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THE SOUTH CENTRAL SUPERPAVE CENTER SUMMARY REPORT

by

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Project Summary Report Number 0-1250-S

Research Project 0-1250
South Central Superpave Center

Conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

November 1999

IMPLEMENTATION STATEMENT

The South Central Superpave Center (SCSC) was established to promote implementation of the Superpave system. By providing technical assistance, workshops, training courses, and Superpave mix designs, the SCSC effectively advanced the implementation of this system. In addition to these implementation activities, a series of Superpave-related research projects were conducted. These projects are explained briefly in this summary report and discussed in detail in separate project reports. The following implementation activities are based on research conducted and on work carried out by the SCSC throughout its 5-year operation:

- On-site mix design training courses were conducted for the state highway agencies of Arizona, New Mexico, Louisiana, Texas, Wyoming, and Illinois.

- Numerous workshops conducted at the SCSC involved hundreds of participants who received training in the Superpave mix design system and in Superpave binder testing and characterization.

- The SCSC took a highly positive step in transmitting and implementing the Superpave technology through its very successful Internet web site.

- The SCSC developed a very successful Internet newsgroup in which experts and authorities discuss and post various practical questions and problems related to this technology.

- During its operation, the SCSC produced four newsletters that were distributed to a very wide audience. These newsletters provided information about the latest developments in the technology and about the activities of the center.

- The SCSC's evaluation of new test equipment and procedures led directly to an increase in the availability and suitability of new models of Superpave gyratory compactors (SGCs).

- The SCSC's cooperation with other organizations allowed the gyratory compaction protocol to be updated and improved.

ABSTRACT

This is the summary report for Research Project 0-1250, "The South Central Superpave Center." Initiated and sponsored by the Texas Department of Transportation and the Federal Highway Administration, the Superpave Center fostered the implementation of the Superpave system within state highway agencies and the asphalt construction industry. Other regional states also participated in partial support of the Center. The 5-year project started in September 1994 and ended in August 1999. This report summarizes Center activities undertaken over the 5-year period.

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Special thanks are extended to Mr. Maghsoud Tahmoressi (CST), the director of the research project, for his continuous guidance and support. The authors would also like to thank Texas Department of Transportation members Katherine Holtz, Jeff Seiders, and Darren Hazlett for their continuous support. In addition, the efforts of John Bukowski (FHWA) were instrumental in getting the SCSC organized and operational. Mr. Jim Gee of the Arkansas Highway and Transportation Department and Mr. Jack Telford of the Oklahoma Department of Transportation provided valuable assistance, engineering, and funding to the Center staff. The authors acknowledge the assistance provided by Mr. Jim Cravens (FHWA), who served on the project monitoring committee. Special thanks are also extended to Ms. Joann Lins of TxDOT for her highly supportive attitude.

Finally, we acknowledge the assistance provided by Ms. Clair LaVaye, Mr. Ray Donley, and other members of the Center for Transportation Research staff.

DISCLAIMERS

Thomas W. Kennedy, P.E. (Texas No. 29596)
Research Supervisor

SUMMARY

A 5-year implementation project was sponsored by the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA) to bring to the user level the implementation of the Superpave system as the latest technology encompassing asphalt material.

Like the other Superpave Centers, the SCSC represented a new and innovative approach to implementing new technology. It effectively began in June 1995 and operated out of the transportation materials laboratory at The University of Texas at Austin. In 1996, the Center developed an entirely new research and training facility at an off-campus location. Its host agency was TxDOT, and a uniquely strong partnership developed among the SCSC and the Bituminous and Asphalt Sections of TxDOT. Cooperating partners included the state highway agencies in Arizona, New Mexico, Oklahoma, Arkansas, and Louisiana, the FHWA, and the Texas Hot Mix Asphalt Pavement Association. The SCSC largely realized its role as a center of expertise to facilitate the implementation of Superpave.

Specialized Superpave training was a major activity of the Center: By August 1999, Center staff had organized and provided such training to more than 2,000 individuals representing all facets of the asphalt materials community. Included in these efforts were numerous on-site mix design training for the state highway agencies of Arizona, New Mexico, Louisiana, Texas, Wyoming, and Illinois. Approximately 1,000 more individuals were reached through miscellaneous symposia.

In addition to organized training, the SCSC transmitted Superpave technology through its presence on the Internet. The SCSC Web site is a very successful endeavor, with “hits” sometimes exceeding approximately 4,000 per week. A Superpave-related e-mail group now contains more than 300 subscribers.

The fact that the SCSC was organized through The University of Texas at Austin necessitated that the Center support graduate students. Through this activity, five master’s degree students and four doctoral students were supported. Two of the students awarded master’s degrees were employees of TxDOT who conducted thesis research on topics pertaining to Superpave.

Applied research was also a function of the Center. This activity was dominated by evaluation of new test equipment and procedures that are part of the Superpave system. SCSC efforts lead directly to an increase in the availability and suitability of new models of Superpave gyratory compactors (SGCs) through standardized compactor comparison experiments. In addition, SCSC efforts in cooperation with other organizations allowed the gyratory compaction protocol to be updated and improved. Through research sponsored by the FHWA, the SCSC was able to make use of the Superpave shear tester to evaluate the sensitivity of engineering properties to number of gyrations. In combination with the NCHRP 9-9 project, this experiment lead to a vastly improved N-design table, which is an important feature in Superpave mix design.

The study conducted on the static creep behavior of Superpave mixes laid the foundation for development of creep criteria for these mixes. This is the test that is currently used by TxDOT as an integral part of mix design for coarse matrix high-binder mixes. Another important applied research was the comparison of Texas and Superpave gyratory compactors. This comparison provided information regarding ways in which the compactors could be correlated. One of the important research activities of the Center focused on responding to the industry demand of an appropriate procedure for determination of mixing and compaction temperature. An SCSC study indicated that the temperatures used could be lower than those that are obtained through current procedures.

One of the last research activities of the center was an evaluation and extensive testing of the binder direct tension tester. This study provided valuable information not only on equipment repeatability, but also on the effect of temperature and strain rate on the engineering properties of the binder at very low temperatures.

While the Center largely accomplished its intended purpose, one factor that impeded the Center's support was the fact that it was not affiliated with one of the five asphalt user producer groups (UPGs). The SCSC's cooperating state highway agencies were members of the Pacific Coast UPG (Arizona), the Rocky Mountain Asphalt UPG (New Mexico), the North Central UPG (Oklahoma), and the Southeast User Producer Group (Arkansas, Louisiana, and Texas). Consequently, there was no central forum for the SCSC to use for management committee meetings, activity updates, etc. Through their UPG activity, SCSC cooperating partners were often placed in the confusing role of supporting other centers because of their UPG affiliations.

The SCSC was well financed over its period of operation. This advantage clearly enabled the SCSC to achieve its intended purpose without the need to pursue funding from outside contract research efforts. Most of SCSC's funding came not from a wide range of cooperating partners, but rather from TxDOT and, to a lesser extent, from the FHWA. By the end of August 1999, the funding provided by TxDOT was approximately $1.5 million, with another $325,000 provided by FHWA. The state highway agencies of Arkansas and Oklahoma also provided $50,000, although only $20,000 of these funds was directly accessible to the Center (the remaining $30,000 was held to fund travel costs of state personnel). In effect, TxDOT and the FHWA built the "team" that made up the Center — a Center whose resources ultimately benefited a wide array of organizations and individuals.

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INTRODUCTION

The Strategic Highway Research Program (SHRP) was a 5-year, $150 million research effort that mobilized state-of-the-art engineering and scientific expertise to solve problems faced by those in the highway engineering community. SHRP was funded by the state departments of transportation and administered by the National Academy of Engineering. Most of the SHRP research occurred between 1987 and 1993. Of the $150 million that was expended, $50 million was spent in the area of asphalt research. The SHRP Asphalt Research Program produced a product called Superpave, which stands for *Su*perior *Per*forming Asphalt *Pave*ments. Although Superpave is called a "product," it is actually a new system for specifying asphalt materials and consists of two principal features: (1) a new asphalt binder specification with a new set of tests to match and (2) a new mix design and analysis system.

At approximately the midpoint of SHRP's 5-year effort, top managers in the state DOTs, industry, and Federal Highway Administration (FHWA) began to contemplate the implementation phase of the various SHRP research products. There was a clear belief that if the benefits of SHRP were to be realized, then a clear, aggressive implementation strategy needed to be followed. Consequently, the Intermodal Surface Transportation and Efficiency Act of 1991 allocated $105 million to facilitate implementation of SHRP research products, with the FHWA charged with coordinating the research efforts.

The FHWA developed a Superpave implementation plan that included many features. One of these features was the establishment of Superpave centers that were to function as regional centers of expertise to expedite Superpave implementation. While the SHRP asphalt researchers produced a finished product in Superpave, there was general agreement that some of the features of Superpave remained in the research arena. As a result, the FHWA believed that the Superpave centers needed to possess engineering research capabilities. Thus, the FHWA arranged for the establishment of the centers at universities, each with a host state DOT to serve as a liaison with other DOTs in the region. Table 1 identifies the centers that were established.

Table 1. Superpave Regional Centers

Regional Center	Host University	Host State DOT
Northeast Superpave Center	Penn State University	Pennsylvania DOT
Southeast Superpave Center	Auburn University	Alabama DOT
North Central Superpave Center	Purdue University	Indiana DOT
Western Region Superpave Center	University of Nevada, Reno	Nevada DOT
South Central Superpave Center	University of Texas, Austin	Texas DOT

Planning of the South Central Superpave Center (SCSC) began in mid-1994, with its first staff hired in early 1995. The SCSC was fully staffed by June 1995, at which point it became fully operational. This report describes the activities of the SCSC from June 1995 through the end of August 1999, when the Center was moved to the Texas Transportation Institute of the Texas A&M University System.

SOUTH CENTRAL SUPERPAVE CENTER STRUCTURE

Administrative Structure

The Texas Department of Transportation (TxDOT) provided principal funding for the SCSC in the amount of $300,000 per year, with an additional $100,000 provided to SCSC by the FHWA. For funding and other administrative purposes, SCSC was established by TxDOT through its normal cooperative research arrangement with The University of Texas at Austin's Center for Transportation Research. Center personnel were hired as employees of the University and all other administrative functions were conducted under the normal rules and regulations (established by TxDOT) that are part of the agency's Cooperative Research and Implementation Agreement with Texas public universities. In other words, the SCSC was administered in the same manner as is any other TxDOT-funded research project at The University of Texas at Austin. TxDOT assigned Mr. Maghsoud Tahmoressi, head of Bituminous Branch, Materials and Tests Section, Construction Division, as the designated project director. Thus, Mr. Tahmoressi served as Director of the SCSC. Dr. Thomas W. Kennedy, Engineering Foundation Professor, Department of Civil Engineering, was designated by the University as principal investigator.

Management Structure

As the host state DOT, TxDOT decided that the SCSC needed to be governed by a management committee consisting of individuals that represented organizations that were to be assisted or affected by Center activities. Committee members included materials engineers from the state DOTs served by the Center, the FHWA, and industry. Thus, in early 1995, TxDOT extended invitations to the state materials engineers in Arizona, New Mexico, Oklahoma, Arkansas, and Louisiana to serve as managers of the activities of the Center. Also invited were representatives of the FHWA Texas Division and FHWA Region 6, which included most of the states that would benefit from the activities of the Center. Additionally, TxDOT invited participation of the Texas Hot Mix Asphalt Pavement Association in an attempt to attract industry participation. Table 2 shows the original management committee of the Center.

During its 5-year operation, the South Central Superpave Center represented a unique partnership among the Texas Department of Transportation, Federal Highway Administration, and The University of Texas at Austin, Center for Transportation Research. Cooperating partners included the Arizona Department of Transportation, the Arkansas State Highway and Transportation Department, the Louisiana Department of Transportation and Development, the New Mexico State Highway Department, the Oklahoma Department of Transportation, and the Federal Highway Administration.

Table 2. Management Committee of the South Central Superpave Center

Management Committee Member	Affiliation
Fred Cooney	New Mexico Dept of Transportation
James Cravens	FHWA Texas Division
Douglas Forstie	Arizona Dept of Transportation
James Gee	Arkansas Highway & Transportation Dept
Katherine Holtz [1]	Texas Dept of Transportation
Ross Martinez	FHWA Region 6
Jarvis Poche	Louisiana Dept of Transportation & Development
Charles Smoot	Texas Hot Mix Asphalt Pavement Assn
Jack Telford	Oklahoma Dept of Transportation

[1] Committee Chair

The center pursued the following objectives during its operation as outlined by the management committee:

1. evaluate and improve Superpave products through applied research,
2. assist and promote uniform Superpave technology,
3. function as an information resource for management level personnel,
4. conduct training in Superpave technology, and
5. provide testing and technical assistance to Superpave Center partners.

The South Central Superpave Center provided expert assistance to agencies, industry, and academia in all areas pertaining to the implementation of Superpave.

Staffing

During its first 3 years of operations, SCSC staff consisted of five principal individuals. Mr. Robert B. McGennis managed the day-to-day affairs of the Center. Dr. Mansour Solaimanian served as project engineer for the Center. Mr. Daniel L. Quire functioned as technical staff and managed binder and performance testing. Mr. Eugene E. Betts also served as technical staff and managed the activities of the Center pertaining to aggregate processing and mix design. Ms. Clair LaVaye worked 25 percent time and administered the Center's presence on the Internet. When Mr. McGennis accepted a position with a private company in September 1998, Dr. Solaimanian assumed the role of program manager for SCSC. Other Center staff included various graduate students and TxDOT loan staff that assisted the Center in activities such as laboratory experiments and training.

Funding

Principal funding for the SCSC was provided by TxDOT and the FHWA at a level of approximately $400,000 per year. Of this amount, $300,000 was provided by TxDOT while $100,000 was provided by the FHWA. By the end of the SCSC project, TxDOT had funded approximately $1,500,000 toward Center activities and the FHWA had funded $325,000. The management committee of SCSC decided that each participating state would contribute $25,000 to the Center, although only $10,000 would be available for Center use. The remaining $15,000 was intended to be used by state DOT personnel to fund their travel to Center and other meetings pertaining to Superpave implementation. However, of the five cooperating states, only Arkansas and Oklahoma elected to provide funding. Arizona, Louisiana, and New Mexico did not provide funding, though Center staff did provide a variety of services to those states.

In addition to providing direct funding, the FHWA loaned a partial set of Superpave equipment to the Center. This equipment included a Pine Superpave gyratory compactor, a Superpave shear tester, a Superpave indirect tensile tester, and a Superpave direct tension tester. Other necessary equipment was purchased by Center staff through the SCSC normal operating budget.

Facilities

In June 1995, the SCSC began operations in the pavement materials laboratory that is jointly operated by the Department of Civil Engineering and the Center for Transportation Research at The University of Texas at Austin. The facility is located on campus in Ernest Cockrell, Jr., Hall and occupies approximately 1,000 square feet of space.

TxDOT and Center personnel designed a 25,000-squar-foot laboratory, research, and training facility. Of this total area, the SCSC occupied a separate 5,000-square-foot area with an additional 1,000 square feet of shared space. Shared space included a storage area, classroom space, and kitchen/break facilities. This facility was located at 2311 West Rundberg Lane in Austin.

COMMUNICATIONS

Newsletter

To meet the goals and objectives of the SCSC, the management committee directed Center staff to prepare a quarterly newsletter to outline center activities and to communicate information pertaining to Superpave implementation. Two newsletters were ultimately produced in 1996. Center staff prepared a mail list of approximately 1,500 names to which these newsletters were mailed. After the first two newsletters, the Superpave centers agreed to have the newsletters published at a central location. The proposed newsletter for each center would consist of a regional section covering articles of interest to the region under a specific center, and a national section presenting articles of national interest. In this way, the national section of the newsletter would be common to all the regional newsletters. The

North Central Superpave Center at Purdue University was designated as the location for processing and publishing the newsletters. The contributions of the South Central Superpave Center resulted in two additional newsletters under SCSC published in the spring and summer of 1999. The personnel from TxDOT and SCSC contributed a number of valuable articles both in the regional and the national sections of the newsletters.

Internet Site

The SCSC Web site, which began operation in April 1996, was developed and administered by Clair LaVaye of The University of Texas at Austin, Center for Transportation Research. It was located on the UTS server at The University of Texas at Austin Computation Center. The site was mirrored and backed up automatically through the University's UNIX system. This system provided a statistical report weekly on hits and visitors to the site.

The site consisted of text files, in HTML, with minimal java scripts, no frames, and compact graphics. This environment ensured that the site displayed its material quickly and reliably to all browsers, including Netscape, Lynx, and Microsoft Internet Explorer. The bulk of the Web site, and its main feature, was an extensive set of articles on Superpave technology and research. There was also an FTP directory that housed useful software for free download to Web visitors. An important feature of the site was the announcement of Superpave training and Superpave-related events in the U.S.

The content of the site consisted of pages that explained the Superpave system and design, provided the mission of the SCSC, listed staff and how to contact them, and had postings of job and internship opportunities in the Superpave area. Finally, there was a links page that held extensive links to more online information about Superpave and about companies that support this technology.

The Superpave Newsgroup began in December 1996 and grew to nearly 300 subscribers by August 1999. This newsgroup was a very popular feature associated with the SCSC Web site. The University of Texas mail server, McFeeley, handled sendmail functions 24 hours a day, 7 days a week, backed up the mail, archived it, and created daily digests. The e-mail was periodically archived into an HTML file and posted on the Web site.

When the Web site began, it received between 700 and 1,000 hits per week, a figure that increased to approximately 4,000 hits per week by August 1999. Many of the hits were on the articles' section of the site, which was where the newest information was kept. Some articles were hit as often as 250 times per week. The hits came from diverse locations worldwide. Governmental agencies were among the most frequent users of the Web site. The site had been accessed by users from such countries as Austria, Australia, Brazil, Canada, Ecuador, Finland, Greece, Indonesia, Ireland, Italy, Japan, South Korea, Mexico, Peru, Sweden, Singapore, and Turkey.

TRAINING ACTIVITIES

Technology transfer was a principal activity of the SCSC. A wide variety of training opportunities were offered by Center staff. This section describes training activities of the SCSC.

Introduction to Superpave

During the initial phase of the SCSC, staff developed a 1-day seminar called "Introduction to Superpave." The goal of this seminar was to quickly acquaint agency and industry personnel with the Superpave system in preparation for the letting of early Superpave projects. The first seminar program dealt with both Superpave binder and mixture technology. Table 3 shows the topics for this seminar.

Table 3. Outline of Introduction to Superpave Seminar

Topic
Introductions and Background of Superpave
Superpave Asphalt Binder Tests
BREAK
Superpave Binder Specification and Selection
Local Agency Selection
LUNCH
Superpave Material Requirements
BREAK
Superpave Gyratory Compactor
Superpave Mix Design
Local Agency Considerations
End of Workshop

These workshops were usually coordinated by local agency and/or industry groups, with Center staff responsible only teaching and for assembling and distributing course materials. The "local agency" features of this program allowed the sponsoring agencies to provide attendees with up-to-date information specific to the local or regional implementation of Superpave. Flexibility in this portion of the program allowed topics such as regional binder selection, aggregate issues, and quality control/quality assurance to be addressed. The principal reference distributed at these seminars was a training manual developed and used at the National Asphalt Training Center (Ref 1). Approximately 1,000 individuals were trained at these programs.

Further details about this and other workshops are provided in the South Central Superpave Center report of activities (Ref 2).

Superpave Binder Analysis Workshops

The effective implementation of Superpave requires that technical staff be trained in the proper methods of running the new Superpave binder tests, including the dynamic shear rheometer, rotational viscometer, rolling thin film oven, pressure aging vessel, and bending beam rheometer. Through The University of Texas at Austin, Division of Continuing Engineering Studies, the SCSC offered a hands-on Superpave binder analysis workshop to fulfill this need. This program was a 4-day event that included 2 classroom days and 2 laboratory days. Table 4 lists the content of the course on Superpave binder testing and characterization. Monday was a classroom session devoted to introducing and explaining the principles underlying the new Superpave binder tests. Tuesday and Wednesday were laboratory sessions in which students received hands-on test procedure training. Thursday was a classroom session in which students learned how to apply the Superpave binder specification and to interpret test results. By sharing data gathered during the laboratory session, students were able to classify the PG 64-22 binder on which all testing was conducted. The workshop manual used in this training was the text developed and used at the National Asphalt Training Center (Ref 3). One of the key features of this workshop was the laboratory instructional assistance provided by Mr. John Casola of Bohlin Instruments, the manufacturer of the dynamic shear rheometer used by most agency and industry personnel. Approximately 100 individuals were trained using this approach.

Table 4. Outline of Introduction to Superpave Seminar

Intro	—	Introduction to SHRP binder testing equipment (classroom session)
DSR	—	Dynamic shear rheometer
RTV	—	Rotational viscometer
Aging	—	Pressure aging vessel and rolling thin film oven
BBR	—	Bending beam rheometer
Spec	—	Specification Testing (classroom session)
Disc	—	Class discussion of binder test results (classroom session)

Superpave Mix Design Workshop

Because the proper implementation of Superpave requires hands-on mix design training, the SCSC staff developed and presented a workshop on Superpave mix design. Like the binder analysis workshops, the mix design workshops were coordinated through The University of Texas at Austin, Division of Continuing Engineering Studies. The program was 3 1/2 days in length. Table 5 shows the schedule for this workshop.

Table 5. Schedule for Superpave Mix Design Workshops

INTRO	—	Intro to Superpave mix Test Equipment and Construction (classroom session)
SGC	—	Superpave Gyratory compactor (laboratory exercise)
DEMO	—	Superpave aggregate, binder, and performance testing (laboratory demonstration)
VOL	—	Principles of asphalt mixture volumetrics (group classroom session)
TEST	—	Volumetric testing of gyratory specimens (laboratory exercise)
ANALYSIS	—	Analysis/Selection of design aggregate structure and evaluation of simulated field control data (classroom session)

The first day was a classroom day aimed at explaining the features in Superpave mix design. This class session included discussion of Superpave material requirements, the Superpave gyratory compactor, and mix design calculations. Days two and three included hands-on use of the Superpave gyratory compactor and measurement of volumetric properties of asphalt mixes. The materials used by students were the laboratory standard materials employed by the SCSC. (A description of these materials is provided elsewhere in this report.) Each laboratory group compacted a different trial blend of aggregate and binder. A demonstration of the Superpave binder, consensus aggregate, and performance tests was included, although participants did not receive hands-on training in these activities. The remaining half day was spent analyzing the data gathered by participants in order to complete a major portion of a Superpave mix design. Nine mix design workshops were ultimately conducted at the SCSC, with 149 individuals trained using this approach.

Workshops for State DOTs

Many agencies requested that hands-on training be conducted specifically for their personnel. Most of these workshops involved Center personnel traveling to the state's central materials laboratory and conducting remote training. This service was provided to state DOTs in Illinois, Wyoming, Louisiana, and Arizona. The state DOTs in Texas and New Mexico requested similar services, with the only difference being that those DOT personnel traveled to the SCSC to receive the training. A brief description of this activity is described below. The details of training and services provided to state DOTs are provided in Research Report 1250-2, "South Central Superpave Center: Report of Activities."

Prior to 1998, TxDOT had let eight Superpave projects and anticipated as many as fifty new projects during 1998. In fact, by July 1997 all TxDOT projects required the use of PG binders; TxDOT also required asphalt suppliers to show that their laboratory personnel had been trained using a program such as that offered at the SCSC. Accordingly, there was a need for training of TxDOT personnel in Superpave principles. Four workshops were conducted for TxDOT — three in late 1997, devoted to Superpave mix design, and one in 1998, devoted to Superpave binder analysis.

Visiting Personnel

One of the early goals of the SCSC was to utilize the loan staff concept, which was intended to allow experienced asphalt laboratory personnel to be placed "on loan" to the SCSC. Thus, the SCSC could make use of experienced personnel in conducting its various activities, while the loaning organization would receive an employee with basic Superpave experience. Unfortunately, the loan staff concept was not fully realized during Center operations because very few agencies were able to provide travel funds for a several-month-long assignment of their personnel.

TxDOT was the principal supplier of loan staff to the Center. At all times, the SCSC had the services of an employee from TxDOT's Bituminous Section. The employee's nominal term of duty with the SCSC was 3 months. Through this program, three engineers and four technical staff personnel were utilized. This arrangement proved very rewarding for both organizations.

Although the loan staff concept was not fully realized, several individuals representing agencies and industry sent their staff to the SCSC for short tours of duty. The Oklahoma DOT sent five individuals to SCSC each for 2-week tours. The Louisiana DOTD sent four employees to SCSC for 1 week to assist in the completion of an SCSC-designed mix for a Louisiana Superpave project. Shell Canada Ltd. sent to the SCSC an employee who assisted in a compactor comparison experiment.

National Highway Institute Workshops

Center staff were subcontractors to the Asphalt Institute (AI) on their National Asphalt Training Center II project, which was sponsored by the FHWA. As subcontractors to AI, the SCSC assisted in the development of Superpave training materials for the National Highway Institute (NHI). Subsequently, SCSC staff served as instructors at the two pilot workshops, the purpose of which was to evaluate these training materials. These pilot workshops were conducted on April 23 and September 8, 1997, at AI headquarters in Lexington, Kentucky. Thirty-eight individuals attended, including staff of the other four Superpave Centers, state DOT personnel, and the FHWA's Superpave Extended Technology Delivery Team. Based on the comments and suggestions of those attending the pilot workshops, final course materials were developed for three NHI Superpave workshops:

- Superpave for the Generalist Engineer and Project Staff (2-day workshop),
- Superpave for Local Agencies (1-day workshop), and
- Superpave for Managers (half-day workshop).

Staff from the other Superpave centers, as well as from the SCSC, were tasked with delivering these workshops on an as-requested basis. The SCSC staff trained close to 600 individuals through thirteen workshops.

Other Symposia

In addition to the training activities already described, Center staff participated in numerous programs, conferences, and workshops. While these symposia did not represent coordinating efforts of Center staff, they nevertheless presented the opportunity for the Center to fulfill its mission of transferring Superpave technology.

Summary of Training Activities

Clearly, training was a major effort of the SCSC. By August 1999, Center staff had provided Superpave training to over 2,000 individuals representing all facets of the asphalt materials community. Approximately 1,000 more were reached through miscellaneous symposia.

DIRECTED RESEARCH

One of the expectations of all Superpave centers, including the SCSC, was that staff would conduct applied research to update or improve Superpave technology. This activity involved conducting experiments using the test equipment that was furnished to each Superpave center. The following paragraphs describe these experiments.

Ruggedness of AASHTO TP4

As AASHTO was adopting test methods produced by the SHRP researchers, there was a need to evaluate the ruggedness of the methods. Ruggedness experiments are conducted according to ASTM C1067, “Conducting a Ruggedness or Screening Program for Test Methods for Construction Materials.” The experiments are intended to determine whether tolerable variations in test parameters produce significant changes in test results. Consequently, one of the first experiments conducted at the SCSC involved estimating the ruggedness of AASHTO TP4, “Standard Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the SHRP Gyratory Compactor.”

SCSC staff fulfilled two roles in this experiment. First, SCSC staff designed the experiment and was primarily responsible for analyzing its results. Second, the SCSC served as one of the participating laboratories on behalf of TxDOT. The experiment analyzed seven main factors using the approach outlined in ASTM C1067 (Table 6). McGennis, Perdomo, Kennedy, and Anderson (Ref 4) present a detailed treatment of this experiment in which the following conclusions were drawn:

- the tolerance on compaction angle ($\pm$ 0.02°) is reasonable,
- a transfer bowl is preferable but not necessary for mold loading,
- the tolerance on compaction pressure ($\pm$ 18 kPa)[*] is too high,
- pre-compaction using a blunt-nosed rod is ineffectual,

[*] Because SHRP and the Superpave system rely solely on metric units, this report will similarly use metrics. It is understood that anyone using this report or working within this area will necessarily use metric measures.

- the tolerance on equiviscous compaction temperature (± 0.030 Pa·s) is reasonable,
- the tolerance on specimen height (± 1 mm) is too narrow, and
- for binders similar to the one used in this experiment, the 30-minute compaction temperature equilibration period can be included in the 4-hour aging period as long as mixture volumetrics are the main response variables.

Effect of Gradation on Volumetric and Mechanical Properties

This experiment, requested by and conducted on behalf of the FHWA (Ref 5), evaluated the effect of aggregate gradation and aggregate mineralogy on voids in the mineral aggregate (VMA). Four aggregate types were evaluated: limestone, gravel, sandstone, and basalt. For each of these aggregate types, three gradations were evaluated: fine, coarse, and very coarse. The fine gradations were designed to plot above the Superpave restricted zone. Coarse gradations plotted below the restricted zone, while very coarse gradations plotted below the lower control point on the 2.36 mm sieve. The very coarse gradation corresponded to mixtures developed by TxDOT called "coarse matrix, high binder mixtures."

One of the goals of this research was to test whether gradation (and its effect on aggregate structure) influenced VMA. It is a well-known, but not well-documented, axiom that gradations plotting farther away from the maximum density line tend to develop aggregate structures that resist compaction, thus increasing VMA.

The experiment validated this axiom in that the coarse and very coarse mixtures, which plotted farthest from the maximum density line, possessed higher VMA values. There was no difference in the VMAs resulting from coarse or very coarse mixes. Sandstone, gravel, and basalt mixes exhibited VMAs about 3 percent higher than that of the limestone mixes. A somewhat remarkable feature of the VMA data was the relatively high values evident — approximately 18 percent for the sandstone, gravel, and basalt aggregates.

While the original intent of this experiment was to evaluate the effect of gradation on VMA, it was decided that the same mixtures could also be evaluated for the effect of gradation on mechanical properties. Thus, the designed mixtures were evaluated using the Hamburg wheel tracking device (HWTD), the Superpave shear tester (SST), and the TxDOT static creep test. The SST tests that were used were the repeated simple shear test at constant height (RSSTCH) and the frequency sweep test (FS).

SST tests generally showed that the fine mixtures with low VMA and low asphalt content had the highest stiffness and lowest permanent strain. This finding was expected, since the volume of asphalt binder was significantly higher for the coarse and very coarse mixtures. Because there is no specimen confinement in the RSSTCH or FS test, it was difficult for the aggregate skeleton to mobilize its full stiffness potential.

Static creep tests did not produce significant differences in the mechanical behavior of the mixes, although there was a tendency for the fine mixtures with the lowest VMA to exhibit higher creep stiffness. Once again, without specimen confinement, the stiffest mixtures were those that had the lowest VMA and lowest asphalt content.

The HWTD showed some differences among the mixtures with different VMA. While there were no definitive trends in creep slope data, the stripping slope data suggested that very coarse mixtures with the highest VMA were more favorable. This finding was expected, since the greater volume of asphalt with these mixtures would tend to inhibit the stripping mechanism.

Ruggedness of AASHTO TP7

This experiment was conducted for FHWA and was one of the experiments in which some Superpave centers were expected to participate. As with the ruggedness analysis of AASHTO TP4, SCSC staff developed the experiment and participated in its execution. The purpose of this experiment was to evaluate the ruggedness of AASHTO TP7, "Standard Test Method for Determining the Permanent Deformation and Fatigue Cracking Characteristics of Hot Mix Asphalt Using the Simple Shear Test." This test method outlines six separate test procedures using the Superpave shear tester (SST). The test method evaluated using this experiment was the simple shear test at constant height. This is a controlled stress test in which a test specimen is subjected to a shear load for approximately 10 seconds. During this shearing action, the specimen tries to dilate. A vertical LVDT is used to control the actions of a vertical actuator, which places sufficient axial force to maintain a constant height. Seven factors were included in this study, as shown in Table 6.

Table 6. Main Factors Evaluated in Ruggedness of AASHTO TP7, Simple Shear Test at Constant Height (First Group)

Main Factor	**Levels**
Specimen Air Void Content	6.5 and 7.5 percent
Temperature Stabilization Time[1]	30 and 60 minutes
Test Temperature	38° and 42 °C
Stress Loading Rate	65 and 75 kPa/s
Glue Type	5-minute and 2-hour epoxy
Specimen Orientation	top and bottom
Order of Test	before and after frequency sweep test

[1] Temperature precondition time held constant at 2 hours.

Five laboratories participated in this experiment:

- The University of California at Berkeley (originating laboratory),
- The Western Region Superpave Center,
- The Southeast Superpave Center,
- The South Central Superpave Center, and
- The Asphalt Institute.

Of the seven main factors, only temperature stabilization time, 30 versus 60 minutes, indicated a significant effect on test results.

In the second phase of this evaluation, sixteen 150 mm compacted specimens were received from the Asphalt Institute in February 1999. The objective of testing these specimens was similar to the objective pursued in phase I: evaluate the influence of different factors on the test results. The main factors considered in this phase are presented in Table 7.

Table 7. Main Factors Evaluated in Ruggedness of AASHTO TP7, Simple Shear Test at Constant Height (Second Group)

Main Factor	**Levels**
Specimen Air Void Content	6.0 and 8.0 percent
Temperature Stabilization Time[1]	30 and 60 minutes
TEST TEMPERATURE	38 ° and 42 °C
Shear Strain	0.00004 and 0.00006
Specimen Preparation	cut and uncut (or cut and full size)
Height Control	height control on, height control off
Order of Test	before and after frequency sweep test

[1]Temperature precondition time held constant at 2 hours.

The tests were performed during early March 1999, and the results were submitted to the Asphalt Institute during the same month.

Update of Design Number of Gyrations

In its role as a subcontractor to AI, the SCSC participated in a study to evaluate and update the design gyration table for use with the SGC. Personnel from the Heritage Research Group and Advanced Asphalt Technology were also active in this study. Most of the effort was undertaken between May 1997 and August 1998. The study, initiated at the request of the FHWA, employed a five-task approach:

1. evaluate in-place air void content of existing Superpave mixtures,
2. evaluate and select an engineering property that indicates mixture performance,
3. measure the sensitivity of the engineering property to number of gyrations,
4. measure the sensitivity of mixture volumetric properties to number of gyrations, and,
5. recommend a revised table for number of design gyrations.

The principal goal of this study was to validate, update, and simplify the N-design table using a research approach that differed from that used by the SHRP researchers. The central premise of the study was that the design number of gyrations could be established on the basis of an engineering stiffness property, in addition to mix volumetrics. The SCSC was primarily responsible for Tasks 1 and 3.

The purpose of Task 1 was to develop a gross estimate of the validity of the N-design table as it was developed by the SHRP researchers. This task operated under the hypothesis that the existing table was mostly correct in terms of its ability to specify the proper number of gyrations. Superpave mixes are designed using 4 percent air voids. Consequently, if the in-place air void content of an existing Superpave mix, after trafficking, was at approximately 4 percent (e.g., 3 to 6 percent), then it could be assumed that the design number of gyrations selected from the N-design table for the project was reasonably valid.

SCSC staff mailed a questionnaire to those state DOTs having a significant number of Superpave projects. In addition, staff interfaced with regional LTPP contractors who were responsible for collecting data from SPS-9 projects. Members of the FHWA Superpave mixtures Expert Task Group were also consulted. All those surveyed were asked whether they had data from coring that would track the in-place air void content of Superpave mixtures. Surprisingly, not a great amount of data was forthcoming. Thus, SCSC staff contacted various state DOTs by phone with a personal appeal for data. As a result, project in-place air void content was secured from Arizona, Arkansas, Louisiana, Texas, Florida, and New York. The New York DOT was particularly forthcoming and made a special effort to core projects representing the six traffic levels in the N-design table. The results of this task generally showed that the in-place air void content of Superpave mixes was in reasonable proximity to 4 percent, which suggested that the number of design gyrations was approximately correct.

Task 2 was conducted by Heritage Research, whose personnel conducted various mechanical property tests on cores from WesTrack, a test facility in Nevada. Cores were taken from Superpave mixtures exhibiting good and bad rutting performance. The results of this task showed that the complex shear modulus (G*) arising from the shear frequency sweep test adequately discriminated between good and bad rutting performance.

Task 4, originally designed to be a part of this study, was abandoned because a similar and more extensive evaluation was concurrently being conducted at Auburn University as part of NCHRP Project 9-9. That study indicated that a change of thirty gyrations resulted in a change in VMA and air voids of about 1 percent.

Task 3, conducted at SCSC, was aimed at measuring the sensitivity of G* to the number of gyrations. Ultimately, it was hoped that this stiffness property could be used as the basis of a new N-design table. The first step in Task 3 was to design six basic mixtures for the measurement of G*. Three of the mixtures (A, B, and C) were composed of crushed limestone, while the remaining three were composed of crushed gravel (D, E, and F). Three levels of design gyrations were used, namely, 70, 100, and 130, which were selected to bracket the values in the existing N-design table. The aggregate structure was varied to achieve approximately the same VMA and asphalt content.

Once the six mixtures were designed, nine specimens were fabricated for each mix. From the nine specimens, three samples from each specimen were compacted to 70, 100, and 130 gyrations. These specimens were tested to measure VMA and air void content and then tested in the SST to measure G*.

The volumetric properties observed in this experiment agreed very closely with the findings of the NCHRP 9-9 study in that a change of thirty gyrations resulted in a change of about 1 percent in air void content and VMA. The frequency sweep test results showed that a change of thirty gyrations resulted in a change in G* of about 30 percent for both the limestone and gravel mixtures.

Based on the results of Tasks 1, 2, and 3, and considering the NCHRP 9-9 experimental results, the researchers developed a recommended N-design table. This table, shown in Table 8, was presented to the FHWA Superpave mixtures Expert Task Group (ETG) for the ultimate purpose of recommending it to AASHTO for adoption. The ETG rejected it in favor of a revised N-design table that combined principles of this and the NCHRP 9-9 study.

Table 8. Revised N-Design Table Based on an Engineering Stiffness Property (G)*

Traffic Level, Millions of ESALs	Design Number of Gyrations
Less than 1	60
1 – 10	80
10 – 30	100
Greater than 30	120

Evaluation of Special Pavement Studies (SPS-9) Project FM 1604

When the FHWA developed the concept of the Superpave centers, one of the expectations was that the centers would provide support for special pavement studies (SPS) projects. SPS-9 projects were experimental test sections aimed at evaluating Superpave. State DOTs were asked to construct these test sections and provide Superpave testing services during construction and periodically after construction. For various reasons the centers never provided a significant amount of assistance to state DOTs on SPS-9 projects. One exception was an SPS-9 project on FM 1604 near San Antonio, Texas. For this project, constructed in 1994, TxDOT requested SCSC assistance in testing project materials. Renato Ceccovilli, a University of Texas at Austin civil engineering graduate student, was assigned to this project. From this project, Ceccovilli produced a master's thesis for his graduate program at The University of Texas at Austin.

The FM 1604 SPS-9 experiment involved testing raw asphalt and aggregate materials and the Superpave mixtures as produced. It also involved testing cores from two test sections at various periods following construction. Both sections utilized the same mix, but with different binders, a PG 64-22 and a PG 70-22. The PG 64-22 binder was the binder that would have been selected based on the climate of the project site. The PG 70-22 binder was a "bumped" grade.

This experiment involved a considerable amount of materials characterization. This exercise ranged from compositional analyses on the hot mix as-produced, to mechanical property testing of laboratory fabricated specimens and cores using the Superpave shear tester and indirect tensile tester. All test data were submitted to the FHWA Long-Term Pavement Performance Division through the south central regional contractor, Brent Rauhut Engineering, Inc., located in Austin, Texas. Presumably, the test data will be combined with similar data sets obtained from other projects for analysis.

Perhaps the most interesting and useful information gleaned from this testing was the densification of the Superpave mix over time. This information was combined with similar information from other Superpave projects to validate and update the N-design table used with the Superpave gyratory compactor.

Comparative Analysis of Superpave and Texas Gyratory Compactors

Among all state DOTs, one of the critical issues in implementing Superpave was the transition from the existing method of laboratory compaction (i.e., the Texas gyratory compactor, or TGC) to the Superpave gyratory compactor (SGC). TxDOT owns approximately 300 Texas gyratory compactors. An approximately equal number is owned by industry and engineering testing laboratories in Texas. Thus, there was a need to evaluate the efficacy of the SGC in comparison with the TGC in terms of a mix design and field control device. Consequently, three independent studies were conducted for this purpose.

In the first study, an experiment was designed and conducted by Mr. Dale Rand (Ref 6). Rand developed a two-phase experiment. Phase I focused on precision and bias of the two gyratory compactors. The loose mixtures were sent to various districts and were compacted in both types of presses. Rand utilized three asphalt mixtures compacted using fourteen SGCs and twelve TGCs. Phase II evaluated strength properties developed in specimens molded using the two devices. In this phase, he compared the slope of the compaction curves of specimens molded in the SGC with Hveem stability and static creep test results from TGC-molded specimens. Phase II involved the use of twenty-seven different mixtures. These included fine, coarse, and very coarse mixtures based on the percent passing the 2.36 mm sieve, with each of these mixtures at multiple asphalt contents. Rand's conclusions were as follows:

- For Superpave mixes, the SGC produced specimens that were 33 to 42 percent less variable in terms of bulk specific gravity.

- For very coarse mixes, such as TxDOT CMHB mixes, the SGCs produced specimens that were slightly more variable in bulk specific gravity than those produced with the TGC, although the differences were not statistically significant.

- For laboratory-batched specimens, a design number of gyrations of 96, and a compaction temperature of 121 °C, the SGC produced specimens that were significantly lower in density than those compacted in the TGC.

- The slope of the compaction curve does not correlate well with either Hveem stability or static creep slope.

- The slope of the SGC compaction curve correlates very well with coarse aggregate content (percent retained on 2.36 mm sieve); Hveem stability and static creep slope also correlate well with coarse aggregate content.

Rand recommended that TxDOT allow the use of the SGC for field control of HMA. He also suggested that TxDOT require that the field control compactor be correlated with the mix design compactor regardless of the type of field control compaction device. Rand believed that the Hveem stability measured during field production could be eliminated in favor of tolerances on gradation, particularly the coarse aggregate content when coarse mixes were being evaluated. With respect to pay adjustments on field-produced mixtures, Rand suggested that TxDOT's current bonus/penalty tolerances be adjusted when an SGC is used for field control.

In another study, TxDOT personnel collected density data from various districts on plant mixes. These mixes were compacted with both a TGC and an SGC located in different districts. The design number of gyrations for this comparison was 96.

Later, at the request of TxDOT, a third study was conducted by the South Central Superpave Center. Plant mixes were used in this study with the idea of having all the compaction taking place at a central laboratory. This way, the variability in operation and equipment was significantly reduced. A single operator was used for the compactors throughout the experiment to reduce the variability.

Loose samples of the hot asphalt mixtures used in actual field construction were obtained at the asphalt mixing plants from the Abilene District and subsequently transported to the SCSC. The loose samples were reheated at 125 °C and compacted using a Texas gyratory compactor and the Superpave gyratory compactor at the same temperature. For this study, samples were prepared from eleven different lots. For each comparison, an average of two SGC specimens and three TGC specimens were used. Oven temperatures were verified prior to the experiment and throughout the mixing and compaction process. A calibrated thermocouple with digital readout was employed.

The results of the three studies are presented in Figures 1 through 3, respectively. Figure 1, based on the first study, does not exhibit a good correlation. However, Figures 2 and 3 indicate that there is a relatively good correlation between the two presses. As shown in Figure 4, the largest difference in magnitude of air voids from the two compactors is about 1 percent. In most cases, the difference is less than 0.6 percent.

An important consideration in making a comparison between the SGC and TGC is the design number of gyrations (N_{des}). Obviously, as the N_{des} changes, the air voids from SGC will change. Figures 1 and 2 are based on an N_{des} of 96, while Figure 3 is based on an N_{des} of 86. If an N_{des} of 96 had been used for this last study, there would have been a shift of data points to the left, presenting results similar to what is shown in Figure 2.

Considering the above correlation, and considering also that, in most cases, the difference between air voids from the two presses is less than 0.6 percent (only for the N_{des} used in this study), one could conclude that the results are comparable within reasonable limits. There may be the possibility of developing shift factors between the results from the machines for other N_{des} values.

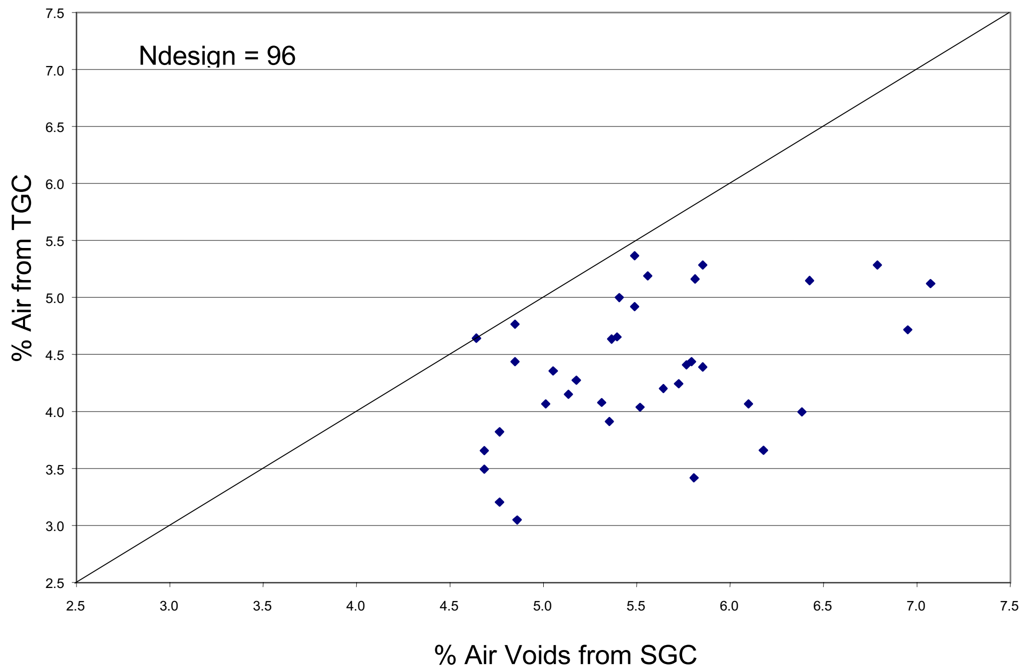


Figure 1. Comparison of Air Voids between SGC and TGC (Data Based on Compaction of Laboratory Mixed and Molded Specimens, Reference 6)

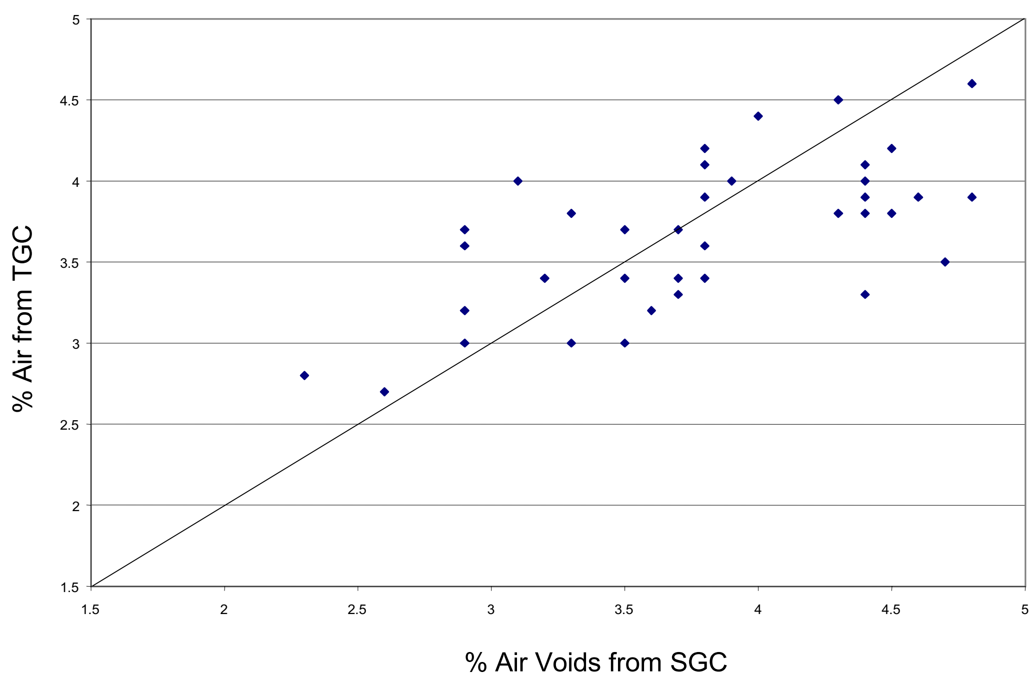


Figure 2. Comparison of Air Voids between SGC and TGC (Data Based on TxDOT tests on Plant Mixes at the Districts, Courtesy of TxDOT)

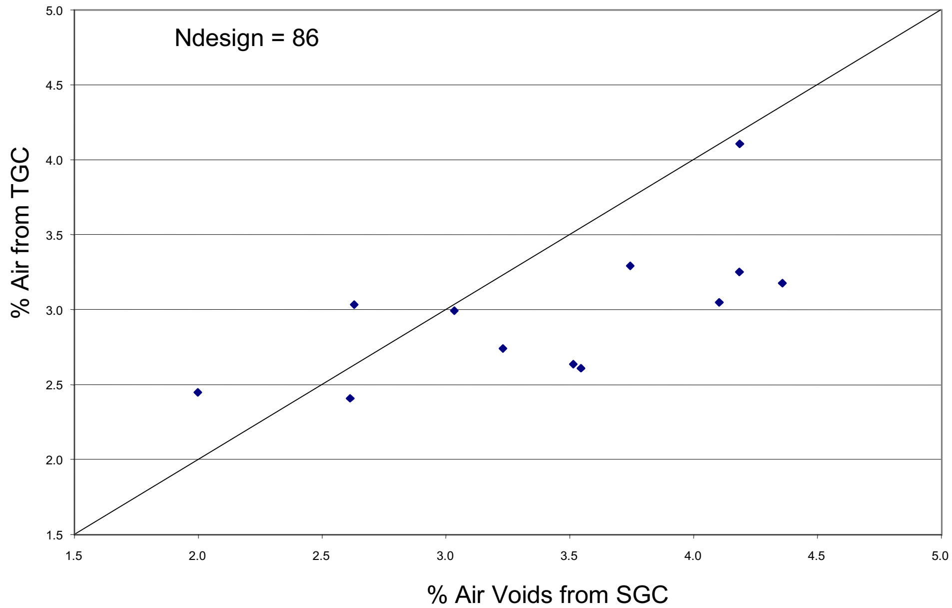


Figure 3. Comparison of Air Voids between SGC and TGC (Data Based on SCSC Tests on Plant Mixes from Districts)

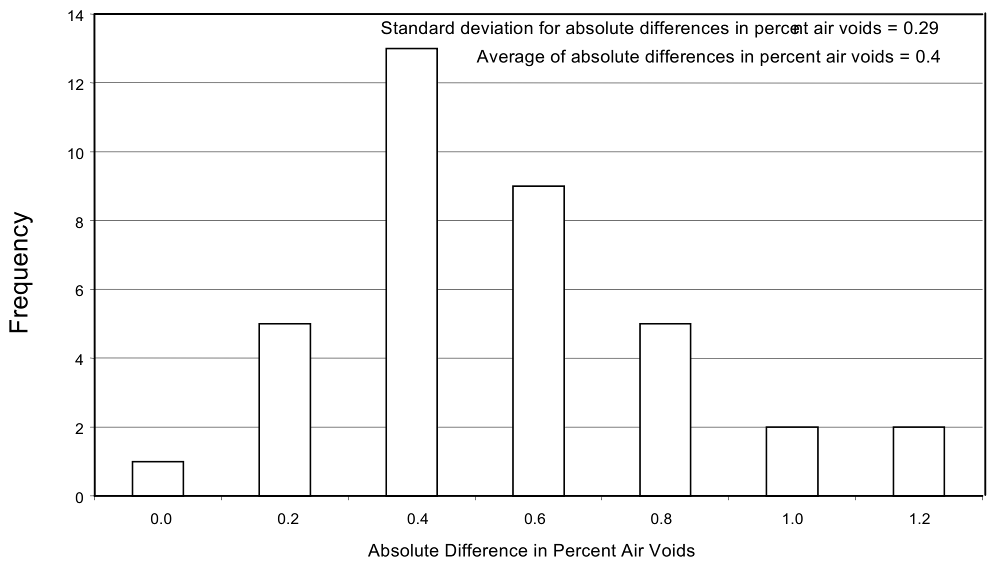


Figure 4. Histogram Showing Percent Air Voids Difference for SGC vs. TGC (Based on Data Presented in Figure 2)

Determination of Reclaimed Asphalt Pavement Content in Asphalt Mixes Using Superpave Binder Specifications

With the development of Superpave, there was a need to develop a methodology for considering the use of reclaimed asphalt pavement (RAP) in Superpave mixes. To respond to this need, the FHWA Superpave Mixtures Expert Task Group developed a set of guidelines for the use of RAP (Ref 7). To support that effort, Mr. Weng On Tam, a civil engineering master's degree student at The University of Texas at Austin, developed an experiment to study the rheological properties of different combinations of simulated RAP binders and virgin binders.

Tam chose six asphalts from the SHRP Materials Reference Library (MRL) to use in his experiment. The experiment and analysis verified that high- and low-temperature stiffness characteristics are significantly affected by the amount of RAP binder used. The rate of change of stiffness was either constant from 0 to 100 percent RAP binder or increased with lower temperatures. While he presented a practical example of determining the maximum percentage of RAP to be used, he also showed that other factors most often govern the amount of RAP that can be used, and that such amounts are not simply a function of the rheological properties of the RAP binder (Ref 8).

Static Behavior of Superpave Mixes

The Texas Department of Transportation (TxDOT) uses the static creep test as an integral part of its mix design for a special asphalt mixture referred to as coarse matrix high binder (CMHB). TxDOT uses the static creep test to determine resistance to permanent deformation of bituminous mixtures at temperatures and loads similar to those experienced by these materials in the field (Texas Department of Transportation, 1994). The test was initially developed as a strength test for crumb rubber modified (CRM) asphalt hot mix, the work primarily completed prior to 1993 (Ref 9).

The procedure includes placing the test specimens into a controlled temperature chamber maintained at 40 ^{o}C for 3 to 5 hours prior to the start of the test to bring the specimens to the test temperature. The procedure to calculate required material properties (the stiffness, the permanent strain, and the slope of the steady-state curve) is described in Texas Test Method Tex-231-F (1994). The test results are compared with the pass/fail criteria on stiffness, permanent strain, and creep slope shown in Table 9.

Table 9. Current TxDOT Static Creep Acceptance Criteria (Texas Department of Transportation, 1993)

Mixture Property	Acceptance Criterion
Max. Creep Slope	0.00000004 mm/mm/sec
Minimum Creep Stiffness	41370 kPa
Max. Permanent Strain	0.0006 mm/mm

This static creep test is one such test that could possibly be used to validate the effectiveness of the Superpave volumetric mix design procedures. Accordingly, TxDOT is investigating the possibility of using this test as a strength test for Superpave mixes. To accomplish this objective, the South Central Superpave Center, under the direction of TxDOT, conducted a research project to investigate the static creep behavior of Superpave mixes. The Superpave shear tester (SST) was also evaluated to determine if it could produce test results similar to those produced by TxDOT's static creep machine. The overall objective was to determine if this test could be used to differentiate between good- and poor-performing Superpave mixes. To achieve this objective, the current static creep test setup was modified to accommodate Superpave gyratory specimens. In addition, the following factors were evaluated:

- the effect of specimen diameter and compaction method
- the effect of using two different machines, TxDOT's current static creep tester and the Superpave shear tester, SST
- the effect of sample preparation method (molded to the correct height as compared to saw-cutting a regular Superpave gyratory specimen)
- the effect of temperature and asphalt content

One major contribution of this research has been the substantial information collected for use in the development of a static creep test for Superpave mixes. In addition, evaluation of the effect of compaction method and specimen diameter on static creep results will help TxDOT to determine the applicability of its CMHB acceptance criteria to Superpave mixtures. The evaluation of the SST will assist state agencies and research institutions to determine the SST's ability to conduct a comparable static creep test. The evaluation of temperatures will also be useful in determining if a test at 64 ^{o}C, instead of at 40 ^{o}C, will better differentiate between a good- and a poor-performing mix. Finally, the evaluation of sample preparation method (molded to the correct height as compared to saw-cutting a regular Superpave gyratory specimen) will help determine if the time and materials savings in using molded specimens accurately replicate results obtained from regular specimens that have been saw-cut. It should be noted that while saw-cut Superpave gyratory specimens have traditionally been tested on the SST, it does not mean that this sample preparation method is superior to molding specimens to the correct height using the Superpave gyratory compactor.

One concern with using the static creep test on Superpave gyratory compacted samples is the differences in compaction machines and specimen diameters. In this research effort, the effect of diameter and the effect of compaction method were not considered separately. Their individual effects were compounded. The reason for this decision lies in the fact that production models of the Texas gyratory compactors can compact only 100 mm diameter specimens and production models of the Superpave gyratory compactor (in its regular setup) can compact only 150 mm diameter specimens. It is highly unlikely that either of these gyratory compactors will be used widely to compact specimens to a different diameter on a production scale. Consequently, the cost associated with acquiring modified equipment to investigate these two factors separately was not justifiable. However, it is important to recognize that there are differences in these two compaction methods. Besides the difference in the specimen diameter, the pressure applied during compaction is also different. In the Texas gyratory compactor, an initial pressure of 345 kPa is applied for most of the compaction process, but compaction ends with a one-time final pressure of 17,238 kPa to level the specimen before the pressure is released and the specimen extracted. The Texas gyratory compactor uses a 5.8-degree angle of gyration. This procedure is outlined in Texas Test Method Tex-206-F (Texas Department of Transportation, 1991). The Superpave gyratory uses a constant pressure of 600 kPa, a 1.25 angle of gyration, and a gyration rate of thirty gyrations per minute. This procedure is outlined in the AASHTO TP4, PP19 procedure (American Association of State Highway and Transportation Officials, 1998).

During SHRP, test methods were developed for the different performance tests. Specimens tested with both the SST and the IDT (indirect tension tester, another performance testing machine developed during SHRP) are saw-cut from the midsection of a regular Superpave gyratory compacted specimen. These saw-cut specimens are approximately 50 mm in height. In recent years, some members of the asphalt industry have started to compact specimens to a height of 50 mm in the SGC, instead of compacting specimens in the traditional manner (to approximately 200 mm), and then saw-cutting out the midsection of that specimen. This method of preparing specimens reduces wastage of materials and leads to substantial savings in sample preparation time (especially in the sieving of aggregates). Currently, work is also underway at the Asphalt Institute to evaluate the effect of sample preparation on the results of two commonly used performance tests run on the SST. These tests are the frequency sweep and the repeated shear at constant height tests.

With the evolution of SHRP and the development of the Superpave system, there has been a move towards testing asphalt mixes at temperatures that are likely to be experienced in the field. This can clearly be seen in the new asphalt binder grading system — performance grading. The Superpave performance grading system requires asphalt binders to be tested at temperatures at which the binder will be exposed to in the field. For example, in central Texas, the average 7-day high temperature is around 64 ^{o}C to 70 ^{o}C. As such, asphalt binders used in central Texas are tested at 64 ^{o}C or 70 ^{o}C to determine if they are adequate for use in this region. However, many creep tests, such as the static creep test, are run at 40 ^{o}C to determine the potential for rutting. In an effort to evaluate the effect of running the mix tests at pavement temperatures, the static creep test was run at both 40 ^{o}C and 64 ^{o}C.

In order to evaluate the effect of asphalt content, three mixes were compacted with varying asphalt contents. This evaluation was undertaken to determine the sensitivity of these mixes to changes in asphalt content.

In order to develop acceptance criteria for Superpave mixes it was important to evaluate a few good- and poor-performing pavements in the field. With the help of TxDOT materials engineers in the Austin, San Antonio, New Braunfels, and Waco Districts, the mix designs of four good performing pavements were selected to represent good mix designs. However, mixes that are not performing well in the field were not selected to represent “poor” performing mixes. When a pavement does not perform well it could be due to poor underlying layers, poor construction practices, or to a number of other factors. For this reason, poor-performing pavement pavements were not selected to represent poor mix designs. Instead, good-performing mix designs were modified to make the "poor-performing" mixes. This modification was achieved by compacting the laboratory specimens with one percent more asphalt than optimum. Having 1 percent more asphalt over optimum is believed to lead to a significantly greater susceptibility to rutting.

TxDOT's static creep tester was designed to test specimens compacted using the Texas gyratory compactor. In the Texas gyratory compactor, specimens are compacted to a diameter of 100 mm and a height of approximately 51 mm. In the Superpave gyratory compactor, specimens are compacted to a diameter of 150 mm and a height of approximately 150 mm. Because current TxDOT static creep equipment is unable to test 150 mm test specimens, modifications were made to the test setup. The load was also increased to 1,251 N so that the stress experienced by the 150 mm specimen is the same as the stress experienced by the 100 mm specimen, 69 kPa.

In this research effort, a few sources of aggregates and asphalts were used. Among the aggregates used were limestone rock from Colorado Materials and Capital Aggregates, sandstone from Delta Materials, and field sand from Odell-Geer Construction. Coincidentally, the three types of asphalts used on all of these projects were supplied by Texas Fuel and Asphalt (TF&A) in Corpus Christi, Texas.

The BIH-35 (New Braunfels) mix design was chosen as the primary mix design. This mix was selected for a number of reasons. For one, the BIH-35 mix design is a coarse (aggregate gradation passes below the restricted zone) Superpave mix that is performing well in the field. Choosing this mix design as the primary will shed more light on the behavior of Superpave mixes. In addition, the mix design was conducted at the South Central Superpave Center. The aggregates (from Colorado Materials) were readily available at the SCSC; the staff has a fair amount of experience with this aggregate source, given that Colorado Materials also provides the laboratory standard aggregates. The AC-20 asphalt used was also readily available from TF&A.

In addition to the three base mix designs, the mix designs for three other mixes that are performing well in the field were selected for evaluation. Once again, the TxDOT district offices assisted in the selection of these mixes. One of the mixes is a Superpave 12.5 mm mix laid down on IH-35 in Waco, Texas. The other two are coarse matrix high binder (CMHB) mixes. The first one is a CMHB-C (coarse CMHB) laid down on IH-35 is Austin, Texas. The second one is a CMHB-F (fine CMHB) laid down on FM 1103 in New Braunfels, Texas.

In the study of diameter and machine, only the effect of machine on slope was of practical significance in almost all cases. Based on the limited scope of this study, it is concluded that the SGC specimens molded to 51 mm in height exhibit similar creep properties to a Texas gyratory compacted specimen compacted to the same height. However, there were practical differences in slope values between specimens tested on the ETS and on the SST.

In the study on sample preparation and machine, only the effect of machine on slope was consistently of practical significance. Based on the limited scope of this study, it could be concluded that sample preparation method ("molded" or "cut") does not affect creep properties of SGC-compacted mixes from a practical standpoint. However, there were practical differences in slope values between specimens tested on the ETS and on the SST.

In the study on asphalt content and temperature, there was a consistent decrease in stiffness, increase in permanent strain, and increase in slope with increasing asphalt content for tests run at 40 °C. However, most of the differences were of no practical significance. The differences observed at 64 °C were even less significant and much more inconsistent in terms of whether higher values were observed at 40 °C or 64 °C.

In the study of "good" versus "poor" mixes, it was observed that "poor" Superpave mixes exhibited lower stiffness, higher permanent strain, and higher slope as compared with the corresponding "good" mixes. The intermediate and fine mixes, from the sensitivity analysis in Phase IV, also show the same trends. However, the "poor" CMHB mixes exhibited higher stiffness and practically similar permanent strain and slope for the "poor" mixes as compared to the corresponding "good" mixes. This finding could be interpreted to mean that the asphalt content used in the field may not really be the optimum for resisting permanent deformation. However, in actual construction, many other factors play into the choice of asphalt content.

The conclusions of this study should be used cautiously. Adequate care must be taken to identify the context of the recommendations and to adapt them to each unique set of circumstances. In order to extend the applicability of these conclusions, additional research is required to verify the findings for a broader range of materials (asphalt and aggregates). Only then can the findings be applied in a broader sense.

One finding underlying the discussion of results and the conclusions is the absence of practical differences in the results, even in the presence of statistical differences. One concern in the current test setup is the fairly large variability in the results. With a fairly large variation among the three replicates, it is difficult to say that one mean is really very different from another. One possible solution would be to increase the stress level at which the test is run. Some other research efforts, such as that undertaken by AAMAS, have used a stress level of 207 kPa — a stress level that should be investigated in the future. Such a stress level will make the test more of a "torture" test and possibly help to better differentiate among mixes.

Another factor of interest is the aspect ratio. Owing to limitations in the testing equipment, the height of the test specimen was maintained at approximately 51 mm, even though the diameter was increased from 100 mm to 150 mm. This change reduced the aspect ratio of the test specimen from 0.5 to 0.33. Further research can be conducted wherein the aspect ratio is kept constant while the diameter of the specimen is increased. For a 150 mm diameter specimen, a specimen height of 75 mm is recommended to maintain a constant aspect ratio.

Owing to the lack of practical differences among the mixes, no attempt was made to develop acceptance criteria. However, it is hoped that the work performed for this project will contribute to the growing knowledge and experience on the static creep test as a means of evaluating the rut resistance of asphalt concrete mixes. The investigation of creep behavior of Superpave mixes is presented in detail in Research Report 1250-4.

Binder Direct Tension Tester

The bending beam rheometer was adopted in the Superpave system as the main piece of equipment to use for capturing the binder engineering properties at low temperatures. However, it was clear that some binders, especially polymer-modified binders, may exceed the 300 MPa stiffness criterion at a specific temperature but still be ductile enough to be stretched without cracking. For this reason, the binder direct tension tester was adopted by the Superpave system to ensure that the binder properties are properly measured and considered when stiffness is beyond the established requirements with the bending beam rheometer.

A direct tension tester built by Instron was installed at the SCSC during in March 1998. This unit was purchased through the Federal Highway Administration's pooled fund for equipment. The SCSC was directed by TxDOT to conduct a ruggedness evaluation of this unit. The evaluation work began in September 1998 and lasted through August 1999. The following factors were included in the study:

- Repeatability of the equipment within the laboratory
- The correlation between the binder stiffness from BBR and the binder modulus from DTT
- Effect of temperature on stress, strain, and modulus
- Effect of the loading rate on stress, strain, and modulus

Eleven unmodified binders and fifteen modified binders were included in the study. Most of the binders were received from TxDOT's materials section in Austin. These binders were among the binders that TxDOT's materials section receives routinely for testing and quality control. The SCSC standard binder, a PG 64-22, was the one used to evaluate the repeatability of the equipment.

Each testing with DTT requires the preparation of six specimens. Typically, the lowest two values are dropped and the remaining four are averaged to obtain the final result. To evaluate the repeatability, thirty-one specimens were prepared and tested at –12 °C. The coefficients of variation were 15 percent and 34 percent for the stress and the strain, respectively. From the results it appears that the testing repeatability needs to be improved through better procedures for sample preparation and testing. The problem is especially noticeable with strain. The frequency distributions are presented in Figures 5 and 6.

Four different stain rates (0.5, 1, 3, and 5 %) were used to evaluate the effect of this parameter on the binder behavior. As expected, lower strain rates (i.e., slower rates of loading) resulted in higher failure strains, lower stresses at failure, and, consequently, lower moduli (Figures 7 and 8).

The effect of temperature on strain and stress at failure is shown in Figures 9 and 10, respectively. For the laboratory standard binder PG 64-22, a 6 °C reduction in temperature from –6 °C to –12 °C has a larger effect on stress and strain change compared to a 6 °C change from –12 °C to –18 °C.

The relationship between the stiffness from the bending beam rheometer (BBR) and the modulus from the direct tension test is shown in Figure 11. These values are for different binders tested at –12 °C. While the relationship is relatively a good one, it does not suggest that from the results of one test (such as stiffness from BBR) the property for another test could be estimated accurately.

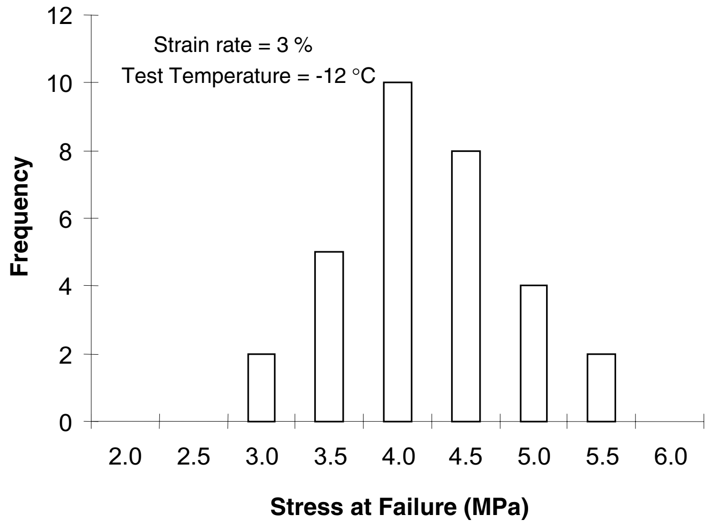


Figure 5. The Frequency Distribution of Stress at Failure from the Direct Tension Test

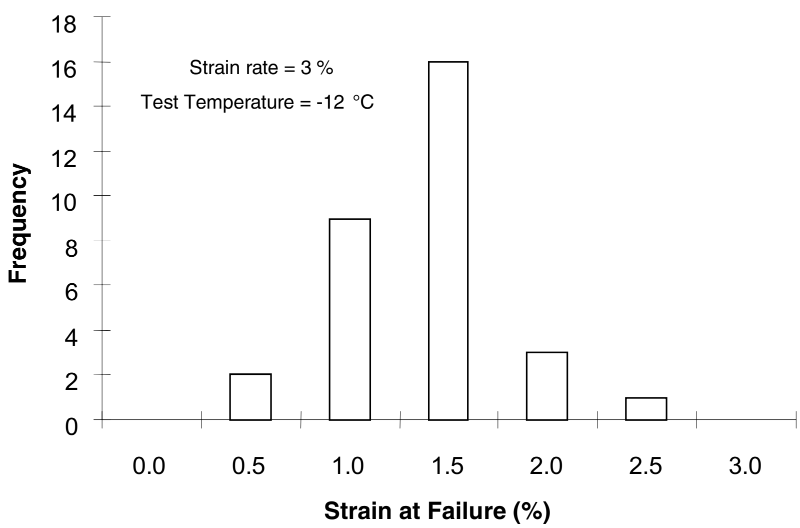


Figure 6. The Frequency Distribution of Strain at Failure from the Direct Tension Test

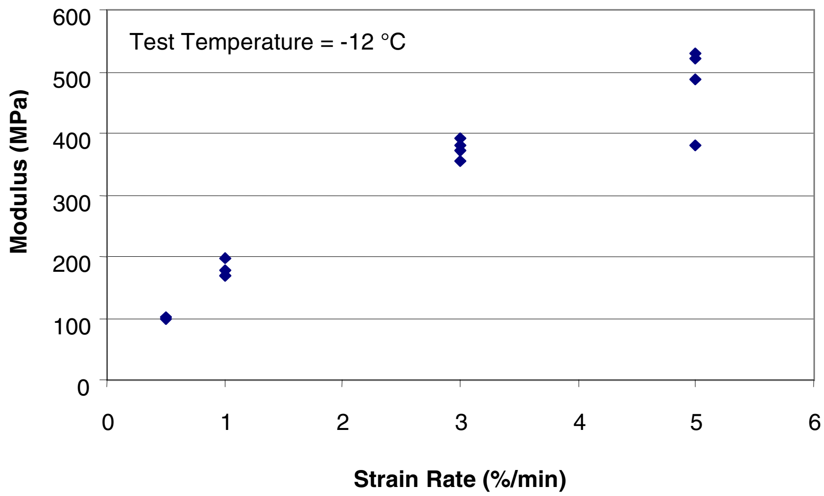


Figure 7. The Effect of Rate of Loading on the Modulus from Direct Tension Test

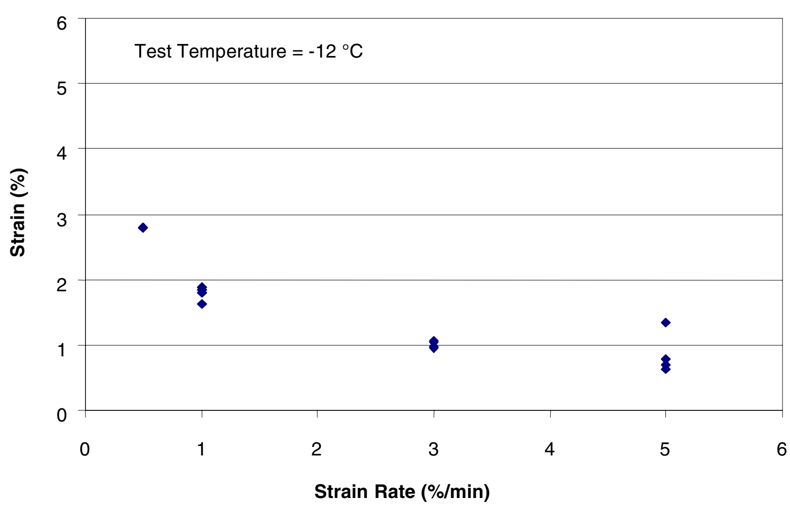


Figure 8. The Effect of the Rate of Loading on Failure Strain

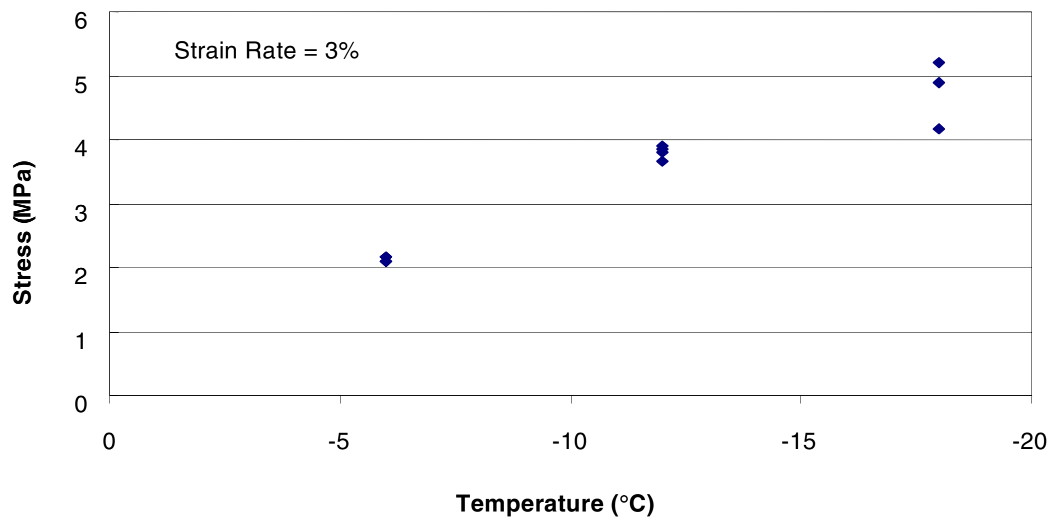


Figure 9. The Effect of Temperature on the Stress at Failure from Direct Tension Test

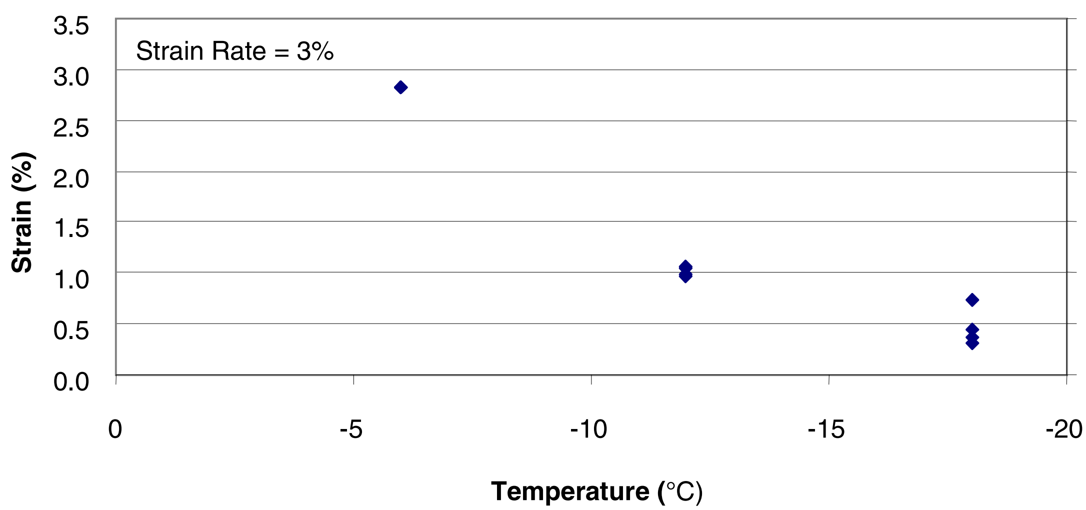


Figure 10. The Effect of Temperature on the Failure Strain from Direct Tension Test

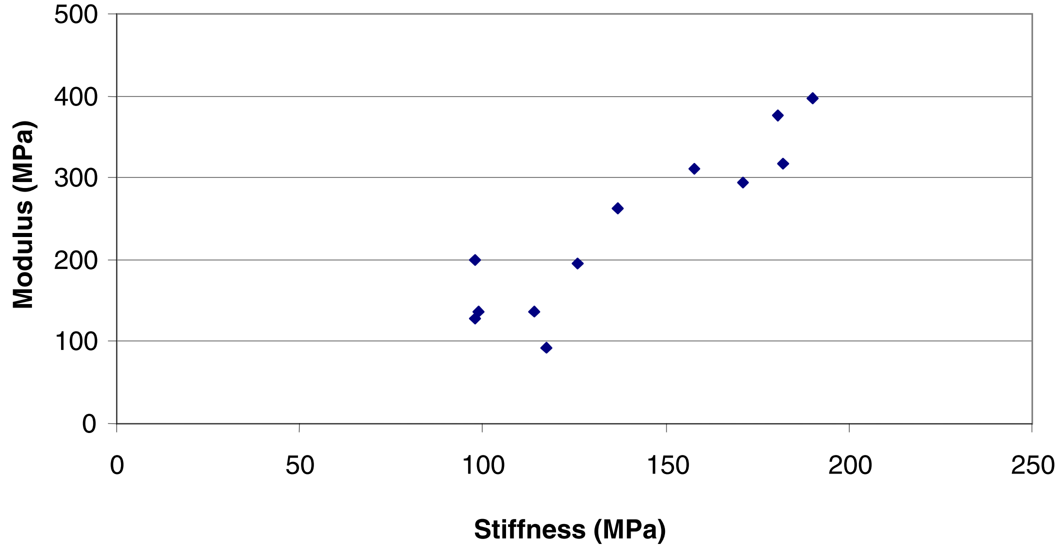


Figure 11. The Relationship between the Modulus from DTT and Stiffness from BBR

Data on Superpave Projects Built in Texas: 1997 and 1998 Superpave Construction Projects

Currently, TxDOT utilizes special specification item 3146 for quality control/quality assurance of hot mix asphalt construction (Ref 11). This latest specification has evolved through TxDOT's continuous improvements to a series of QC/QA specifications first adopted in early 1990s. The densities of both in-place specimens and laboratory-molded plant mix specimens are the parameters considered for determination of pay factors. Other factors such as deviations in asphalt content and percent aggregate retained on individual sieves are used as quality control parameters but not as pay factor parameters. Because of the significant impact of such factors on the quality of the product and the level of payment, TxDOT's construction division initiated collection of construction data on all Superpave projects built in Texas. The data collection in its comprehensive form was started by TxDOT in 1997, with such data organized into a specific user-friendly format to simplify the analysis. Later, TxDOT assigned to the South Central Superpave Center the task of data organization and analysis for 1998 Superpave projects.

Attempts were made to maintain the format already developed by TxDOT, even though some slight modifications were made. As the 1998 Superpave construction data became available, they were added to the database and the required graphs were plotted. For each project, the construction data included such parameters as asphalt content, laboratory and in-place densities, and aggregate gradations. The data were obtained from different sublots for each project.

The ten Superpave projects constructed in 1997 are presented in Table 10. Except for the projects in Amarillo and San Antonio (FM 1517), which are of 12.5 mm maximum nominal size, the remaining projects are with a maximum nominal size of 19.0 mm. Counties were not available and therefore were not included in this table.

Table 10. 1997 Superpave Projects

District	Highway	Max. Nom. Size (mm)	Location w.r.t. the restricted Zone
Amarillo	SH 152	12.5	Below
Atlanta	SH 43	19.0	Below
El Paso	Loop 375	19.0	Below
San Antonio	FM 1517	12.5	Below
San Antonio	BI 35	19.0	Below
Tyler	IH 20	19.0	Below
Tyler	SH 31	19.0	Below
Waco	IH 35	19.0	Below
Waco	Loop 396	19.0	Below
Wichita Falls	US 82	19.0	Below

The eight Superpave projects built in 1998 are listed in Table 11. Five of the eight projects have maximum nominal size of 12.5 mm. Two projects are of 25.0 mm maximum nominal size and only one is of 19.0 mm.

Table 11. 1998 Superpave Projects

District	County	Highway	Max. Nom. Size (mm)	Location w.r.t the restricted zone
Atlanta	Cass	FM 3129	12.5	Below
Atlanta	Harrison	US 80	12.5	Below
Childress	Briscoe	SH 256	25.0	Below
Lubbock	Hockley	NH 98	25.0	Below
Pharr	Cameron	FM 802	12.5	Below
Tyler	Smith	IH 20	19.0	Below
Waco	Bell	IH 35	12.5	Below
Wichita Falls	Montague	US 82	12.5	Below

The frequency distributions for several important volumetric properties are presented in Figures 12 through 17.

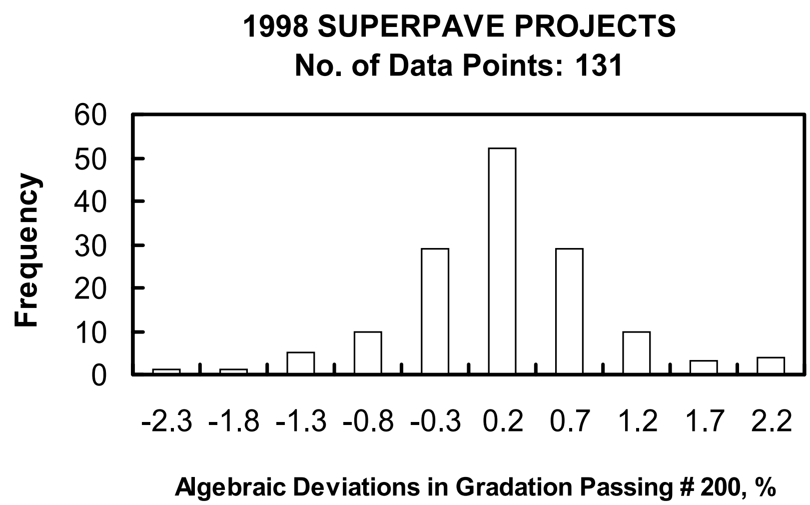


Figure 12. Distribution of the Algebraic Deviations in Gradation Passing No. 200 (0.075 mm) Sieve for the 1998 Superpave Projects (All Data Points Included)

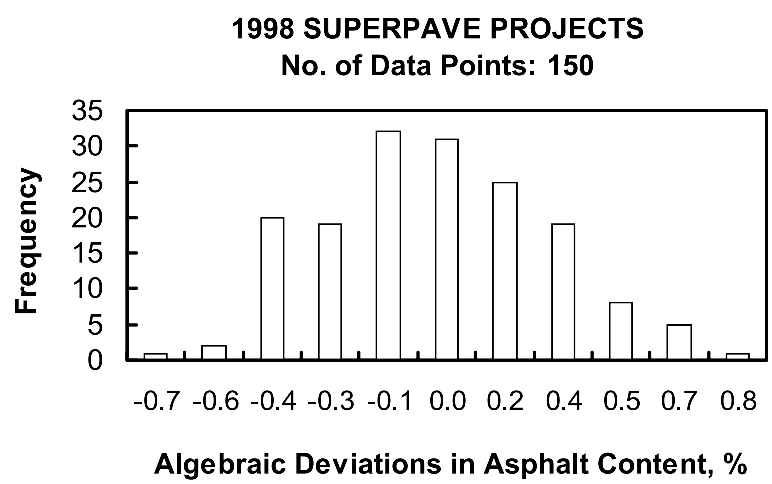


Figure 13. Distribution of the Algebraic Deviations in Asphalt Content for the 1998 Superpave Projects (All Data Points Included)

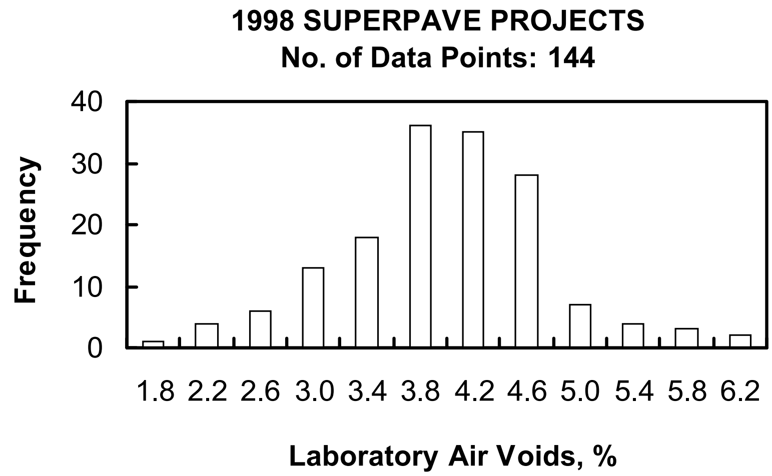


Figure 14. Distribution of the Laboratory Air Voids for the 1998 Superpave Projects (All Data Points Considered)

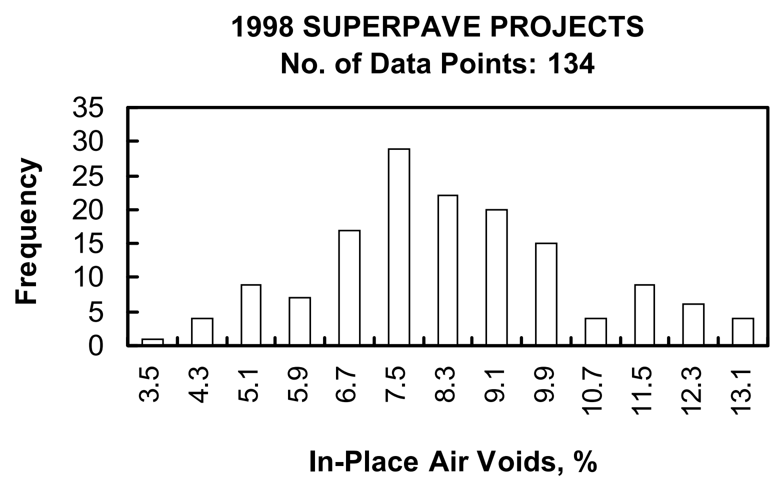


Figure 15. Distribution of the In-Place Air Voids for the 1998 Superpave Projects (All Data Points Included)

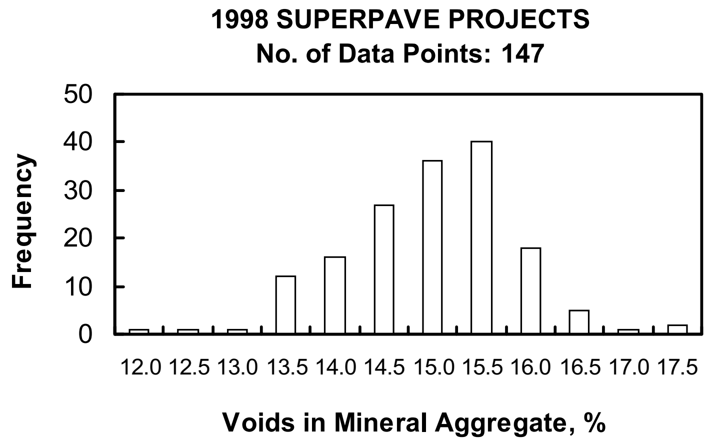


Figure 16. Distribution of the Voids in Mineral Aggregate for the 1998 Superpave Projects (All Data Points Considered)

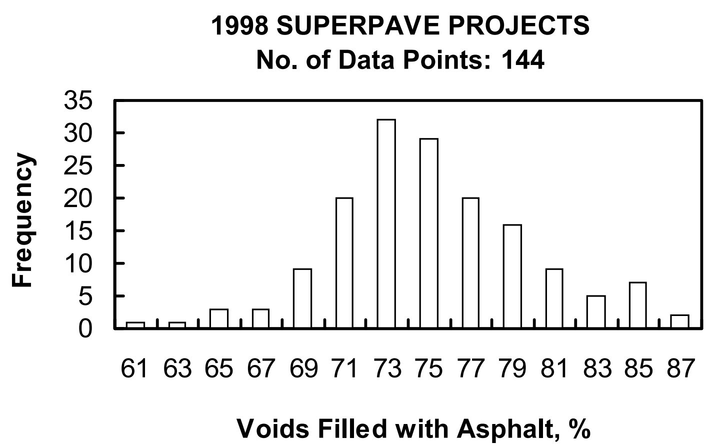


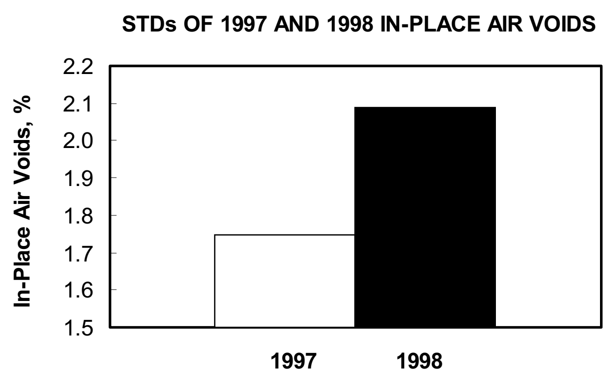
Figure 17. Distribution of the Voids Filled with Asphalt for the 1998 Superpave Projects (All Data Points Included)

The results of 1997 and 1998 construction are compared in Table 12. The table indicates that the equality of the 1997 and the 1998 Superpave projects is not statistically supported at both the risk levels of 0.10 (i.e., less conservative) and 0.05 (i.e., conservative). In other words, when all six control parameters are considered at the same time, the 1997 projects differ from the 1998 projects. The superiority of one group of projects over the other needs to be determined in terms of each individual control parameter. In Figure 18, the mean (8.1 percent) of the in-place air voids for the 1998 projects appears to be smaller than that (8.7 percent) of the 1997 projects even though the standard deviation (2.1 percent) of the

1998 projects is slightly larger than that (1.7 percent) of the 1997 projects. Similarly, the mean and the standard deviation of laboratory air voids of the 1998 projects were found to be smaller than those of the1997 projects.

Table 12. Results of Hypothesis Tests on the Variances and Means of 1997 and 1998 Superpave Projects When the Risk Level, α, is 5 %

Control Parameters	Significant Difference in Variance	F Statistic	F Critical	Significant Difference in Mean	T Statistic	T Critical
# 200 Sieve, %	Yes	1.34	1.31	No	1.13	± 1.97
AC, %	No	0.73	0.78	Yes	2.80	± 1.97
Lab Air Voids, %	Yes	2.20	1.30	Yes	3.03	± 1.97
In-Place Air Voids, %	No	0.70	0.76	Yes	2.69	± 1.97
VMA, %	Yes	2.27	1.30	No	1.80	± 1.97
VFA, %	Yes	1.85	1.30	Yes	-2.57	± 1.97



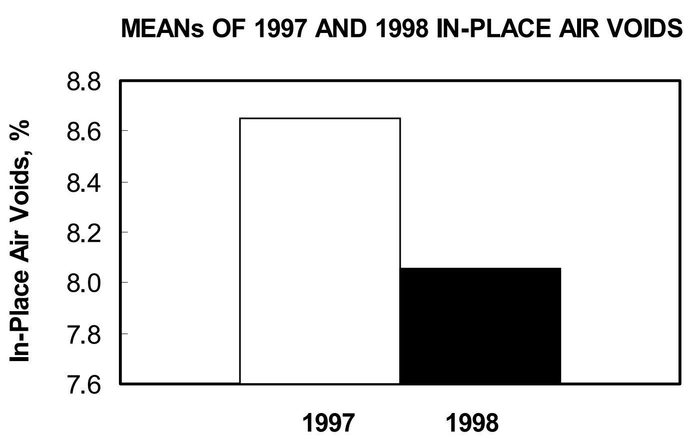


Figure 18. Comparisons of the Means and the Standard Deviations (STDs) of In-Place Air Voids between the 1997 and the 1998 Superpave Projects

SPECIAL PROJECTS

Numerous special experimental projects were conducted at the SCSC. These experiments were normally undertaken at the request of various organizations participating in Center activities or as activities pursuant to the normal goals and objectives of an applied research and training facility.

SCSC Laboratory Standard Experiment

At the outset of the SCSC project, an experiment was conducted to develop a set of laboratory standard materials for routine Center use. It was intended that these materials would be used in the Center training activities as well as in various Center experiments. Like the other Superpave centers, SCSC was a highly visible organization and, as such, probably could have obtained highly superior aggregates from any source in the U.S. However, that strategy was not employed. Center staff believed that a more "normal" set of materials, representing average state highway agency use, would set a better standard for training and experimental purposes. Consequently, it was decided that a typical central Texas crushed limestone would form the basis of the SCSC laboratory standard aggregate. This material was graciously supplied in large quantities by the Colorado Materials Company from its quarry and hot mix facility in Hunter, Texas. Laboratory standard binders were furnished by Neste Trifinery of Corpus Christi, Texas.

Evaluation of Materials in Northeast Texas

In 1996, the SCSC assisted a task force that included TxDOT and industry officials from northeast Texas. The task force was charged with determining the cause of poor asphalt pavement performance in the Atlanta and Tyler Districts of TxDOT. The poor performance was manifested in a variety of ways, but there was general agreement that the primary cause was moisture damage. TxDOT officials believed that a local gravel source, which began to be used at approximately the same time as the moisture damage began to be detected, was a causative factor. As a result, TxDOT prohibited the use of the local gravels. The SCSC was asked to serve as a materials evaluation resource for the task force.

Because Superpave utilizes a stripping test that was already in common use in Texas, that feature of the Superpave system did not offer promise in terms of evaluating the northeast Texas materials. However, other Superpave mixture requirements (SGC densification requirements, consensus aggregate requirements, etc.) needed to be investigated to determine whether the troublesome mixtures would have been identified.

The TxDOT Atlanta District provided typical materials, including the local coarse gravel aggregates and three natural sands. The SCSC reproduced some of the poor-performing mixtures and evaluated the mixtures and component materials using the Superpave system. This experiment showed that the gravel/sand mixtures failed the Superpave densification criterion at an initial number of gyrations. Several of the gravel/sand mixtures failed the Superpave sand equivalent requirement for moderate- or high-trafficked pavements. The SCSC experiment identified two of the three natural sands as being inappropriate for use on moderately or highly trafficked pavements.

An additional experiment was conducted to determine whether substituting a higher-quality fine aggregate would provide better Superpave mix design properties. The SCSC laboratory standard manufactured sand and natural sand were employed for this purpose. This study indicated that it was possible to use the local gravel aggregates with a reasonable expectation of performance by using a limestone-manufactured sand similar to the SCSC standard. McGennis (Ref 11) presents a more thorough explanation of the northeast Texas materials evaluation.

Superpave Mix Designs

For the first 2 years of SCSC activity there was a general lack of Superpave mix design expertise, which is normal when implementing new technology. Thus, one of the early functions of the Center was to provide mix designs for requesting agencies. Table 13 presents the mix designs carried at SCSC for different projects.

Table 13. Projects with Superpave Mix Design at SCSC

Highway	Year of Design
US 59, Livingston, TX	1995
IH 10, Baton Rouge, LA	1996
US 79, Tylor, TX	1997
Eckert Rd, San Antonio, TX	1997
Loop 396, Waco, TX	1997

Compactor Comparison Experiments

One of the major missions of the SCSC, as directed by the management committee, was to "evaluate and improve Superpave products through applied research." This mission was manifested in many ways, for example, in the ruggedness experiments involving the Superpave gyratory compactor and Superpave shear tester. A similar and equally significant activity was the evaluation of new Superpave gyratory compactors.

The FHWA developed a standard protocol for the systematic evaluation of new SGCs. This protocol was reviewed by the FHWA Superpave Mixtures Expert Task Group (ETG) and changes were made based on this review. This protocol has now been standardized as AASHTO PP35-98, "Standard Practice for Evaluation of Superpave Gyratory Compactors (SGCs)." The SCSC utilized this protocol to evaluate six new SGCs:

- Interlaken,
- Test Quip,
- Pine Model AFG1A,
- Troxler Model 4141,
- Rainhart, and
- Updated Interlaken.

The AASHTO protocol involved testing four Superpave mixes (12.5 mm, 19 mm fine, 19 mm coarse, and 25 mm) in a highly controlled experiment. Two of the mixes (12.5 and 25 mm) utilized SCSC laboratory standard materials. The other two mixes (19 mm coarse and fine) involved using materials from the Texas US 79 project for which the SCSC conducted the mix design. Six specimens of each mix were compacted in a candidate compactor and a referee unit. The referee units were either the Troxler Model 4140 or Pine Model AFGC125X. Thus, the experiment involved compacting a total of forty-eight specimens (4 mixes × 2 compactors × 6 replicates). Specimens were individually batched and stored in plastic bags prior to use. As required by the protocol, the four mixes were designed according to AASHTO PP28 and met all the Superpave requirements.

Data were analyzed as required by AASHTO PP35. The response variable used for comparison was the bulk specific gravity of the test specimens at an initial, a design, and a maximum number of gyrations. Thus, for a given comparison experiment, there were a total of twelve comparisons (4 mixes × 3 levels of gyrations). For the two compactors to be considered comparable, the difference in their average bulk specific gravities needed to be less than 0.010. Table 14 summarizes the results in terms of comparability for the six compactor comparison experiments.

Table 14. Summary of SGC Comparability

Compactor		
Candidate	Referee	Comparability
Interlaken	Pine Model AFGC125X	9/12
Test Quip	Pine Model AFGC125X	11/12
Pine Model AFG1A	Pine Model AFGC125X	11/12
Troxler Model 4141	Troxler Model 4140	12/12
Rainhart	Pine Model AFGC125X	12/12
Updated Interlaken	Pine Model AFGC125X	12/12

The detailed results of the compaction comparisons can be found in Research Report 1250-3 (Ref 12).

SUMMARY AND CONCLUSIONS

Like the other Superpave Centers, the SCSC represented a new and innovative approach to implementing new technology. It effectively began in June 1995 and operated out of the transportation materials laboratory at The University of Texas at Austin. In 1996, the Center developed an entirely new research and training facility at an off-campus location. Its host agency was TxDOT and a uniquely strong partnership developed among the SCSC and the Bituminous and Asphalt Sections of TxDOT. Cooperating partners included the state highway agencies in Arizona, New Mexico, Oklahoma, Arkansas, and Louisiana; the FHWA; and the Texas Hot Mix Asphalt Pavement Association. The SCSC largely realized its role as a center of expertise to facilitate the implementation of Superpave.

Specialized Superpave training was a major activity of the Center. By November 1998, Center staff had organized and provided such training to 2,000 individuals representing all facets of the asphalt materials community. Included in these efforts were numerous on-site mix design training for the state highway agencies of Arizona, New Mexico, Louisiana, Texas, Wyoming, and Illinois. Approximately 1,000 more individuals were reached through miscellaneous symposia.

In addition to organized training, the SCSC transmitted Superpave technology through its presence on the Internet. The SCSC Web site was a very successful endeavor. The Superpave-related e-mail group had more than 300 subscribers.

The fact that SCSC was organized through The University of Texas at Austin necessitated that the Center support graduate students. Through this activity, five master's degree students and one doctoral student were supported. Two of the students awarded master's degrees were employees of TxDOT who conducted thesis research on topics pertaining to Superpave.

Applied research was also a function of the Center. This activity was dominated by evaluation of new test equipment and procedures that are part of the Superpave system. SCSC efforts led directly to an increase in the availability and suitability of new models of SGCs through standardized compactor comparison experiments. In addition, SCSC efforts in cooperation with other organizations allowed the gyratory compaction protocol to be updated and improved. Through research sponsored by the FHWA, the SCSC was able to make use of the Superpave shear tester to evaluate the sensitivity of engineering properties to number of gyrations. In combination with the NCHRP 9-9 project, this experiment led to a vastly improved N-design table, which is an important feature in Superpave mix design.

While the Center largely accomplished its intended purpose, one factor that impeded the Center's support was the fact that it was not affiliated with one of the five asphalt user producer groups (UPGs). The SCSC's cooperating state highway agencies were members of the Pacific Coast UPG (Arizona), the Rocky Mountain Asphalt UPG (New Mexico), the North Central UPG (Oklahoma), and the Southeast User Producer Group (Arkansas, Louisiana, and Texas). Consequently, there was no central forum for the SCSC to use for management committee meetings, activity updates, etc. Through their UPG activity, SCSC cooperating partners were often placed in the confusing role of supporting other centers because of their UPG affiliations.

The SCSC was well financed over its period of operation. This fiscal security clearly enabled the SCSC to achieve its intended purpose without having to pursue funding from outside contract research efforts. Most of the SCSC's funding came, not from a wide range of cooperating partners, but rather from TxDOT and, to a lesser extent, from the FHWA. Through August 1999, TxDOT had provided funding of almost $1.6 million, with another $325,000 provided by FHWA. The state highway agencies in Arkansas and Oklahoma also provided $50,000, although only $20,000 of these funds was directly accessible to the Center (the remaining $30,000 was held to fund travel costs of state personnel). In effect, TxDOT and the FHWA built the "team" that made up the Center; through this effort, a wide array of organizations and individuals benefited from the resources of the SCSC.

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