHTO 2002),” both described elsewhere in this document.

- It is possible that a mechanized, truck mounted DCP can be developed as part of this Implementation Project, to increase the speed and reduce the personnel needed to operate the DCP under Caltrans highway conditions.

Currently, Caltrans design and maintenance engineers must rely on as-built documents or cores or trenches, which are highly destructive. Typically, information regarding the condition of existing pavement layers below the surface is only obtained once construction has begun and the surfacing is removed, which can lead to costly contract change orders to deal with previously unidentified problems.

3.1.3.3 Expected Benefits

Implementation of the DCP for use in evaluating existing pavements for rehabilitation, reconstruction and maintenance will greatly improve the ability of Caltrans engineers to identify problems, and characterize pavement materials below the surface. The DCP is minimally intrusive and destructive, requiring only a 38-mm core hole through the pavement surface. The time to collect data on each hole is one to 15 minutes, depending on the thickness and resistance of the pavement layers. For Long-Life pavement rehabilitation, the DCP can be used to measure the thickness and quality of CTB layers beneath the existing concrete slabs during short weeknight traffic closures. This information can be used instead of, or in combination with, Falling Weight Deflectometer data to evaluate the CTB and aggregate base layers during the design phase, rather than during construction, which will reduce the cost of construction change orders.
Development of calibrations that relate DCP results with stiffness, and thicknesses measured using the DCP, will provide the key input to mechanistic-empirical design of flexible pavement overlays.

3.1.3.4 Potential Partners

The primary partners for this work are the Caltrans districts and Caltrans METS Office of Pavement Rehabilitation. The METS OPR group was identified as the patron for this effort during the South African Pavement Technology Workshop. The three other states in the four-state State Pavement Technology Consortium (SPTC), Minnesota, Texas and Washington, currently use the DCP, and can provide information for initial calibration relations with stiffness. The CSIR and other pavement engineering organizations in South Africa will also play a large role in this work. The US Army Corps of Engineers and associated military pavement agencies currently routinely use the DCP to characterize airfields and roads, and are interested in partnering on the development of calibrations of DCP results with stiffness and strength. The URS Corporation has purchased a DCP and is interested in providing data to the PPRC to aid in the calibration of the device for California materials.

3.1.4 Quality Assurance Laboratory Testing for AC Long-life Pavement Mix Designs (I710)

Caltrans has recently worked with the Southern California Asphalt Paving Association and the UC Contract Team to develop innovative designs for AC Long-life pavements for urban freeway reconstruction. The first application of two of those designs is currently being constructed on the southern portion of Interstate 710 in Long Beach.

The UC Contract Team is assisting the contractor, District 7 Construction and Caltrans METS Bituminous Materials in Quality Assurance (QA) testing of the three mix designs (PBA-
6A, AR-8000, AR-8000 Rich Bottom) for the project to determine if they meet the mechanistic based specifications. The testing includes shear testing and flexural beam testing.

3.1.4.1 *Expected Benefits*

The help of the UC Contract Team will aid Caltrans in performing the QA testing, and the successful completion of the project.

3.1.4.2 *Partners*

The partners are Caltrans METS Bituminous Materials, Construction, District 7, the asphalt paving industry in California, and the I-710 contractor team.

3.1.5 *Development of New Asphalt Concrete QC/QA Pay Factor Tables*

Appropriately weighted construction pay factors are needed to provide the correct incentives to contractors for quality control (QC) on Caltrans construction projects. An efficient way to weight pay factors is to correlate the effects of QC variables with expected pavement life cycle cost. Pavement performance models are required to calculate expected life cycle cost.

The UC Contract Team is currently working with a task group composed of staff from Caltrans METS Bituminous Materials, Construction and Maintenance and the asphalt paving industry to produce pay factors for Caltrans QC data. These models are weighted using performance models developed from PPRC laboratory testing, HVS testing and the results of the WesTrack project (FHWA).
3.1.5.1 Expected Benefits

The expected benefits are AC paving pay factors that are weighted to minimize Caltrans life cycle cost, and appropriately reward or penalize the contractor for better or worse expected pavement performance. This should result in lower life cycle cost for Caltrans AC pavements.

3.1.5.2 Partners

The partners are Caltrans METS Bituminous Materials, Construction and Maintenance, and the asphalt paving industry in California.

3.2 New Implementation Projects to be Started in 2003/2004

3.2.1 Calibration Sites for Falling Weight Deflectometers (FWD), Profilers, and Skid Resistance Devices

3.2.1.1 Background

Caltrans uses Falling Weight Deflectometers (FWD) to measure pavement deflections, profilers to measure pavement profile for calculation of roughness, and skid resistance trailers to measure pavement friction coefficient. Until 2002, Caltrans calibrated its FWD at a facility run by the Nevada DOT near Carson City, Nevada, set up with the help of FHWA. The Nevada facility has been closed and currently Caltrans must send its deflection equipment to Colorado for calibration. Caltrans currently calibrates its profilers and skid resistance trailers at a facility operated by Texas A&M University in College Station, Texas.

In addition to calibration of current equipment, facilities of this type are often used for research on new methods of measurement and equipment.
3.2.1.2 Objectives

Through this implementation project, the PPRC will set up and operate an FWD calibration facility at UC Davis, as part of a larger pavement research facility. UC Davis will staff the FWD calibration facility. Caltrans use of the facility will be paid for through this, and subsequent, research contracts. All other DOTs, contractors, and consultants will pay for use of the facility and its staff time on an hourly basis.

It is planned that UC Davis will investigate the set-up and operation of profiler and skid resistance calibration sites at a Caltrans facility, such as McClelland AFB. It is likely that the same staffing and cost arrangement described for the FWD calibration facility would apply to these facilities as well.

3.2.1.3 Expected Benefits

The primary benefits of this implementation project will be decreased cost to Caltrans of calibrating its equipment, and the ability to check the equipment faster and without the need for out-of-state travel. Caltrans will also be able to perform more efficient evaluation of new equipment and research on new methods, if desired. This work will also benefit the Caltrans-sponsored UC pavement research by providing an extra income source to help support the Caltrans facility. Caltrans currently operates 2 to 5 of each of the three types of equipment. If Caltrans begins to implement mechanistic-empirical pavement design methods, such as elements of the AASHTO 2002 method, it will need to rely more heavily on FWDs to characterize existing pavement properties. For example, Texas DOT currently operates a fleet of 15 FWDs.
3.2.1.4 Potential Partners

Partners within Caltrans are the users of the Caltrans equipment: METS Office of Pavement Rehabilitation, Construction and Maintenance. Potential outside partners are the FHWA, which will provide some FWD calibration equipment and plans; western state DOTs; western LTPP contractors; consultants; local government, if they also implement elements of mechanistic-empirical design.

3.2.2 Evaluation of Profilers and Automated Distress Data Collection Equipment

3.2.2.1 Background

Caltrans METS Office of Pavement Rehabilitation and Maintenance are interested in the evaluation of road surface profiling and automated video distress data collection equipment. Several manufacturers currently produce equipment of this type, and the Texas DOT and Texas A&M University have developed an integrated approach to developing this equipment and mounting it on a single multi-purpose vehicle.

3.2.2.2 Objectives

The objectives of this proposed work are:

- Work with Caltrans (METS OPR and Maintenance) to identify their needs and appropriate criteria for evaluating equipment,
- Develop a plan for evaluating existing equipment
- Work with Caltrans to perform the evaluation testing and analyze the results.
It must be understood that the objectives of this proposed implementation project do not include development of new equipment. It is possible that no existing equipment is identified that meets Caltrans criteria. If this is the result, then Caltrans will need to decide whether to amend their criteria, fund development of new equipment, or continue with existing practice.

3.2.2.3 Expected Benefits

A multi-purpose vehicle would improve the efficiency of data collection efforts.

3.2.2.4 Potential Partners

Caltrans METS Office of Pavement Rehabilitation, Maintenance, and the equipment industry.

3.2.3 Process for Evaluating Strategies for Recycling Materials into the Pavement Structure, with First Case Study “Recycling of PCC Grindings Slurry”

3.2.3.1 Background

Caltrans is moving towards greater recycling of materials, including materials in existing pavements and recycled materials from other sources. Before moving to statewide implementation of new strategies that include recycled materials, these strategies must go through an evaluation process that includes an initial investigation, submission to OPS to become experimental strategy, pilot projects, final evaluation, and then development of standard special provisions and design guidelines.

Criteria upon which the success or failure of new recycling strategies is ultimately determined include the following:
- Pavement performance versus cost, compared to existing strategies,
- Constructability,
- Ability to routinely characterize in the field, and
- Ability to meet applicable environmental regulations.

Currently, there is no comprehensive checklist or process for PST to evaluate proposed strategies, or for people or agencies proposing new strategies, such as district pavement engineers, to follow the evaluation of the new strategies. METS staff are currently evaluating new products, and are working to develop criteria for their categorization and evaluation.

Caltrans and its concrete pavement grinding contractors are currently having difficulty finding a reuse or disposal strategy for the slurry that results from grinding concrete pavements. There is no clear process for developing a recycling strategy for this material, or a checklist for evaluating several proposed recycling strategies.

3.2.3.2 Objectives

The objectives of this work will be:

- Develop a checklist for evaluation of new strategies involving recycled materials that covers the criteria listed above,
- Develop a process for identifying and gathering information to evaluate a proposed strategy against the checklist, or to develop a new strategy for recycling,
- Test the checklist and process with a first case study to develop and evaluate strategies for recycling concrete pavement grinding slurry.

This work is intended to support the work of PST New Pavement Products evaluation, and the evaluation of recycling strategies proposed to PST, Maintenance and Construction.
3.2.3.3 Expected Benefits

The results of this project are expected to speed the development and comprehensive evaluation of new strategies for recycling materials into the pavement structure. The results of the project should aid the PST New Pavement Products evaluation effort.

3.2.3.4 Potential Partners

Potential partners for this project are the New Pavement Products evaluation team of PST, Caltrans HQ Construction, Caltrans HQ Maintenance, the Division of Water Quality of the State Water Resources Control Board, the Integrated Waste Management Board. The latter two organizations are part of Cal/EPA.

3.2.4 Development of Integrated Databases to Make Pavement Preservation Decisions

3.2.4.1 Background

Caltrans engineers and managers need pavement data to make informed decisions at the strategic level, for network management, and for project level engineering.

At the strategic level, examples of questions that must be answered with pavement data are:

- What performance parameters should be measured, and what time spans are optimal for implementation of warranties for pavement performance?
- Which maintenance, construction and rehabilitation strategies are providing the best performance?
• What is the impact of changes in pavement technology, funding, or management strategies that have been made in the past?

Network management questions that require pavement data include:

• What is the expected future performance of the pavement network and expected future costs over different time horizons?

• What is the optimal timing of pavement preservation strategies?

At the project level, pavement engineers need data to answer questions such as:

• What was the construction quality on the last rehabilitation on this project, and how will that effect my current rehabilitation?

• What maintenance has been done on this section?

• How thick is the existing pavement?

In order to answer these questions, and the numerous other questions that must be answered to improve Caltrans pavement management and engineering, Caltrans needs integrated databases that make the information required to answer these questions accessible and adequate for analysis.

The Mechanistic Empirical (ME) design procedure discussed under Section 4.1 of this Strategic Plan provides a framework for identifying the databases necessary for pavement engineering and management. These databases and their use were discussed in more detail in the “Vision Document” written in 2000 and appended to this Strategic Plan. These databases include:

• Traffic data, including ADT, truck classification counts, and weigh-in-motion (WIM) data,
• Climate data, including temperature profiles and rainfall, either regional or specific for a location;

• As-Built drawings from pavement projects;

• Deflections, back-calculated stiffnesses, thicknesses, and other non-destructive or partially destructive test information regarding the existing structures of rehabilitation and reconstruction projects;

• Asphalt concrete mix design information and as-built thickness, air-void contents, gradations, asphalt contents, stiffnesses, strengths, and fatigue properties;

• Hydraulic cement concrete mix design information and as-built thicknesses, water/cement ratios, cement contents, gradations, strengths, and chemical durability test results;

• Unbound base, subbase and subgrade as-built thicknesses, compactions, water contents, gradations, and plasticity information;

• Deflection data and other structural evaluation data;

• Condition survey data quantifying the type, extent, and severity of distresses observable on the pavement surface and shoulders, collected by human surveyors and non-destructive automated devices (if possible);

• Pavement smoothness data, both in terms of summary IRI, and more detailed pavement profiles or calculated values that can be used to identify distresses not visible to human or automated condition surveyors, such as rigid pavement faulting;

• Maintenance activity data;

• Maintenance cost data;
• Construction cost data;

• Potentially, other non-destructive data that can be collected routinely regarding the pavement structure;

• Pavement research data; and

• Construction productivity data.

• Caltrans currently collects the majority of this data. However, many of the “databases” listed above are not in electronic form, and/or are not organized as databases but instead consist of various paper records that are often thrown away after a relatively short period of time. Those that are in electronic form are not linkable to each other, so for a given location in the Caltrans pavement network, the various data cannot be tied together. If they cannot be tied together, performance models and other analyses cannot be developed to answer questions such as those posed above.

The linked databases that are the goal of this project are the required basis for a full-scale “Pavement Management System” (PMS). The existing Caltrans PMS and its database are very limited in the scope of information they contain compared to the list above, and are therefore limited in the analyses that can be performed using them. The current PMS and database provide a starting point, and are meeting their intended original objective of permitting comprehensive programming of maintenance and rehabilitation based on the current surface condition of the pavement. Evaluation by the UC Contract Team, documented in a recent report, suggests that a more comprehensive and rigorous approach to Caltrans data collection, storage, access and usage is necessary to significantly improve the efficiency of Caltrans business practices for pavement data and pavement management.
3.2.4.2 Objectives

The objectives of this implementation project are:

- Identify Caltrans pavement data business practices,

- Identify elements of the databases that already exist. These include, but are not limited to:
  - the PMS surface condition survey database operated by Maintenance,
  - the asphalt concrete QC/QA database operated by Construction, the Weigh-In-Motion (WIM) and other traffic databases operated by Traffic Operations,
  - the pavement design database operated by the district Design units,
  - the construction as-built database operated by the HQ and district Construction units,
  - the materials testing and design databases operated by HQ and district Materials units,
  - the pavement structural and functional evaluation study databases operated by HQ METS Office of Pavement Rehabilitation.

- Work with Caltrans pavement organizations, primarily the Pavement Standards Team, but also other pavement data users not represented on the PST to perform a needs analysis for Caltrans pavement data, including the precision of the linear referencing system, and identify Department initiatives and regulations for databases and linear referencing systems.

- Develop recommended changes to pavement data business practices. Develop recommended database tables and dictionaries for these databases, and any variables
that are missing or that are currently being collected but are not necessary, and also
identify key issues that must be resolved before databases can be integrated such as
linear reference system and Caltrans information technology requirements.

• Based on the first four objectives listed above, prepare a report summarizing the
findings and making recommendations for changes. This report would need to be
submitted for review and management approval and planning for implementation.

Funding for the five objectives shown above is available within the existing research
contract. Funding for the following objectives is not possible within the existing research
contract, except on a very limited basis:

• Populate databases with existing data, and perform preliminary analyses,

• Develop recommendations for ongoing collection and database management
procedures to be implemented and operated by Caltrans functional units.

High-level management support will be needed to complete the final two objectives, and
should not be sought until the cost of the final two objectives has been determined.

Successful completion of all of these objectives will require close interaction and
cooperation with the Caltrans functional units responsible for the various databases and
collection and analysis of the data. The recommendations in the report covering the first five
objectives will be a plan for an enterprise-wide system that will be operated by the functional
groups operating the various databases following Caltrans regulations. The net result is intended
to be a data warehouse that consists of the database elements operated by the various functional
groups, linked to each other to permit data users to compile the integrated, comprehensive
databases to perform their desired analyses and investigations.
3.2.4.3  *Expected Benefits*

The integrated databases will provide an easily accessible and continuously updated historical record of Caltrans pavement design, construction, construction quality, and performance. They are essential to effective pavement management efforts and will allow Caltrans to make informed, effective, and efficient pavement preservation decisions.

The databases are needed to provide feedback to Caltrans management regarding the costs and benefits of changes in Caltrans pavement technology and management. They will also provide Caltrans engineers with data necessary to make informed decisions regarding the design, maintenance, and rehabilitation on individual pavement projects. In addition, they provide the data needed for effective development and implementation of innovative changes to Caltrans pavement related business practices, such as the use of warranties, and the implementation of mechanistic-empirical design procedures, and feedback on the success or failure of these changes once implemented.

3.2.4.4  *Potential Partners*

Caltrans Maintenance, METS, Design, Construction, Traffic Operations, ESC Office of Geometrics, GIS Management Committee and Technical Working Group, and Districts. Cooperation and insight is expected from states moving in this direction, including the Washington State DOT, Maryland DOT, and Arizona DOT.
3.2.5 Documentation of Pavement Performance Data for Pavement Preservation Strategies and Evaluation of Cost-Effectiveness of Such Strategies. (FPP 3.2 and 6.6)

3.2.5.1 Background

The Pavement Performance databases described above under Section 3.2.4, once populated, will provide the ability to track performance of pavement preservation strategies. This information, coupled with relevant cost information, will allow evaluation of cost effectiveness of these strategies. This proposed implementation project incorporates key elements of FPP Research Goals 3.2 and 6.6 is intended to meet most of the objectives of those goals. The purpose of this implementation project is to perform preliminary analyses using data that is the limited data that is currently available or can be gathered from existing sources.

3.2.5.2 Objectives

The work in this implementation project includes:

- Tracking of pavement preservation projects through the performance databases. For this project, it will only be possible to track a limited number of projects, because current Caltrans databases do not contain comprehensive maintenance, structure, and traffic information for the network that can be tied together.

- Estimation of pavement performance for various strategies and application times, for an applicable set of pavement variables (structure, climate region, traffic, construction quality, etc.)

- Analysis of lifecycle cost for the various strategies and development of recommendations for optimum timing and strategy selection.
3.2.5.3 *Expected Benefits*

This work will provide a preliminary identification of the most cost-effective pavement preservation strategies used by Caltrans, and a methodology for future update and for evaluation of new preservation strategies. Better selection and timing of pavement preservation strategies has the potential to save Caltrans substantial sums of maintenance and rehabilitation dollars.

3.2.5.4 *Potential Partners*

Caltrans Maintenance, METS, Design, districts.

3.2.6 *Development of Improved Patching Procedures for OGAC Overlays*

3.2.6.1 *Background*

Open graded asphalt concrete (OGAC) overlays are used primarily for improved pavement surface drainage and friction by Caltrans. Their ability to reduce noise is currently being evaluated. Currently Caltrans maintenance procedures use dense graded asphalt concrete (DGAC) for patching potholes and filling grinder digouts in OGAC overlays, which defeats the purpose of the OGAC overlay.

3.2.6.2 *Objectives*

The objectives of this proposed implementation project are:

- Investigate the extent of the problem through consultation with HQ Maintenance and districts,
- Identify alternative patching procedures used by other agencies that would maintain the porosity of the OGAC overlays and have the same expected life of the existing
OGAC, while still being constructable under typical construction and maintenance conditions, and

- Investigate any new procedures and/or materials if current procedures used by other agencies do not meet the criteria stated above.

3.2.6.3 Expected Benefits

Improved OGAC patching procedures would extend the useful life of OGAC overlays, while maintaining the desired properties of OGAC.

3.2.6.4 Potential Partners

Caltrans Maintenance, METS Bituminous Materials, District 1, other state DOTs and agencies outside the United States.

3.2.7 Pilot Projects for Compaction Specifications for Aggregate Base and Aggregate Subbase/Use of the Rapid Compaction Control Device (RCCD)

3.2.7.1 Background

The development of improved compaction specifications for granular materials and the use of the Rapid Compaction Control Device (RCCD) were identified by Caltrans at the March 2000 Workshop on South African Pavement Technology as important technologies that should be implemented in California. The primary objective of improved compaction specifications for granular materials (aggregate bases and aggregate subbases) is to increase the compaction required to levels approximately comparable to those required by the Federal Aviation Administration and the Army Corps of Engineers.
The primary objective of implementation of the South African RCCD is to provide a simple field device to assess granular materials compaction that will be faster and easier than the nuclear density device. The RCCD likely be used by the contractor and Caltrans to rapidly check compaction and to control compaction operations, but will not replace the nuclear device for final inspection of compaction.

The RCCD is a low-cost rapid, nondestructive, essentially non-intrusive device used to measure compaction at the surface of pavement layers.

Most state highway agencies in the west have granular base and subbase compaction specifications that were developed at a time when rapid construction of many kilometers of new pavement to a reasonable quality standard was the objective. It has been demonstrated by research, and field experience in South Africa and on airfield pavements in the United States, that substantially better pavement performance can be obtained by better compaction of the same granular materials currently being used by Caltrans and other state DOTs. Additional compaction takes some more time, and more attention from the contractor, but for the short stretches of new pavement currently being built, and for the relatively short stretches of pavement being rehabilitated, the improved compaction can contribute to a significantly longer pavement life.

It is also common in other states to require a “curing” period for granular bases and subbase before placement of the cemented surface layers to permit relief of pore pressures developed during compaction and development of suction which greatly increases the strength and stiffness of these materials. Immediate placement of the prime coat slows this process, and may actually prevent it from completion. Caltrans current practice does not consider this process.
3.2.7.2 Objectives

Some work has already been completed. The completed work primarily consists of an evaluation of triaxial test results at different compaction levels for Caltrans aggregate base materials as part of PPRC (and CAL/APT) Goal 5, and a special forensic study with District 2. The effects of curing have also been investigated during construction of the modified binder test sections at Richmond (part of Goal 9). This work will continue as part of the Research Goal “Development of the First Version of a Mechanistic-Empirical Pavement Rehabilitation, Reconstruction and New Pavement Design Procedure for Rigid and Flexible Pavements (pre-Calibration of AASHTO 2002).”

The new work included in this implementation project includes:

- development of new draft specifications based on research by UC and others, and existing compaction specifications used in South Africa and on airfield pavements (FAA and Army Corps of Engineers specifications),
- working with interested districts and HQ METS to review the draft specifications, and identify pilot projects for use of the improved compaction specifications,
- development of calibrations for the RCCD for California materials, making use of existing calibrations from South Africa, and
- working with interested districts to use the RCCD on field construction projects.

3.2.7.3 Expected Benefits

The expected benefits of improved granular layer compaction specifications are longer life for asphalt concrete pavements, and potential reduction in the required thicknesses of aggregate bases and subbases which will reduce the amount of new materials required.
The expected benefit of implementation of the RCCD is better control of granular layer compaction control because contractors will be able to perform many rapid tests without having to wait for Caltrans or their own technicians to test with the nuclear gauge.

3.2.7.4 Potential Partners

The primary partners for this work will be the Caltrans districts, Office of Pavement Rehabilitation and Office of Flexible Pavements, and Construction. The patron for Caltrans implementation identified at the South African Pavement Technology workshop is the Materials branch of District 2. Other state DOTs may be interested in partnering on the development of new compaction specifications, particularly within the four-state SPTC. Local government agencies and contractors may also be interested in partnering on implementation of the RCCD.

3.2.8 Pilot Projects for Chip Seal Specifications based on South African Design Practice (FPP Statement 2.1)

3.2.8.1 Background

This technology was presented at the Workshop on South African Pavement Technology presented as part of the CAL/APT project in March 2000, and identified by Caltrans as a key technology that should be implemented. This has also been identified as draft Problem Statement 2.1 at the FPP workshop in Sacramento. Aggregate seal coats (often referred to as chip seals) are a very cost-effective strategy for maintaining low- and medium-volume flexible pavements. Aggregate seal coats are a useful tool for Caltrans Maintenance engineers. However, problems have occurred during construction with the current Caltrans chip seal technology, which limits its use in California.
The chip seal design criteria used in South Africa, Australia, and New Zealand are significantly different from the current Caltrans chip seal specification, especially with regard to aggregate gradation and characteristics. These criteria are generally considered worldwide to be the “state-of-the-technology” for chip seal technology. The primary differences from Caltrans technology are the aggregate shape and gradation requirements, and the design method for the quantities based on actual aggregate, asphalt and existing pavement characteristics.

3.2.8.2 Objectives

The work of the UC Contract Team will be to aid Caltrans districts interested in using the South African type of chip seal technology in experimental projects. The aid can include help with development of specifications, laboratory and field testing, provision of construction experts from South Africa to provide guidance during design and construction, and aid in developing a longer-term performance monitoring program. The proposed thrust at this time is to assist District personnel in identifying potential projects where this technology would be viable in order to initiate a pilot project using South African expertise provided through the PPRC contract.

3.2.8.3 Expected Benefits

Successful implementation of the South African chip seal technology will likely lead to a reduction in the problems currently encountered with the current Caltrans chip seal technology, particularly stone retention. The cost-effectiveness of chip seals has been identified by Maintenance, and an expected reduction of the risk associated with their use will likely result in cost savings to Caltrans and local agencies.
3.2.8.4 Potential Partners

Local agencies in California and other state DOTs are likely partners for this research goal. Other potential partners include industry groups in California that construct and produce materials for thin asphaltic surfacings. Caltrans HQ Maintenance was identified as the patron of this project at the South Africa Pavement Technology Workshop.

3.2.9 Development of Guidelines for Effective Maintenance Treatment Evaluation Test Sections (FPP 4.1)

3.2.9.1 Background

Caltrans has constructed numerous pavement test sections over the past several decades in order to evaluate pavement performance, including the comparative performance of various maintenance treatments. Unfortunately, many of these test sections were constructed adjacent to each other on existing pavements which appeared to be relatively consistent but were subsequently found to be substantially different. As a result, the comparative performance tests were inconclusive because the treatments were subject to significantly different conditions.

3.2.9.2 Objective

The work under this task is to develop a set of guidelines for evaluating candidate existing pavement sections for constructing test sections that will produce unbiased and more statistically sound results than most current test sections.

A pilot project was completed on SR138 in 2001 to determine uniform and consistent locations for applying a number of maintenance treatments. The procedures used by the PRC for identifying these locations are based on typical project level evaluation procedures and included
deflection measurements, visual condition surveys, and coring to determine existing layer thicknesses. The approach used on SR138 will be used to develop general guidelines to evaluate the consistency and uniformity of candidate test locations.

Work is also underway on this subject at the national level, the results of which will be incorporated into this project. The Caltrans Office of Flexible Pavements has also recently completed a Guide for Pavement Forensic Evaluations, and the results of this project will need to be compatible with that document and other similar Caltrans references.

3.2.9.3 Expected Benefits

Guidelines developed under this item will allow Caltrans to effectively construct and evaluate maintenance treatment test sections.

3.2.9.4 Potential Partners

Caltrans METS, Maintenance and Districts.

3.2.10 Mix Design Procedure for Asphalt Concrete Base for Rigid Pavements

3.2.10.1 Background

Three primary mechanisms by which Caltrans rigid pavements fail are:

- Faulting,
- Corner cracking,
- Transverse cracking when slab lengths are greater than 4.6 m (15 ft.), and
- Early-age cracking.
All of these distresses are strongly influenced by base performance. For more than 50 years, Caltrans has relied on soils treated with cement as base material for concrete pavements. Over the years, the durability of the cemented base materials has been improved through changes in mix design and construction practices, and currently Lean Concrete Base (LCB) is typically recommended and used.

Although it has been difficult to comprehensively evaluate the improvement in performance of LCB over previous CTB materials, it is apparent from Caltrans and national experience and research that the move to LCB by itself has not solved the problem of faulting. For this reason, Caltrans has recently incorporated the use of dowels in new concrete pavements, and is investigating and using dowel bar retrofit as a rehabilitation strategy.

A recent evaluation of the HIPERPAV software by the UC Contract Team indicates that the use of LCB may increase the risk of early age cracking in hot environments such as the desert and Central Valley because of greater friction between the concrete and the base. The relative performance and benefits, and definitive recommendations regarding where to use LCB and asphalt concrete bases require further research. For constructability and durability reasons, some districts are using a capping layer of asphalt concrete on top of their LCB base layers.

A number of state DOTs, including Washington and Illinois, routinely use dense graded asphalt concrete (DGAC) as a base layer for PCC pavements. Caltrans permits the use of DGAC as a base material for concrete pavements, but it is often not used, even in the desert and Central Valley. In addition, the DGAC specified for use as a concrete pavement base material by Caltrans is the same DGAC that is optimized in the mix design process to prevent rutting, which is not the mode of failure under concrete pavement. The properties needed by a concrete
pavement DGAC mix are very different from those needed for a DGAC mix used in a flexible pavement.

3.2.10.2 Objectives

The objectives of this proposed implementation project are:

- Review mix design, structural design, and construction practices for DGAC concrete base materials in states with a successful history of using it. Agencies currently identified are Washington, Illinois, Texas, and Minnesota DOTs.

- Identify primary failure mechanisms for this material and properties desired to provide very long durability. The likely failure mechanisms are:
  - Moisture damage and stripping,
  - Excessive stiffening due to aging, which increases friction and reduces ability to accommodate curling movements in the concrete slabs,
  - High friction resulting in tensile stresses in the concrete slabs.

- Develop a mix design process for this material, using as much of current Caltrans technology as possible.

- Work with Caltrans to develop specifications and structural design recommendations.

- Work with Caltrans to validate the design, construction and performance of this material, and guidelines for its use.

3.2.10.3 Expected Benefits

This work will provide Caltrans a summary of current U.S. practice and observed performance for DGAC bases under concrete pavements. Development of a mix design process
specific to the use of DGAC as a concrete pavement base material will improve the long-term durability and performance of this material.

3.2.10.4 Potential Partners

Potential partners for this proposed implementation project are Caltrans METS Concrete, METS Bituminous Materials, METS Office of Pavement Rehabilitation, Design, and districts; and, Washington State DOT, University of Washington, University of Illinois, Minnesota DOT, Texas DOT.
4.0 RESEARCH GOALS CURRENTLY UNDERWAY


4.1.1 Background

A National Cooperative Highway Research Program (NCHRP) project is currently underway to produce a new AASHTO pavement design guide by 2003 or 2004 (originally 2002), which will be based on the use of mechanistic-empirical procedures. This method is commonly referred to as “AASHTO 2002.” Mechanistic-empirical (ME) methods offer advantages for new pavement design and rehabilitation compared to empirical methods such as the current AASHTO method and the current Caltrans procedures. These advantages include:

- Greater ability to consider new pavement designs and materials;
- Better ability to consider changes and differences between projects in traffic loading and climate;
- Ability to consider construction quality; and
- Greater ability to be integrated with pavement management systems to evaluate and predict pavement performance.

The UC Contract Team is currently at work on mechanistic-empirical (ME) procedures for Caltrans for rehabilitation, reconstruction, and new pavement design for flexible and rigid pavements. This work includes evaluation of the AASHTO 2002 methods and procedures (referred to as “pre-calibration of AASHTO 2002”) and preparing information such as input data and calibration data for Caltrans to be able to test the AASHTO 2002 procedure. This work also
includes the development of new procedures extend and improve the AASHTO 2002 procedures for particular Caltrans problems that were not considered in the AASHTO 2002 method.

The mechanistic-empirical procedures being developed for Caltrans by the UC Contract Team can be considered to augment the AASHTO 2002 Guide for the following reasons:

- The AASHTO 2002 team is not permitted by the NCHRP panel to perform or use any new research for inclusion in the Guide. The Caltrans procedures will include research from the CAL/APT project and this current research contract, and other recent research underway outside of California,

- The AASHTO 2002 Guide will be designed to meet national needs and will be calibrated for national conditions, including many conditions that are not found in California. The Caltrans procedures will be designed to specifically meet Caltrans needs, and will be calibrated for California climates, traffic, materials, strategies and costs, and the inventory of existing Caltrans pavements that must be rehabilitated or reconstructed in the coming decades. Where it is efficient, work from the AASHTO 2002 Guide will be calibrated for California conditions.

The UC Contract Team will keep abreast of developments in the AASHTO 2002 Guide and avoid any unnecessary differences or duplicated efforts between them.

4.1.2 Objectives

The procedures are intended to:

- Take concepts and procedures included in AASHTO 2002 and review them with regard to Caltrans operational constraints (time, resources, previous performance data),
• Prepare procedures for distress mechanisms and climate regions that are important for California but are not included in AASHTO 2002, or for which the AASHTO 2002 procedures are not appropriate.

• Prepare Caltrans for evaluation of ME design to determine where it provides cost-effective benefits relative to current empirical procedures,

• Capture most of the research results produced for Caltrans over the past eight years by the UC Contract Team and combine them with the best ME design research and practice available worldwide.

This research goal includes the analysis, development and coding to produce the first version of the design procedure to be delivered to Caltrans. The work also includes

• Identification of desired pavement types and relevant distress mechanisms;

• Identification of Caltrans operational constraints and needs;

• Development of required design input databases for ME design;

• Calibration of distress development models;

• Production of a “design catalog” of options for typical sections and different sets of climate, traffic, materials and cost variables; and

• Verification of the models by comparison with observed pavement performance; training for Caltrans in the new procedures; and,

• Technical support to Caltrans during initial use and evaluation of the method.
4.1.3 Current Progress

The UC Contract Team has made significant progress in the development of the ME pavement analysis and design procedures. A workshop for Caltrans pavement staff was held in January 2003 to present a review of the basic premises and requirements of ME design, an update on the procedures to be included in the AASHTO 2002 method, and a review of the procedures being developed for Caltrans. Draft versions of the flexible pavement software and the rigid pavement design check spreadsheet were demonstrated.

It is expected a detailed draft of the Caltrans method will be ready in the summer of 2003 for initial use by a small group of Caltrans users to develop feedback. The first version of the method with software, documentation and initial calibration should be ready for review by the Pavement Standards Team by late in the fall of 2003.

4.1.3.1 Evaluation of AASHTO 2002 procedures for Caltrans implementation

The UC Contract Team has followed AASHTO developments through the AASHTO contractor’s presentations and documents, and through participation of members of the AASHTO contractor’s team in PPRC meetings. However, because of information handling rules in the National Cooperative Highway Research Program (NCHRP), all information received from members of the contractor’s team is informal and unofficial. Some official presentations have been made available that augment the unofficial information obtained by the UC Contract Team. The delivery of the AASHTO 2002 software and final documents has been delayed until late in 2003 or early 2004.
4.1.3.2 Seasonal deflection monitoring sites

Seasonal monitoring sites are needed to determine seasonal variation of pavement layer properties throughout the year in the different California climate regions that ME design considers. Locations for 7 Northern California sites have been identified, and 5 have been instrumented and are collecting data. Several potential Southern California sites have been identified, and one site has been instrumented to date.

4.1.3.3 Climate database

The UC Contract Team has contracted to customize and further develop Integrated Climate Model (ICM) database software, which provides input to the ICM for use in the Caltrans ME procedures. The original software was developed for the FHWA LTPP program. Seven climate regions have been identified for the ME procedures. The ICM database software provides site-specific climate and weather predictions, which could also be used for construction planning purposes. The ICM database software is expected to be completed in 2003. A workshop was held for Caltrans staff in April, 2002 to provide feedback to the software developer, Pavement Systems, Inc., of Bethesda, Maryland.

4.1.3.4 Truck traffic database (WIM)

All Caltrans Weigh-In-Motion (WIM) truck traffic collected to date has been reduced and loaded into a relational database for use with Caltrans ME design. A report has been produced that shows analysis performed using the database to answer basic questions for ME design in California, and includes recommendations to Caltrans regarding maintenance and use of the WIM facilities and database. Work is beginning on improving the database following
procedures being developed by the University of Washington for NCHRP to reduce the size of the WIM database for design purposes.

4.1.3.5 Typical Caltrans materials properties for mechanistic-empirical design input

Some characterization of typical Caltrans materials has been performed as part of other PPRC research goals and implementation projects. Work is underway to correlate moduli with DCP results and R-value results for typical materials. Standard protocols for routine development of ME design inputs are currently being developed, including a Falling Weight Deflectometer testing manual. Improvements in Caltrans practice, such as the Forensic Study Manual produced by the METS Office of Flexible Pavements are being reviewed to provide compatibility.

4.1.3.6 Design algorithms

The basic design algorithms have been selected for flexible and rigid pavement design. A recursive damage calculation has been developed by Prof. Per Ullidtz. Considerable work remains for both rigid and flexible algorithm development, particularly for rigid pavements where a wide variety of loading conditions must be included in a stress calculation algorithm that will operate on a desktop computer. The rigid pavement algorithms are being developed by Prof. J. Roesler of the University of Illinois under the direction of the UC Contract Team, in consultation with Prof. L. Khazanovich of the University of Minnesota.

A three-dimensional finite element program for analysis of rigid pavements, called EverFE and originally developed for the Washington State DOT, has been updated for Caltrans by Prof. W. Davids of the University of Maine.
4.1.3.7  Customize FHWA Life Cycle Cost Analysis software

This work has not been started.

4.1.3.8  Verification/calibration of design systems

Plans for calibration and verification of the flexible pavement design systems have been developed. This program will rely heavily on accelerated pavement testing results from PPRC and other partners, including the CSIR in South Africa, the Army Corps of Engineers Cold Regions Laboratory, and the National Center for Asphalt Technology test track. Data is currently being collected through cooperation with those organizations. Current Caltrans empirical design algorithms have been coded into the software to permit rapid comparison with ME designs, and to facilitate use of the current empirical methods.

Plans for calibration and verification of the rigid pavement design systems will be developed in mid-2003.

4.1.4  Expected Benefits

The work on Development of the First Version of a Mechanistic-Empirical Pavement Rehabilitation, Reconstruction and New Pavement Design Procedure for Rigid and Flexible Pavements will provide Caltrans with a state-of-the-art pavement design procedure, calibrated for California conditions, and specifically designed to meet Caltrans needs. The Caltrans ME procedures will permit the rapid quantitative evaluation of new materials and strategies, without waiting years or decades to obtain this information as is currently done in Caltrans practice. The Caltrans procedures will also permit rapid evaluation of changes in conditions, such as traffic (for example: NAFTA trucks, or increases in tire pressures or axle types). It will also provide an easy means for evaluating the damage caused by special permit loads.
The Caltrans procedures will be designed to work with Caltrans databases, and to provide data for a Caltrans Design Database. It will permit use of QC/QA data obtained from construction.

It is expected that implementation of the Caltrans procedures will lead to much more rapid innovation in Caltrans pavement designs, which will result in cost savings from more effective designs using new materials and strategies. It is also expected that the ME procedures will provide more cost effective designs, calibrated for the different climate regions of California. An added benefit from the ICM database software will be the possibility of site-specific weather prediction from nearby weather station data for construction purposes.

It is expected that ME design will be used initially on an experimental basis, and primarily for cases that cannot be easily analyzed using the current empirical method. The current empirical method likely be used for many years in the future for routine design of cases for which it has been calibrated and verified.

4.1.5 Partners

Several states are following this work, and may include some of the procedures developed for Caltrans in their own procedures to augment the AASHTO 2002 method, including the Washington State DOT. The University of Washington (Professor J. Mahoney) is a key partner in this effort. European partners working as part of the UC Contract Team include Per Ullidtz, formerly of the Technical University of Denmark and now working for subcontractor Dynatest Consulting Inc., and Ronald Blab of the Vienna Institute of Technology. The University of Illinois is developing the rigid pavement design procedures, and providing insight based on FAA work and work for the Illinois DOT that they have performed.
Calibration and verification data is being obtained from the Minnesota DOT, the Washington State DOT, Arizona DOT, the Army Corps of Engineers Cold Regions Laboratory, and CSIR in South Africa. Expertise is being provided by Prof. L. Khazanovich of the University of Minnesota and formerly a key staff member of ERES (ARA) Consultants, developers of the AASHOT 2002 rigid pavement design procedures.

Pavement consultants from ERES are helping with the development of rigid pavement design algorithms and approaches to speed calculation of stresses. Other neighboring state DOTs may wish to participate in the further development of the mechanistic-empirical procedures once the first version is delivered to Caltrans.

The key Caltrans development and implementation partners to date are the Pavement Standards Team (PST), and Design and METS Office of Pavement Rehabilitation are participating in the technical working sessions and evaluation of results.

4.2 Evaluation of Rigid Pavement Long-Life Pavement Rehabilitation Strategies (LLPRS-Rigid) (HVS Goal 4)

4.2.1 Background, Objectives and Current Progress

This research has been underway since March 1998. It was designed to provide Caltrans with information regarding LLPRS-Rigid design options being considered to increase the performance and reliability of urban freeway rehabilitation and reconstruction projects. The HVS testing and laboratory work on the original materials for this Goal has been completed. Some testing is continuing on a new material (very early high strength Type III Portland cement) developed by Caltrans and industry and added to the experiment at a later date. The objectives of the research are to:
• Evaluate the adequacy of structural design options (tied concrete shoulders, doweled joints, and widened truck lanes) being considered by Caltrans at this time, primarily with respect to joint distress, fatigue cracking and corner cracking. The preliminary evaluation using existing methods has been completed. A more sophisticated analysis is underway. These features have been tested in comparison with each other under the HVS testing that was completed in November 2000 (a small amount of additional testing on a previously unfailed section is being performed in April/May 2003).

• Assess the durability of concrete slabs made with cements meeting the requirements for early ability to place traffic upon them and develop methods to screen new materials for durability. This laboratory work and analysis has been completed except for some remaining ASR tests, and some additional materials (high early strength Type III mixes) being tested for strength and fatigue.

• Measure the effects of construction and mix design variables on the durability and structural performance of the pavements.

• Evaluate the erosion performance of LCB versus typical Caltrans CTB (this is has been completed).

To achieve these objectives three types of investigation were performed:

• Computer modeling and design analysis, including use of existing mechanistic-empirical design methods, and estimation of critical stresses and strains within the pavement structure under environmental and traffic loading for comparison with failure criteria. Preliminary evaluation is complete. Additional analysis is underway.

• Laboratory testing of the strength, fatigue properties and durability of concrete materials that will be considered for use in the LLPRS pavements. This is complete
except for tests on the new Type III mixes, which should be completed by the summer of 2003.

- Verification of failure mechanisms and design criteria and validation of stress and strain calculations under traffic and environmental loading by means of accelerated pavement testing using the Heavy Vehicle Simulator (HVS) on test sections constructed in the field. The HVS testing is complete.

Nine reports from this research goal have been completed and are available. All reports will be completed by the fall of 2003.

The work that remains after April 2003 includes:

- Publication of the report on laboratory testing for strength, fatigue performance, and some effects of construction variation on strength and fatigue performance, and some analysis and reporting on the laboratory results;

- Completion of the secondary analysis of the Palmdale HVS test sections, including finite element modeling of their performance, being completed by the University of Illinois.

- Completion of the report on the first level analysis of the North Tangent HVS test results.

- Completion of the long-term ASR testing (ASTM 1293). A detailed test plan has been prepared for this research goal.

4.2.2 Expected Benefits

The expected benefits of completion of the remaining work in Evaluation of Rigid Pavement Long-Life Pavement Rehabilitation Strategies (LLPRS-Rigid) should result in large
life cycle cost savings for Caltrans, and reduction of traffic delay costs by minimizing maintenance and rehabilitation activities during the 30-40 year design life for these projects.

Some results of Goal 4 have already been implemented by Caltrans, including:

- Use of large dowels in new rigid pavements,
- Abandonment of FSHCC as the primary material for LLPRS-Rigid and expanded consideration of Type III mixes,
- Use of widened truck lanes.

Some of the results from this goal are being incorporated into the new version of the Caltrans Highway Design Manual. This implementation is expected to result in large long-term savings to Caltrans, and reduced traffic delays and smoother pavements for the travelling public.

4.2.3 Partners

The Washington, Minnesota and Texas DOTs, and the Federal Highway Administration are interested in implementing the results of this goal. Some of the information developed as part of this goal may be used in the AASHTO 2002 design guides, and will be used for calibration of additional rigid pavement design procedures for Caltrans.

4.3 Performance of Drained and Undrained Flexible Structures Under Wet Conditions (HVS Goal 5)

4.3.1 Background, Objectives and Current Progress

Caltrans currently requires the use of a 75-mm Asphalt Treated Permeable Base (ATPB) layer in new flexible pavements between the asphalt concrete and aggregate base layers, unless special permission is given to not use it. Pavements with the ATPB layer and an edge drain
system connected to it are referred to as “drained” pavements. Pavements with only an aggregate base layer are referred to as “undrained” pavements. The intention of the ATPB layer is to catch surface water coming through cracked or porous asphalt concrete layers, and prevent it from damaging the unbound layers below. A prime coat on the surface of the aggregate base layer is intended to act as a filter for fine materials that might pump up from the aggregate base and other unbound layers and enter the ATPB layer and drainage system, reducing their permeability. The prime coat is also intended to act as an impermeable membrane that prevents water flowing laterally through the ATPB from passing down into the unbound layers.

As part of the CAL/APT project, drained and undrained flexible pavements were tested with the HVS for cracking and subgrade rutting performance. Those first tests, referred to as Goal 1, were performed under dry conditions, with no surface water applied to the pavement and the only water content changes occurring due to capillary action from the clay subgrade. The HVS results and extensive laboratory testing and analysis indicated that the ATPB increased fatigue life of the pavement, because it was a stiffer material than the aggregate base it replaced. Additional laboratory work, analysis, and a survey of past Caltrans research work and experience indicated that ATPB has a high probability of stripping as it is currently used, which reduces pavement fatigue life in the long term. The damage to the ATPB and how it becomes clogged results in a weak layer just below the asphalt concrete layers. This influences the performance of all future overlays and can trap water in the pavement.

Work was begun under the CAL/APT project on HVS Goal 5. The work on this goal includes:

- HVS testing under wet conditions, meaning that water was flowed into the ATPB through the asphalt concrete as if the asphalt concrete was cracked.
• Measurement of flow rates and monitoring of water content changes.

• Laboratory testing on typical Caltrans aggregate bases of the effects of construction compaction on their permeability, and of water content and compaction on their shear strength, stiffness and rutting properties.

• Development of improved constitutive relations for granular pavement materials based on the laboratory and HVS test data, to provide greater insight into the performance of these materials in flexible pavement designs, and the impacts of construction on their performance.

• Analysis of the results.

• A 150-mm diameter triaxial testing system for the aggregate base has been developed, and laboratory testing begun in 2000.

All the work in this goal has been completed, except for editing of the individual test section reports. A summary report has been completed. A detailed test plan has been prepared for this research goal.

4.3.2 Expected Benefits

This goal will be used to make final recommendations to Caltrans regarding the efficiency of drained pavement structures using ATPB as a layer between the asphalt concrete and aggregate base. Changes to the design practice could substantially reduce the cost of new flexible pavements or lanes. Some of these changes are being considered for inclusion in the next version of the Caltrans Highway Design Manual.

The results of this goal will also be used to make recommendations regarding increasing the compaction specification for granular materials, which could result in slight increases in
initial cost, but substantial savings due to increased pavement performance and potential reductions in the thicknesses required for aggregate bases and subbases. The information and analyses from this goal will be vital to the development of ME pavement design methods, and for the development and implementation of non-destructive, deflection-based, flexible pavement structural capacity assessment methods.

4.3.3 Partners

The US Army Corps of Engineers and CSIR have granular material compaction specifications and a great deal of useful data and expertise that were used extensively for this research goal. CSIR worked directly on this goal, and the Corps of Engineers has been consulted. The four states in the State Pavement Technology Consortium have granular material compaction specifications similar to those of Caltrans, and are interested in the results. Caltrans districts, Design and METS Structural Section Design will be the primary partners for the implementation of the results. The results of the research goal form the basis for the proposed implementation project “Compaction Specifications for Granular Base and Subbase/Rapid Compaction Control Device” described in Section 3.2.8 of this document.

4.4 Development of Asphalt Concrete Rutting Performance Tests and Analysis Procedures

4.4.1 Background, Objectives and Current Progress

Currently used constitutive relations used for asphalt concrete do not adequately model the behavior of asphalt concrete at high temperatures, which can result in costly early failures in
some cases, and inadequate procedures for routine use to evaluate the performance of asphalt concrete mixes with respect to rutting.

The objectives of this research goal were to:

• Finalize work on the development of a constitutive relation that permits accurate modeling of asphalt concrete behavior under traffic loads at elevated pavement temperatures. This work is close to being completed and is currently being validated using laboratory tests. The validation was delayed for more than a year due to problems with the Pavement Research Center simple shear tester. Testing has begun using the new triaxial device.

• Based on the understanding of the material behavior, produce a procedure for the analysis of test data to predict asphalt concrete rutting performance based on data from one or a few simple tests that can be performed on a simple machine or machines,

• Analyze work already performed to determine the relation between specimen size, sample size, and test variability for asphalt concrete at high temperatures, so that the specimen dimensions and number of samples required can be optimized with respect to permissible variability of the test results. This work has been delayed due to the problems with the Pavement Research Center simple shear tester.

• Develop a prototype device based on the simple shear tester to perform the test(s). The device should cost less than about $70,000 and fit in a construction trailer or district laboratory. A new device using a sample that measures 6 in. wide by up to 6 in. high and 16 in. long has been developed by Cox & Sons, but the cost is about $85,000.
• Validate the model with HVS and field test results obtained previously and by other researchers. HVS results will be analyzed including those from Goal 3 (previously completed) and from Goal 6, described in Section 4.7 of this Strategic Plan. The PRC team is also working with Contra Costa County personnel monitoring various field sites and performing laboratory tests on cores for comparison with results from HVS Goal 3 research.

• Code software to perform the analyses. This will commence on completion of the constitutive relation and analysis procedures.

• Shadow current mix design procedures to help verify and calibrate the procedures, and provide the technology transfer to Caltrans, and

• Provide training on use of the equipment and procedures.

The last two tasks above will proceed on completion of the software coding.

Work completed during the CAL/APT project identified a good candidate for the form of the constitutive relation, validated by iterations of model development and laboratory testing. Some work has also been performed to determine test specimen dimensions required to obtain a Representative Volume Element, meaning a specimen large enough so that several large aggregates cannot control the test result.

The work currently involves continued iterative laboratory testing and numerical analyses (finite element methods) to model material behavior in the laboratory tests under a no-cost time extension to the subcontract. The results are being used to adjust the constitutive relation. Existing HVS results, or the results of a few quick rutting tests taking less than a month, and field test results from Caltrans, WesTrack, and Contra Costa County test sections will then be
used to verify the model. The Contra Costa County test sections all include gap-graded asphalt-rubber concrete (RAC Type G) produced following Caltrans mix designs.

Prototypes of tests required to define the constitutive relation for different mixes have been developed. The calibrated constitutive relations for typical Caltrans materials has been used in simulations to evaluate the WesTrack project (performed as part of the FHWA WesTrack project). The test and analysis methods will be used to “shadow” Caltrans mix designs to provide predictions of rutting performance, as a final check on the reasonableness of the procedures and predictions.

4.4.2 Expected Benefits

Caltrans currently needs a more reliable method for designing asphalt concrete mixes to prevent rutting, particularly for modified and rubberized mixes. Increased truck tire pressures, the introduction of radial tires and increased truck load repetitions make the original calibration of the Hveem Stabilometer increasingly less reliable. The Hveem Stabilometer does not provide reliable results for many mixes containing modified binders, or non-traditional mixes such as RAC Type G.

The methods developed will be designed to fit into the Caltrans QC/QA procedures, providing the contractor and agency with reliable predictions of rutting performance. It is expected that the results of this will provide Caltrans with more effective mix design methods to prevent costly early failures of asphalt concrete overlays. The procedures would be applicable to the non-traditional mixes mentioned above for which the current Caltrans method does not provide good results.
4.4.3 Partners

The results of NCHRP Project 9-18 may produce the prototype test device for this research goal. A member of the UC Contract Team is on the advisory panel for that project, and will monitor the potential for the device being evaluated and changed in that project. The Federal Highway Administration has funded much of the work performed to date through the WesTrack project. The National Cooperative Highway Research Program funded further development and evaluation of the field shear tester. The Vienna Institute of Technology may be interested in field trials of prototype devices in Europe, and is interested in the results of this project. The asphalt paving industry in California and/or nationally will also be approached to participate in the verification and calibration tasks. Contra Costa County is providing test sections and providing data and cores from those sections.

The key Caltrans partner is the METS Bituminous Materials group.

4.5 Calibration of Mechanistic-Empirical Design Models

4.5.1 Background, Objectives and Current Progress

The ME design procedures being developed for Caltrans need calibration with field data as well as HVS and laboratory testing and analysis. The two primary sources of long term pavement performance data for Caltrans pavements are test sections on mainline pavements and information stored within the Caltrans pavement management system and construction databases. The objectives of this research goal are as follows:

- Obtain the Caltrans, Arizona, and Washington State PMS databases, and identify the variables in them. This has been done, and the WesTrack database was also obtained. The Caltrans database has been extensively cleaned and recommendations have been
made for improving its organization to permit performance modeling. A preliminary model has been developed for reflection cracking of asphalt concrete overlays on rigid pavements. Preliminary models for several other distresses were also evaluated using the Caltrans data. Models built using the Caltrans database suffer from the lack of structural information in the database. These results were included in a recent report to Caltrans. The Arizona and WSDOT databases have been evaluated for compatibility with the Caltrans database, and reflection cracking models have been calibrated using the Arizona database. Modeling is underway with the Washington database. These models will then be used with the Caltrans models to develop joint models for climate regions that are common to California and the other two states. Asphalt concrete fatigue cracking and rutting models have been calibrated using the WesTrack database.

- Provide Caltrans with a list of all known field test sections in the state and organize this list with respect to different pavement deterioration issues (this objective was completed in the CAL/APT project). In April 2003, the UC Contract Team should receive in the structural and materials information collected by another Caltrans Research contractor on sections identified from this list to see if they can be integrated into the Caltrans database;

- Perform laboratory testing on the material samples. This work has been completed for the WesTrack project. The other Caltrans Research contractor is performing some tests on asphalt concrete specimens taken in the field and measuring the thicknesses of underlying layers, but is not collecting or testing any other materials in the pavement structure. The laboratory and field deflection test results from that
contractor will be included in the databases when it is obtained. Laboratory testing will be performed on the Contra Costa County RAC Type G sections described in “Development of Asphalt Concrete Rutting Performance Tests and Analysis Procedures” in Section 3.4 of this Strategic Plan.

- Use the laboratory data, field performance data, and the data from the PMS databases to calibrate mechanistic models for key distresses to the extent permitted by the data. This work has been possible only for the WesTrack data and is included in a recent report. Full-scale calibration of mechanistic-empirical data will only be possible once integrated databases have been developed and populated, following the recommendations developed in Implementation Project 3.2.4.

The distresses to be modeled include reflection cracking, fatigue cracking, and rutting of flexible and composite pavements. Some calibration of maintenance strategies was intended to be performed, but the Caltrans PM database does not include information on maintenance activities.

4.5.2 Expected Benefits

The results will provide definitive ties between HVS and laboratory results already produced for Caltrans, and field performance. The results will provide strong calibrations of all ME design procedures that will be produced for Caltrans, greatly increasing their reliability. The laboratory test results will provide information to Caltrans from the field test sections that have been built over the years to help explain their behavior. The net result will be the capture of a large amount of data that will result in recommendations to Caltrans to improve pavement design, rehabilitation design, materials, maintenance practices, and pavement management.
Because mechanistic modeling of reflection cracking has not reached an advanced enough state for mechanistic-empirical design, it is expected that the calibrated empirical models developed as part of this goal will be included in the ME design procedures being developed as part of Research Goal 4.1.

4.5.3 Partners

The Arizona and Washington State DOTs have provided their PMS databases and are helping the UC Contract Team understand the variables and data in those databases. Contra Costa County is providing information for this goal through the RAC Type G sections. An early partner in this effort was the Federal Highway Administration through the WesTrack project. The Nevada DOT may be able to provide information from test sections on Interstate 80 that are satellites of the WesTrack project.

Other states and organizations may be interested in the laboratory test results from field test sections that overlap with their needs, including the other two states in the State Pavement Technology Consortium (Texas, Minnesota), and Illinois and the Army Corps of Engineers Cold Regions Laboratory.

The results will add to the value of the mechanistic-empirical design procedures being developed for Caltrans, which has potential partners identified for that research goal. The key development partners are Caltrans Maintenance, Caltrans Research, and the districts.
4.6 Development of Rehabilitation Construction Productivity Analysis Products

4.6.1 Background

One of the primary objectives of the Caltrans Long-Life Pavement Rehabilitation Strategies (LLPRS) is minimization of traffic delays during rehabilitation or reconstruction work. During the CAL/APT project, it was found during that quantitative methods for estimating construction duration and the impacts of materials type, structural cross-section, the number of lanes closed to traffic, and contractor resources constraints were not available. Similarly, it was found that no method was available to Caltrans traffic planners regarding the estimated duration of reconstruction and rehabilitation projects until the plans were completed and the contractor selected.

For this reason, the UC Contract Team, with Caltrans agreement, added the development of methods for prediction of construction duration, identification of constraints on productivity, and for evaluation of the impacts of material types, pavement structure, etc., to the scope of the CAL/APT project.

It has since been found that models have not been calibrated for the simulation and prediction of traffic delays during construction in urban areas. Caltrans traffic engineers must currently develop Traffic Management Plans (TMP) based on past experience, which makes it difficult to evaluate new situations, such as Long-Life Pavement Rehabilitation. For this reason, the verification of Caltrans TMPs and the evaluation, calibration, and verification of urban traffic simulation models has been included in this research goal.

Final selection of optimal pavement strategies, construction strategies, and traffic handling strategies within the constraints that Caltrans faces must be integrated through the use of life cycle cost analysis.
4.6.2 Objectives

This work has been divided into three phases as presented in the following three sections.

4.6.2.1 Construction productivity analysis

Initial development and verification has been, and includes:

- Development of a database structure for construction productivity measured in the field,

- Development of an analysis method for estimating field construction duration, currently completed for LLPRS-Rigid and two AC Long-life rehabilitation strategies,

- Coding of software for the analysis procedures developed in CAL/APT (Partnered and funded by the four states of the State Pavement Technology Consortium)

- Some evaluation of LLPRS projects to calibrate the procedures. (Completed for I-10 rigid pavement long-life rehabilitation project; I-710 asphalt long life pavement project currently underway)

4.6.2.2 Construction closure traffic delay estimation

This phase of the work is currently underway and includes:

- Measurement of traffic delay and construction productivity on pilot projects (I-710 AC Long-life project),

- Evaluation of a current Traffic Management Plan (prepared by District 7 for I-710 project),

- Evaluation of network level models for predicting traffic delay during pavement rehabilitation and maintenance activities. The set of potential models to be evaluated
in detail has been narrowed down to MITSIM (from the Massachusetts Institute of Technology) and Paramics (currently being upgraded by the California PATH project),

- Comparison of the simulation model results with the pilot study, and
- If the model has promise, use of it to evaluate various project staging strategies for LLPTS projects, and development of heuristics for traffic handling and construction production in terms of lanes used for construction to minimize total traffic delay.

4.6.2.3 Inclusion of Life Cycle Cost Analysis

This work will include:

- Inclusion of economic analyses in the construction productivity analysis procedures. (This task will be tied to the life cycle cost analysis system work done as part of the development of mechanistic-empirical design procedures.) The new FHWA method for life cycle costing has been coded by WSDOT personnel and will be customized for Caltrans, and

- Evaluation of several example projects.

The final part of this research will be technology transfer to Caltrans on use of the products developed as part of this goal. Some technology transfer has already occurred through training of Caltrans and I-710 contractor staff on the construction productivity analysis software in District 7. Some technology transfer has also been performed with Districts 4 and 8.
4.6.3 Expected Benefits

The results of “Development of Rehabilitation Construction Productivity Analysis Products” will greatly enhance and expand the usefulness of the rehabilitation construction productivity analysis system developed under the CAL/APT contract. The analysis software will provide Caltrans with a tool that can be used by policy makers regarding materials types, pavement cross sections, and traffic control at construction sites. It can be used by traffic planners to provide early information to local authorities, residents, and businesses regarding the duration of rehabilitation projects, and to optimize traffic control to total traffic delay over the entire time of the project. Finally, contractors can use the software to obtain an approximate early estimate of project duration before they perform detailed critical path analysis.

This process has already occurred on the I-710 reconstruction project in District 7, where the contractor has used the software to check construction plans, and on a project to reconstruct part of I-15 near Devore in District 8 where Caltrans has used the program to traffic closure strategies.

Research goal will provide information that is critical for success of the Caltrans 10-year effort to reconstruct the urban freeways in the state.

4.6.4 Partners

The State Pavement Technology Consortium (Caltrans, WSDOT, TxDOT and MnDOT) has funded coding of the construction productivity analysis software since Fall 2000. This partnering effort will result in substantial cost savings to Caltrans. The Innovative Pavement Research Foundation (IPRF), a joint program of the FWHA and the concrete paving industry, has already funded one case study (I-10). The National Asphalt Paving Association (NAPA) has contributed funds to the evaluation of the I-710 AC Long-life project. Other states and the
The City of Long Beach is working with the UC Contract Team to provide local street data for the I-710 project. California PATH is working with the UC Contract Team for the measurement of traffic on the I-710 project and for the evaluation of the simulation program Paramics.

The primary Caltrans partners are District 7, District 8, HQ Design, HQ Maintenance, and HQ Traffic Operations.

4.7 Verification of Asphalt Concrete Long-Life Pavement Strategies (HVS Goal 6)

4.7.1 Background, Objective and Current Progress

Caltrans has long-life pavement rehabilitation strategies for urban freeway pavements that involve asphalt concrete, portland cement concrete, and other hydraulic cement concrete products.

The objective of this goal is to evaluate and verify the effectiveness of long-life pavement rehabilitation strategies for damaged pavements that involve asphalt concrete (AC Long-life Strategies). These strategies include Crack, Seat, and Overlay strategies, and full depth asphalt concrete pavements. Methods to improve these strategies have been developed based on the results from previous research by the UC Contract Team through a partnership of the AC paving industry, Caltrans, and the UC Contract Team.

Work in this research goal includes:

- Laboratory tests,
- HVS tests, and
- Analysis and reporting.
4.7.1.1 Crack, Seat and Overlay

- Laboratory tests are underway on materials from the Crack, Seat, and Overlay Strategy test section at the Richmond Field Station,

- Laboratory testing will be performed on alternative materials and the effects of construction quality on the expected performance,

- HVS tests on sections constructed by industry partners at the Richmond Field Station have begun, and two key HVS tests, one for rutting and one for cracking, have been completed. These tests provided additional support for the expected PBA performance in the I-710 long-life AC design. The final HVS tests for rutting and cracking at the Richmond Field Station are currently underway.

- The results of the laboratory testing and HVS tests from the Richmond Field Station section are also being used for finite element analysis and verification of the analysis as part of the Research Goal 4.10 “Development of Improved Rehabilitation Designs for Reflection Cracking (HVS Goal 9).”

A detailed test plan has been prepared for this portion of Goal 6.

4.7.1.2 Full-Depth Reconstruction

Whether and when this portion of the study will be conducted is still under consideration.

4.7.2 Expected Benefits

The expected benefits from Verification of Asphalt Concrete Long-Life Pavement Strategies include:
• Early confirmation of the expected performance of implementation of the crack seat and overlay strategy on the Long Beach Freeway (I-710), and other AC Long-life projects being considered,

• Identification of any problems or potential improvements to the strategy, and

• Evaluation of the effects of construction quality control on the performance.

4.7.3 Partners

The Southern California Asphalt Paving Association has donated materials and cost of construction for the HVS test section at Richmond to evaluate the Crack, Seat and Overlay strategy, and may wish to participate in other aspects of this goal. The National Asphalt Paving Association is very interested in the research and design concepts being developed in California and may wish to play a larger role in this goal.

4.8 Dowel Bar Retrofit of Rigid Pavements (HVS Goal 7)

4.8.1 Background

Since the early 1950s, Caltrans rigid pavement practices have relied on non-erodable bases and aggregate interlock at the transverse joints to control transverse joint faulting. At that time Caltrans stopped using dowels because of problems encountered with dowel alignment during construction, the relatively small benefit obtained from the small dowels used at the time, and the level of traffic at the time. Caltrans has used dowels in new concrete pavements since 2001, and has begun using dowel bar retrofit as a rehabilitation strategy for existing undoweled pavements.
Currently, faulting on Caltrans pavements typically occurs on rigid pavements within several years after construction, reconstruction, or grinding. Faulting results in a rough ride and can increase noise. Improved techniques for retrofitting existing concrete pavements have been developed over the past seven years by the Washington State DOT, among others. Dowel bar retrofitting consists of sawing grooves, insertion of dowels across the transverse joints and grouting, followed by grinding to remove the faulting and smooth the grout surface. The joint load transfer provided by the dowels significantly slows the development of new faulting under truck loads. The life of dowel bar retrofitting of slabs with longitudinal cracks, and retrofitting of transverse cracks is of interest since many older Caltrans pavements have some form of cracking, but the cracks have not led to widespread failure.

Manufacturers are proposing alternatives to epoxy coated steel dowels, such as fiber reinforced polymer dowels and stainless steel dowels. There are also questions regarding the number of dowels needed per wheelpath and the effects of construction quality variables on performance. Construction quality variables include dowel alignment, grout strength, and bonding of the grout to the concrete, among others.

A key factor in the cost-efficient implementation of dowel bar retrofit (DBR) will be estimation of the life of dowel bar retrofit pavements so that the Life Cycle Cost of this strategy can be compared to other alternatives. Dowel bar retrofit pavements can fail due to

- distresses caused by the retrofit itself (dowel misalignment and lockup),
- deterioration of the dowel due to corrosion, cracking or loosening, or
- loss of load transfer efficiency across the joint and return of faulting at a rate that is similar to that of joints that have not been retrofitted.
4.8.2 Objectives and Current Progress

The objectives of this research goal are to:

- Compare the performance of retrofitted joints and transverse cracks with joints and transverse cracks that are not retrofitted through HVS testing. Heavy Vehicle Simulator testing was completed in May 2001 on sections of old faulted existing concrete pavement at Ukiah to determine the load transfer restoration of dowel bar retrofit and evaluate the loss of load transfer efficiency under traffic of retrofitted pavements, with new doweled and undoweled pavements, and old pavements that have not been retrofitted. Additional HVS testing has been carried out at Palmdale since November 2001, and is expected to continue through April 2003. Variables included in the Palmdale test sections include:
  - The number of dowels per wheelpath,
  - Epoxy coated steel, fiber reinforced polymer and hollow stainless steel dowels, and
  - Variations of slab condition including the presence of longitudinal cracks and transverse joint spacing.

- Analyze dowel bar retrofit variables using finite element analysis to extrapolate the results of the HVS test sections to other conditions. This work requires the use of specialized finite element programs. A finite element program developed through WSDOT contracts, called EVERFE, has recently been upgraded under contract to the PPRC, and is being used for the verification of the HVS test section results to be followed by analysis of additional cases and variables.
• Evaluate the performance of different dowel types, potentially including traditional epoxy coated steel, stainless steel, and non-ferrous composite materials with respect to corrosion durability of the metallic dowels, degradation of the fiber reinforced polymer dowels, and chemical durability of the grout materials. Use of the upgraded EVERFE program will assist in the work. The first set of metallic corrosion tests has been performed. A second set of tests will be performed starting in the summer of 2002 based on evaluation of the initial results by the UC Contract Team, Caltrans METS Concrete group, and WSDOT.

• Develop performance estimates for dowel bar retrofit based on the results of the studies described above and analysis of WSDOT sections that have been in place for up to 10 years.

• Develop preliminary life cycle cost analysis estimates for DBR.

A detailed test plan has been prepared for this research goal.

4.8.3 Expected Benefits

The results of “Dowel Bar Retrofit of Rigid Pavements” will provide Caltrans and other research partners with the information needed to design and construct dowel bar retrofit projects to obtain maximum performance, and to determine where dowel bar retrofit is the most cost-effective strategy for rigid pavement rehabilitation. DBR offers the potential for a much longer-term improvement of smoothness for concrete pavements compared to other strategies.
4.8.4 Partners

The Washington State DOT is the primary outside partner for this project. Other partners include dowel bar manufacturers who are providing samples for laboratory testing and HVS test sections, and the Western State Chapter of the American Concrete Paving Association. The Federal Highway Administration is currently funding research on non-ferrous dowel types and has expressed interest in further testing and analysis of dowel bar retrofits with composite dowels. The Highway Innovative Technology Evaluation Center (HITEC) is interested in looking at Fiber Reinforced Polymer (FRP) Composite Dowel Bars and Stainless Steel Dowel Bars, and may be a possible research partner.

The key Caltrans partners are the METS Concrete group, Design and Districts 1 and 7.

4.9 Investigation of Asphalt Concrete Moisture Damage (HVS Goal 8)

4.9.1 Background

Stripping can be defined as separation of asphalt from aggregate in an asphalt concrete mix. Water damage or water sensitivity can be defined as a reduction in stiffness, strength, shear, or fatigue resistance of an asphalt concrete mix caused by exposure to water. Stripping and water damage have been found to be a function of the chemistry of the aggregate, traffic levels, time of exposure to water, and climate. This distress mechanism has also been shown to be influenced by mix design variables such as asphalt content and use of modified binders, and by construction variables such as compaction and segregation. At present, difficulties have been identified with existing laboratory tests and/or criteria used with existing tests for stripping and water sensitivity. These difficulties include:
• The tests do not work well in identifying vulnerable mixes,

• The tests may identify mixes as having high risk, yet the same mixes have good performance histories under certain sets of conditions (climate, traffic, mix design, construction quality),

• High variability of the test method results.

Questions exist regarding:

• how to test mixes in the laboratory in a manner that will identify mixes that should not be used, mixes that will require some additional treatment, and mixes that can be used with no additional treatment,

• how to calibrate the results from tests for expected field conditions, and what criteria to apply from the calibration,

• how to develop the database to be used for calibration,

• how to account for variability of the results in the analysis of the results.

At this time, Caltrans and the asphalt paving industry have established a task group to address issues of identification of moisture sensitivity/stripping; to develop recommendations regarding testing and test results; and to develop and deliver technology transfer products regarding understanding of the technical issues and the results of practice and research in solving them. The work to be performed in this research goal will primarily be defined and coordinated through that task group.

A national seminar and workshop on this subject was held in San Diego in February 2003, funded in part by this project, and organized by the Transportation Research Board and Caltrans Research.
4.9.2 Objectives

The objectives of this research goal are:

- Investigate the extent to which aggregate source is the primary cause of stripping or water sensitivity, and the extent to which construction, mix design, climate, and traffic variables are the cause or large contributors,

- Distribute information developed nationally to date on this problem, and aid Caltrans in identifying the causes of premature mix failures on a case-by-case basis, including stripping and water sensitivity, and tests and solutions for the problem being used elsewhere,

- Evaluate potential laboratory test methods and calibrate criteria for their use in California,

- Build and test asphalt concrete pavements, subject them to water conditioning, test them with the HVS, and analyze the results. potentially include:
  - Traffic level,
  - Aggregate source,
  - Mix design binder content,
  - Construction compaction, and
  - Treatment [e.g., lime, lime construction process (dry on wet aggregate, marination), liquid anti-strip].

These results will be used to verify the relative contributions to moisture damage of these variables, and the ability of treatment methods to mitigate the problem, obtained from the statistical field studies and laboratory studies.
• Potentially, develop recommendations regarding mix design, construction specification, test method(s) for stripping and water sensitivity, and help develop and implement new tests, procedures and specifications.

Caltrans and Industry, with technical support from the UC Contract Team, are currently developing shorter-term solutions to deal with this problem for the next several years. The results from this research goal are intended to help Caltrans and Industry as much as possible in the shorter term, while developing data and analysis for longer-term solutions.

4.9.3 Current Progress

The following work on this goal has been completed to date:

• The UC Contract Team has worked with Caltrans and industry to establish common definitions and understanding of the causes and identification of stripping and water sensitivity and associated variables. This is underway and UC Contract Team personnel are members of three Caltrans subcommittees of the Caltrans/Industry task group: Moisture sensitivity identification; Testing and evaluation; and, Technology transfer.

• The UC Contract Team has developed a database structure and data input questionnaire, and a draft decision tree for moisture damage. The database structure and data input questionnaire provide a means of documenting case histories regarding moisture sensitivity and stripping on a mix/project basis. This allows for determining whether moisture damage is the cause of problems on a given project and also for the identification of other or associated factors such as mix design, construction issues, traffic, climate region, and drainage. The questionnaire has been delivered to the
Caltrans/Industry task group. The decision tree is being converted into an easier-to-follow format.

- The questionnaire has been used to begin to populate a database. The intention is to populate the database with 4 to 6 well-documented case histories for approximately 8 aggregate sources. Data has been collected in District 2, Washington State, Nevada, and Contra Costa County. Other Caltrans districts have also been contacted, but no definitive arrangements have been made for data collection, and the lack of records on pavement structure and construction quality make collection of Caltrans data difficult.

- Literature searches have been performed regarding current testing and treatment practice and research. These documents have been delivered to the Caltrans/Industry task group.

### 4.9.4 Expected Benefits

Currently, Caltrans is trying to determine when and how to require lime treatment of aggregates for asphalt concrete mixes. The asphalt paving industry is providing input to Caltrans on this issue. Lime treatment increases the cost of asphalt concrete. However, stripping and water sensitivity are costly to Caltrans when they result in premature failure. Development of an effective program to deal with this problem has the potential to result in large cost savings to the state.

The HVS results will provide verification under controlled conditions of the other elements of Goal 8. The results will provide verification for any laboratory tests selected by Caltrans, and help with the setting of specification criteria.
4.9.5 Partners

The primary partners for this goal are the METS Bituminous Materials group, Construction, Design and the District Materials Engineers. The California Asphalt Paving Associations, aggregate suppliers and additive suppliers (lime, liquid anti-strips, etc.) are participating in the work of the task group and have contributed to the research effort. This is also a national problem, and there is considerable interest in this goal from other state DOTs and their asphalt paving industry organizations, and the National Asphalt Paving Association.

4.10 Development of Improved Rehabilitation Designs for Reflection Cracking (HVS Goal 9)

4.10.1 Background

The Caltrans METS Office of Pavement Rehabilitation group estimates that approximately 90 percent of the HA-22 deflection studies it analyzes each year result in a design deflection less than the tolerable deflection, in which case California Test Method 356 then requires an overlay based on reflection cracking considerations. The CAL/APT Goal 3 HVS testing clearly illustrated that asphalt concrete overlays of flexible pavements commonly fail by reflection cracking. Reflection cracking is the primary mode of failure of asphalt concrete overlays of rigid pavements.

Current approaches for asphalt concrete overlays of flexible and rigid pavements, including those used by Caltrans, typically rely on reflection cracking criteria based on engineering judgment. Development of better understanding of the mechanisms that cause reflection cracking, and better empirical models of current reflection cracking performance, will lead to improved design methods.
Some previous work contributes to this goal, such as the Caltrans METS development of a test method for asphalt concrete specimens. This test method attempts to simulate the loading conditions that are considered to cause reflection cracking. The Goal 3 and Goal 6 HVS test data also include information that can be used in the verification of reflection crack design methods. Empirical reflection cracking models are being developed for the research goal “Calibration of Mechanistic-Empirical Design Procedures” (Section 4.5 of this Strategic Plan).

4.10.2 Objectives and Current Progress

The objectives of this goal are:

- Parametric sensitivity studies of improved empirical models of reflection cracking in California developed as part of Research Goal 4.5, that consider different materials, climate regions, traffic levels, and overlay technique (crack, seat and overlay and fabrics, for example),
- Development of improved mechanistic models of reflection cracking, after evaluation of work done in the past and selection of the likely most effective analysis strategies,
- HVS testing to verify and calibrate empirical and mechanistic models,
- Use of the models to evaluate the most effective strategies for reflection cracking in overlays of flexible and rigid pavements.

A detailed work plan has been developed for initial HVS and laboratory testing to compare MB overlays with RAC Type G and DGAC overlays for reflection cracking. Finite element modeling work to be done in the research goal has been written into a detailed doctoral thesis work plan, and some of it remains to be determined. The work in this goal includes:
• Evaluation of the empirical reflection cracking models developed in Research Goal 4.5 for insight into the mechanics of the problem,

• Laboratory tests of overlay materials for use in mechanistic models, including material types and construction variables. Work currently underway involves flexural testing of AC beams that are subsequently sliced and digitized for Finite Element Method (FEM) analysis.

• Mechanistic modeling of reflection cracking for flexible overlays of flexible and rigid pavements, to determine the most effective strategies. Once the FEM model is verified for the beams, it will be verified using HVS data from Goals 3, 6, and 9, and then used to evaluate different reflection cracking strategies/materials for different underlying pavement conditions.

• HVS testing of alternative asphaltic overlays of flexible pavements, including traditional asphalt concrete, RAC-G, and modified binder mixes. Synthesis of the results of the empirical and mechanistic studies to develop preliminary recommendations for the most effective strategies and performance estimates for different strategies, for different traffic levels, environments and construction quality.

• Calibration of models and verification of recommendations using the HVS and field test results. This work is underway with the RACTAG experimental design committee, that is developing and designing HVS and field tests for calibration purposes.

• Development of design procedures for reflection cracking.

• Laboratory fatigue study to evaluate MB binder specification parameters (in cooperation with the Pacific Coast User-Producer Group). Sub-tasks include:
· Evaluate the experiment for the binder fatigue parameter study being conducted by the UC PRC for the Pacific Coast Conference on Asphalt Specifications (a pooled fund study with Arizona DOT as the lead state) to see if has sufficient range of binder types to provide Caltrans with information to evaluate the MB binder specification parameters (including SSV/SSD),

· For the binders not included in the PCCAS experiment, perform additional mix fatigue beam testing to evaluate performance-related parameters (including SSV and SSD) for AC binder specification for cracking, and

· Work with Caltrans to analyze the data to help develop improved binder specifications for reflection cracking and bottom-up fatigue cracking.

4.10.3 Expected Benefits

The primary result of this work will be improvement of overlay designs to resist reflection cracking. Specific benefits include:

- improved overlay performance and therefore lower life cycle cost, and
- improved ability to predict performance and therefore improve planning, scheduling and budgeting efforts for overlay projects.

The results of this goal would considerably increase the ability of Caltrans to design effective rehabilitation strategies for reflection cracking. Currently, Caltrans typically

- applies a uniform overlay thickness on rigid pavements for reflection cracking,
- designs overlay thickness for flexible pavements based on deflections intended to prevent fatigue cracking due to bending, or uses judgment to select overlay thickness for reflection cracking.
Implementation of the results of this goal will likely result in reduction in the over-design and under-design of asphalt concrete overlays for reflection cracking, generating considerable cost savings from safe use of thinner overlays. The models will provide a means for Caltrans for preliminary evaluation of potential new methods for reducing reflection cracking without having to build test sections on mainline pavements and wait many years to obtain results.

The results of laboratory binder study will provide Caltrans with information to help evaluate the MB binder specification parameters, and potentially develop improved specifications. Improved binder specifications for reflection cracking will extend asphalt concrete overlay life, which can potentially reduce lifecycle cost.

4.10.4 Partners

The AASHTO 2002 design method will only have a “placeholder” reflection cracking model (a term used by a member of the advisory panel for that project). The “placeholder” model will be evaluated as part of this research. There are efforts underway at this time to initiate an NCHRP project to evaluate reflection cracking, led by Transportation Research Board subcommittees on which UC Contract Team members participate. This research goal would be coordinated with that effort. Most state DOTs are facing large problems with reflection cracking, and it would be expected that several would be interested in participating in this project. The key Caltrans partners are the METS Bituminous group, Design, Construction, Maintenance, and the METS Office of Pavement Rehabilitation. The other three states in the State Pavement Technology Consortium are also interested in this goal.

Partners in the laboratory binder study are the PCCAS, the Arizona DOT, and the members of the Rubber Asphalt Concrete Technical Advisory Group (RACTAG) which includes Caltrans METS bituminous group, METS structural section design, Design, Construction,
Maintenance, the Rubber Pavements Association, the California Asphalt Paving Associations, and other industry groups.

4.11 Evaluation of Hydraulic Cement Concrete Mix Design for Pavements

4.11.1 Background

Current Caltrans hydraulic cement concrete mix design procedures were originally designed to proportion mix components for relatively low strength concrete using Type I/II portland cement and few admixtures. At present, Caltrans is facing a variety of issues having to do with concrete mix design, including

- the use of fly ash,
- new chemical admixtures,
- use of hydraulic cements other than portland cement,
- increased use of Type III portland cement to obtain faster strength gains,
- alkali-aggregate reaction, and
- potential introduction of a QC/QA system that transfers greater responsibility for mix design to the contractor.

4.11.2 Objectives

The objectives of this research goal remain to be determined by Caltrans. Three subcommittees were established at the December 2001 Paving Conference (structural design, testing standards, mix design), and the UC Contract Team is committed to participate in all of them. Some potential work that might be performed includes:
• review of materials and pavement structural issues that should be addressed in the concrete mix design process,

• review of effectiveness of current mix design procedures to address those issues,

• review of concrete mix design procedures used outside of Caltrans with the intent of identifying procedures that would improve practice in California,

• evaluation of mechanistic-empirical pavement design for rigid pavements,

• development of a revised concrete mix design procedures based on synthesis of the results of the previous objectives, and

• verification of the revised procedures using laboratory tests and later field implementation projects.

4.11.3 Expected Benefits

This work should improve the ability of Caltrans to design and construct concrete pavements, and result in improved performance and reduced life cycle costs. The work should also reduce the potential for early development distresses in concrete pavements and increase the potential for the contractor to be innovative, which should reduce initial cost.

4.11.4 Partners

The key Caltrans partners for this goal are the METS Concrete group, Design and Construction.
4.12 Development of Improved Mix and Structural Design and Construction Guidelines for Deep In-Situ Recycling (DISR) of Cracked Asphalt Concrete as Stabilized or Unstabilized Bases (HVS Goal 10)

4.12.1 Background

Current Caltrans practice for the management of low- and medium-volume flexible pavements is to maintain them by means of seal coats and crack sealing, and then eventually rehabilitate them with an asphalt concrete overlay. The asphalt concrete overlays are typically thin relative to the existing pavement structure, and fail by reflection cracking.

The current overlay strategy may be most cost-effective for some projects, but not for many others. Deep In-Situ Recycling (DISR) involves the following steps:

- Grinding of the existing cracked asphalt concrete into a granular material, with a gradation similar to that of aggregate base, mixing it with at least part of the existing aggregate base,

- The ground material can be compacted as aggregate base as is, or mixed with a stabilizer (asphaltic or cementitious, or a combination of the two) prior to compaction. Because of the delay times (weeks) associated with asphaltic stabilization using asphalt emulsions (included in the Caltrans Highway Design Manual as Cold Recycled Asphalt Concrete), foamed asphalt is the preferred treatment in locations such as California where traffic delay is important,

- Placement of a wearing course on the new base to complete the rehabilitation.

The grinding, shaping, stabilization, and compaction is performed as a single process. This process eliminates reflection cracking from the existing asphalt concrete through the new asphalt surface layer. The process is relatively fast and the resulting pavement structure is
similar to new construction without the costs and problems of removal and reconstruction.

These strategies were presented at the South African Pavement Technology Workshop at the Richmond Field Station in March 2000. Based on that presentation, District 3 has constructed an experimental test section (SR20) using DISR to produce a foamed asphalt/cemented base material, and plans to construct two more. The Office of Pavement Standards (OPS) is evaluating these experimental sections. District 2 has constructed an experimental test section (US395) using DISR to produce compacted granular base material.

The Gauteng Provincial Department of Transportation (Gautrans) in South Africa is currently evaluating DISR using their Heavy Vehicle Simulator (HVS), although they have very limited funds. Gautrans is also constructing experimental test sections and has had some success to date, but is concerned about standardizing mix design and structural design practice. Gautrans experience primarily involves treating new, sub-standard granular materials, not recycled asphalt concrete pavement (RAP). This work is being performed for Gautrans by the CSIR, a member of the UC Contract Team.

The Texas DOT has constructed one foamed asphalt test section which failed quickly. The Texas DOT has investigated but has not assigned the failure to construction quality, materials, or design.

Work is expected to begin on this research goal in May 2003.

4.12.2 Objectives

The purpose of this research goal is to characterize and test foamed asphalt treated DISR material, thereby extending the existing guidelines for the structural design of foamed asphalt treated materials to include foamed asphalt treated RAP. This will be achieved through the combination of an extensive laboratory testing program validated by accelerated pavement
testing under Heavy Vehicle Simulation performed in South Africa in conjunction with the
current testing of various foamed treated materials conducted by the CSIR.

The two objectives of this research goal are:

- Laboratory investigation of foamed asphalt treated RAP, which includes 3 main tasks:
  - Task 1: identification and preparation of the parent material. The RAP selected 
    for investigation will meet Caltrans specifications and will be characterized based 
    upon the testing procedure developed by CSIR for the investigation of foamed 
    treated materials. The deliverables of this task are the complete material 
    characteristics of the RAP and the provision of a basis for comparison with the 
    foamed asphalt treated RAP material.
  - Task 2: characterization of foamed asphalt binder and optimum mix design. This 
    task will focus on the foaming characteristics of selected Californian asphalt types 
    and the mix design process based on the procedures currently being employed by 
    CSIR for the investigation of foamed asphalt treated materials. Deliverables 
    include the optimization of foaming temperature and foamant water content of 
    each binder tested, and an optimized mix design with respect to asphalt content 
    and mixing water content.
  - Task 3: Characterization of foamed asphalt treated RAP material. The optimum 
    design and variations thereof with respect to asphalt content and cement content 
    will be used for the preparation and testing of specimens for the complete 
    characterization of the foamed asphalt treated RAP material. Particular attention 
    will be given to improving the properties of the stabilized material, without 
    stabilizing it to the extent that it becomes a cemented material that will eventually
crack and present future reflection cracking problems. Deliverables include the engineering properties of foamed asphalt treated RAP materials and a comparative analysis of the effect of stabilization on the engineering properties of the RAP material.

- Construction and testing of a foamed asphalt treated RAP test section for validation and extension of the analysis results from the first objective. It is proposed that three HVS test sections be constructed for accelerated testing under three trafficking situations (high, medium, low) to investigate the areas of application of this rehabilitation process. Deliverables include:
  - Elastic stiffness models for the treated and untreated RAP; suggested input stiffness values derived from the models for incorporation in pavement design guidelines
  - Permanent deformation and shear failure models for the estimation of bearing capacity of treated and untreated RAP; comparison with existing models
  - Flexural strength parameters for the treated materials
  - First level analysis of HVS data of the three test sections
  - Investigation of the failure mechanisms of test sections under HVS trafficking
  - Recommendations for the modification of the guidelines for the structural design of foamed asphalt pavements layers to include foamed asphalt treated RAP materials.
4.12.3 Expected Benefits

The results of this study will provide the basis for the development of a guideline for the application of foamed asphalt treated RAP in California, and improve the reliability with which foamed asphalt treated RAP materials can be designed for use in pavement structures. This work will be based on the extensive work already performed to date by North Region Materials, CSIR, and the University of Canterbury in New Zealand. This research would furthermore speed up of the development and implementation of viable, cost-effective alternative maintenance and rehabilitation strategies. Specific benefits could include:

- reduced cost of rehabilitation,
- improved performance of low volume highways and roads through elimination of reflection cracking,
- reduced traffic disruption due to rehabilitation, and
- reduced environmental impact through reduced asphalt and virgin aggregate demand for overlays.

4.12.4 Potential Partners

Other state DOTs that have large networks of low- and medium-volume highways in their networks are interested in these approaches, particularly the state DOTs of Washington, Arizona, Nevada, and Oregon. Gautrans and CSIR in South Africa will be direct partners in the research, and there is a potential for substantial cost sharing for this project with them in terms of a common HVS and laboratory testing plan that could be performed in California and South Africa. Some proprietary manufacturers of equipment and materials producers will also be interested in participating in this research goal.
The primary Caltrans partners will be North Region Materials and the METS Office of Pavement Rehabilitation.

4.13 Validation of Asphalt Concrete QC/QA Pay Factors (HVS Goal 11)

4.13.1 Background and Objectives

The objective of this goal is to obtain further validation of new pay factors developed by UC for the Caltrans asphalt concrete QC/QA system. The current pay factors have been validated for high quality construction by the CAL/APT Goal 1 results. Additional verification has been obtained from the WesTrack project for different asphalt contents and air-void contents, and a revised set of pay factors is being developed.

However, aggregate gradation was not varied much at WesTrack and not at all in the CAL/APT test sections, and all of the WesTrack aggregate gradations follow Superpave specifications that are different from Caltrans specifications. Also, accelerated pavement tests and laboratory tests of field constructed rehabilitation projects are needed for a broader range of construction quality than is included in the current data.

The proposed work for this goal includes laboratory tests at UC Berkeley, accelerated pavement tests on test sections at the Richmond Field Station, analysis, management, reporting and technology transfer.

The HVS test sections will focus primarily on pavements not included in previous HVS tests or the WesTrack project, such as overlays. Laboratory testing will be performed to verify and extrapolate the HVS test results. The HVS and laboratory results will be used to update models of pavement performance. Pay factors for rutting and cracking previously developed by the UC Contract Team for Caltrans and the WesTrack project will be recalibrated or verified.
using the new data. The pay factors will be based on Life Cycle Cost Analysis that considers the change in costs due to premature or delayed pavement failure.

Work is expected to begin on this goal in 2004 or 2005.

4.13.2 Expected Benefits

The primary benefit of “Validation of Asphalt Concrete QC/QA Pay Factors” is verification of pay factors for asphalt concrete construction. These pay factors will give appropriately weighted incentives to contractors to provide the quality needed to optimize pavement performance, and will reduce that chance that bonuses are paid for asphalt concrete that does not perform well. The pay factors will capture the economic risks of short-term distresses such as rutting and long-term performance such as cracking.

4.13.3 Potential Partners

The most likely potential partner on this project will be the California and national asphalt paving industries. Other state DOTs will also be interested in this research goal, as will local governments in California (which purchase twice as much asphalt concrete as does Caltrans per year). The key Caltrans partners are Construction and the METS Bituminous group.

4.14 A Framework for Implementing Innovative Contracting Methods for Transportation Infrastructure Rehabilitation/Reconstruction

4.14.1 Background

Developers of rehabilitation and reconstruction projects for transportation infrastructure (especially urban freeways and long-span bridges) face the need to reduce construction time,
thereby mitigating user inconvenience (user delay cost), while maintaining or improving quality
and costs. Although several innovative contracting methods have been introduced to deal with
these problems, further refinement and development of the methods are necessary in order to
implement them more effectively.

4.14.2 Objectives

The objective of this proposed research is to develop an analysis framework to perform
the following tasks:

- to assist the state transportation agency in determining optimal contracting method for
  a specific project,
- evaluate the impacts of implementation,
- adjust the contracting methods to the specific environments,
- determine the best practices for each contracting method, and
- ultimately, build specific contracting strategies.
- develop an analysis tool (program) based on the framework

The framework would be investigated within the context of the laws and regulations
applicable to the California Department of Transportation. The framework would
include urban freeway rehabilitation projects involving the use of concrete and
asphalt pavements. Contracting methods to be investigated would include:

- Warranty (C),
- Cost + Schedule (A+B) + Incentive/Disincentive, and Pay Factors, or
- the combinations of these (for example, A+B+C)
4.14.3 Expected Tasks

Expected tasks include investigation of:

- Implementation Issues:
  - Issues related to Methods: Advantages and disadvantages, impact on projects (LCCs, performance, time, etc.) risk allocation, and required conditions to initiate and implement.
  - Issues related to Agency: Existing low bid system, administration practices, organization structure, budget, training, and financing alternatives.
  - Others: Goals/risks/responsibilities of all the parties, industry practices, and capabilities of contractors.

- Special Considerations of Each Method

- Study of the components of each method. For example,
  - Warranty: warranty specification, length of warranty, performance indicator, maintenance issue (monitoring, remedial actions, CRT), risk management (Surety issues when the contractor is in default)
  - A+B with I/D: RUC (Road User Cost - converting time bid into a dollar value), Max/Min duration, determining target milestone, liquidated damage, A+B specification, I/D provisions (bonus or penalty with respect to the milestone).
  - Pay Factor: selection of pay factor, pay-factor schedule, converting the level of quality to a dollar value, how much of quality will be enhanced by pay-factor method, incorporation into the conventional QA/QC, performance-based specification (special provision or supplemental specification), currently used or
reasonable factors, verification of effectiveness of pay-factor, reasonable performance targets, quality measurement methods, and sampling.

· Study of the possible combinations or new approaches: features, feasibilities, and effects of the combinations.

• Selection Criteria/Process Issues

• Development of the procedure to find the best matching contracting method for a rehabilitation/reconstruction project.
  · Selection Criteria: Project features to be accomplished, prioritization
  · Methodology of measurement: how to measure the level of satisfaction of each criterion by different methods?
  · Selection Process – a matrix or a flow chart: how to match it?
  · List of Potential Projects: identifying possible types of projects for each method.

• Implementation Procedure through Stages of Each Method (After Selection)
  · Different implementation procedure for the different contracting methods.
  · Defining each stage of the project according to different contracting methods.
  · Success factors: General success factors and success factors for each stage.
  · Developing an implementation procedure that exercises the success factors.

• Process of Feedback and Continuous Improvement of Method
  · Mechanism to improve the methods continuously and ultimately develop the agency’s own contracting strategy.
  · Data Collection: What kind of data from the project outcomes should be obtained? How to collect and keep it?
· Evaluation: How to evaluate those data? What are the targets to be compared?
· Feedback Process and Reflection Process: Organization and culture issues should be studied.

- Develop Analysis Tool: A knowledge-based computer program (software) based on the framework would be developed. The software could be used by Caltrans as an analysis tool in the planning stage to speed up their decision making process. The software should be able to quantify the benefits of implementing the innovative contracting methods.

- Case Studies
  - Concrete rehabilitation projects: I-15, I-10, I-40
  - AC rehabilitation projects: I-710

Work is expected to begin on this goal in late 2003 or early 2004.

4.14.4 Expected Benefits

It is expected that the results of this research goal will provide Caltrans with a better understanding of the risks associated with the different contracting methods, and a tool to aid in the selection of the most appropriate contracting method for specific projects. These results would increase the effectiveness of Caltrans contracting, and would be expected provide Caltrans with a more efficient transportation system for the money that it is spending. The results should also aid Caltrans in appropriately assigning risk to themselves and the contractor, which should help reduce claims and other unforeseen costs.
4.14.5 Partners

The primary partners will be Caltrans Design, Construction, and Maintenance. Traffic Operations will also be interested in the results.

Other state DOTs, particularly those in the State Pavement Technology Consortium will also be interested in the results.

4.15 Development of Integrated Pavement Strategy Decision Support System

4.15.1 Background

Pavement design and maintenance decisions are very complex today, going beyond the technical engineering and materials issues that traditionally have governed their design. Pavements must now be viewed as part of a network, viewed from a lifecycle cost perspective, and viewed from a scheduling perspective. Engineers planning pavement projects must also be able to analyze numerous objective functions, including the prudent and efficient allocation of financial resources. Such a system must be able to model the underlying issues of:

- combining and optimizing different “types” of money;
- the timing of those expenditures and revenues;
- the packaging of the project as an individual segment or a combination of segments;
  and
- the scheduling of construction and maintenance work.

Caltrans faces the application of these principles in its programming rehabilitation and reconstruction of its highway network. At present, many highways and freeways in California are in need of rehabilitation or reconstruction. However, few studies about the application of
lifecycle cost analysis (LCCA) in pavement reconstruction/rehabilitation exist. Most work available in the literature addresses the selection of pavement type for new construction. The traditional LCCA considers rehabilitation as a major maintenance method, and the reconstruction stage is not comprehensively considered. After repeated rehabilitations, the remaining pavement is counted as salvage value. Therefore, there is no complete analysis for the lifecycle cost of pavement or no sufficient tool supporting development of efficient reconstruction programming strategies.

4.15.2 Objectives

The first objective of this research is to develop a support system for the state transportation agency that allows the modeling and optimization of a project’s life cycle cash-flow in its decision making process. Variables would include:

- key pavement design concepts (material of reconstruction, pavement thickness, etc.);
- the timing of its construction (accelerated construction schedule or more typical);
- various combination of project financing (federal aid versus state aid, private funds, tolls); and
- the segments being planned for construction or rehabilitation.

The second objective of this research would be to expand the project level concepts to the network level.

The proposed scope of work includes:

- Establish alternative pavement design strategies for the analysis period.
- Review data from an existing project database to develop typical “project templates.”
• Identify the alternative strategies with the combination of initial design and maintenance method.

• Study the performance deterioration behavior of concrete and asphalt pavement and provide the pavement condition curve along its lifetime for all alternatives.

• Identify the scope and timing of reconstruction in each alternative depending on the developed pavement condition curve.

• Estimate user costs for all alternatives.

• Study the user cost items and identify the factors representing the value of each user cost item.

• Apply the California data to measure the user cost numerically.

• Evaluate reconstruction design related with the user cost

• Define the major design factors affecting the user cost during reconstruction and maintenance period.

• Estimate the tradeoff between the pavement performance improvement and the incurred user cost along the lifetime for the alternative values in design factors.

Economic analysis:

• Identify the revenues sources used to finance different projects, including their key terms and conditions (e.g., fixed versus adjustable interest rates, prepayment options and penalties, call provisions).

• Identify the typical Operations & Maintenance cashflows associated with different project types.
• Unify these different input variables into a process model that allows calculation of the project’s discounted lifecycle cashflow.

• Develop the model
  · Assemble the process model into a software test platform (MS Excel or Access, to be determined).
  · Test the model’s viability by applying test cases from asphalt and concrete projects.

Work is expected to begin on this goal in mid-2003.

4.15.3 Expected Benefits

The results of this research program will provide

• a better understanding of the life cycle costs of pavement reconstruction projects and

• a proof-of-concept model that can be used in the future to assess different project planning combinations.

The model will be developed and programmed so that Caltrans engineers and policy makers can assess various project alternatives.

4.15.4 Potential Partners

The primary partners will be Caltrans Design, Construction, and Maintenance and the districts. Other state DOTs, particularly those in the State Pavement Technology Consortium, will also be interested in the results.
5.0 ESTIMATED SCHEDULE OF CURRENT ACTIVITIES

The estimated schedule (Gantt chart) for current activities described in this Strategic Plan is shown in the following figure. At the bottom of the schedule, the current schedule for HVS testing is broken out. A revised schedule will be prepared after prioritization of proposed implementation projects and research goals.
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<td>Quality Assurance Laboratory Testing for AC Long-Life Pavement Mix Designs (I-710)</td>
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