SUPERPAVE Adoption by State Highway Agencies: Implementation Status, Assessment and Benefits

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**16. Abstract**

Asphalt concrete pavements have been failing prematurely throughout the nation. The premature failure can mainly be attributed to an increase in traffic loads and adverse environmental factors. The failure reduces pavement smoothness and requires frequent maintenance and rehabilitation. To overcome premature failure problems and improve the nation’s highways, a five year 150 million dollar Strategic Highway Research Program was initiated in 1987. A major component of this research was a 50 million dollar asphalt program that led to the development of Superpave.

At the end of Strategic Highway Research Program, the Federal Highway Administration assumed responsibility for further development and validation of Superpave systems. It also initiated a national program to encourage the adoption of the system by all state highway agencies. The American Association of State Highway and Transportation Officials Task Force on Strategic Highway Research Program implementation developed the concept of Lead States for uniform implementation of Superpave. Although initial implementation progress and state highway agency needs were documented by the Lead States, the implementation status and needs beyond 2000 are not identified. This information is essential for future implementation planning and allocation of resources. The gathered information can also be used to demonstrate the major benefits of the new Superpave system and current costs of Superpave mix in comparison of conventional mixes. A review of existing literature and survey of state highway agencies was performed to identify the implementation status. The gathered information and conclusions are presented in this report.

**17. KEY WORDS**

Superpave, Implementation, Asphalt, Binder, Mix Design, PG Grade, SHRP

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SUPERPAVE Adoption by State Highway Agencies: Implementation Status, Assessment and Benefits

Of the approximately $110 billion spent each year on our nation’s highways, about $15 billion is spent on hot mix asphalt concrete \(^1\). Despite this large expenditure on asphalt concrete, coupled with the fact that more than 90% of our paved highways are surfaced with this material, relatively little is spent on asphalt research and development \(^2\). The result is that asphalt concrete pavements have been failing prematurely throughout the nation. To improve performance of asphalt concrete pavements, the Strategic Transportation Research Study in 1984 identified asphalt concrete as one of the six-priority areas for research and development \(^3\). As a result, asphalt concrete became one of the key areas in the Strategic Highway Research Program (SHRP) established by Congress in 1987. A major product of the SHRP research is the development of the Superior Performing Asphalt Pavements (Superpave) system for the comprehensive design of asphalt concrete pavements \(^4\). The objective of the Superpave mix design system is to design an economical blend of asphalt binder and aggregate, which results in a paving mixture having sufficient workability, and satisfactory performance characteristics over service life of the pavement \(^4\).

To successfully implement Superpave, various organizations pooled in their resources together, and the Federal Highway Administration (FHWA) took the lead to implement Superpave at the national level. To achieve this objective, various activities were identified, committees were formed and centers were created \(^7,\ 4\). Although initial implementation progress and state highway agency needs were documented by the New York Department of Transportation \(^5\), the implementation status and needs beyond 2000 are not identified. This information is essential for future implementation planning and allocation of resources. One of the major selling points of Superpave is that it improves the performance of asphalt pavements. However, there are additional benefits of Superpave implementation that have not been documented. In addition, the initial Superpave mix cost was higher than conventional mixes. The cost of Superpave mixes has, however, dropped over the years and the current cost comparison is not documented. Therefore, FHWA sponsored this study to document implementation status, to assess current needs of state highway agencies, to identify cost of Superpave mixes in comparison with conventional mixes, and to identify direct and indirect benefits of the Superpave implementation.

To achieve the objectives of this study, an extensive literature review was performed and various organizations (state highway agencies, Superpave centers, and User Producer Groups) were contacted. Based on the literature review and discussions with these organizations, questionnaires were prepared and sent to state highway agencies (SHAs), User Producer groups (UPGs), Superpave centers (SCs), and hot mix asphalt contractors. The literature review information and the survey results are presented in this report. First, the Superpave implementation status is presented and then the needs are discussed. In the end, the cost comparison and benefits of Superpave implementation are discussed.
Superpave Implementation Status

Although numerous products were developed under SHRP, several of the developed products needed further research before they could be implemented. The main asphalt concrete products/recommendations selected for implementation are: performance-based asphalt binder specifications, aggregate consensus properties, and Superpave mix design system.

Performance Grade Asphalt Binder Specifications

Existing grading systems specified a set of test temperatures regardless of the temperature a particular pavement will experience. In addition, measured test properties were either empirical or empirically related to performance. To eliminate deficiencies in the existing asphalt binder grading systems, new test equipments and performance grade (PG) asphalt binder specifications were developed. The PG specifications suggested testing of asphalt at a temperature that will be experienced by the pavements and measured properties that can be mechanistically correlated to performance. The PG specifications have almost been adopted by all the SHAs as shown in Figure 1. The full implementation has been accomplished by 47 states and District of Columbia. Two states, Nevada and Massachusetts, have started implementing PG specifications by specifying them in new projects. California does not have any plans to switch to PG specifications in the near future because they already have Performance Based Asphalts (PBA) specifications in place.

![Figure 1 - Asphalt Binder Implementation Status](image)

In general, SHAs are satisfied with the PG specifications and some states have even subdivided the state in different binder groups. For instance, Washington DOT sponsored a research project that established three binder groups based on temperature data. Nevada DOT decided to subdivide the state in the north and south. Additionally, local agencies have also started specifying PG specifications in new projects.

Aggregate

Aggregate is one of the major components of the mix design and a poor or marginal aggregate may significantly reduce the service life of the pavement. However, hauling cost of aggregates from sources farther away from construction sites prohibits implementation of national level aggregate specifications. In addition, SHAs' have already developed and implemented specifications to eliminate poor and marginal aggregates being used in pavements. Therefore, a list of consensus aggregate tests was developed that can further improve the performance of mixes. The consensus aggregate tests are: fine aggregate angularity (FAA), coarse aggregate angularity (CAA), flat and elongated (F&E) particles, clay content, and new gradation parameters. The objective of FAA and CAA is to limit the usage of round and fine materials in
the mix and increase the requirements for crushed aggregate faces for better internal friction. The F&E requirement limits the usage of aggregate that can easily be broken during compaction process. The amount of clay content limits the amount of deleterious material present in the mix. The gradation parameters restrict usage of fine mixes and will be discussed in the mix design section.

A discussion with various SHAs indicated that consensus properties are a good tool to reduce or eliminate poor or marginal performing aggregates. The results of the discussion are shown in Figure 2 and are based on responses of 39 state highway agencies. Twenty-three states have implemented the requirements and six of them have modified the requirements to allow usage of local aggregate sources. Only ten SHAs have not specified the consensus aggregate properties. However, this does not mean that these SHAs are not interested in implementing them. Seven out of ten SHAs performed a preliminary investigation and identified that their existing specifications satisfy the consensus aggregate properties. Therefore, it can be stated that thirty states have specified the consensus aggregate properties. Additionally, some SHAs have specified usage of rut testing machines (like APA or HWTD) to reduce or minimize the rutting potential of mixes consisting of aggregates not meeting consensus aggregate properties.

### Superpave Mix Design

The Superpave mix design system is based on the volumetric proportioning of asphalt binder and aggregate materials, and laboratory compaction of trial mixes using the Superpave gyratory compactor (SGC). At the end of SHRP, three levels of mixture design were identified: Level 1, Level 2, and Level 3 based on traffic loads (Equivalent Single Axle Loads). However, this terminology has been changed and now Level 1 is considered to be the Superpave volumetric mix design procedure, while Level 2 and 3 are considered to be mix analysis tools rather than mix design procedures. In the Superpave volumetric mix design, specimens are prepared using SGC and the following volumetric properties need to be specified: gradation parameters, number of gyrations ($N_{\text{ini}}$, $N_{\text{design}}$, and $N_{\text{max}}$), air voids levels associated with $N_{\text{ini}}$, $N_{\text{design}}$, and $N_{\text{max}}$, voids in mineral aggregates, and voids filled with asphalt binder. The number of gyrations ($N$) depends on the pavement service temperature and traffic load, while gradation parameters depend on the size of the aggregate used.

Superpave volumetric mix design has not been as widely accepted as PG specifications. There are three schools of thought on this issue. One school of thought is that we have previous experience with well performing conventional mixes; therefore, there is no need to change to a new design system. The second school of thought believes in letting other states implement the Superpave system, identify all the problems associated with the new mixes, and find solutions to those problems. These states will implement the Superpave mix design system
when all the bugs have been removed. The third school of thought believes that it is a good design system and it should be implemented.

Surveys conducted in this study, by NYS DOT (5) and FHWA Division office identified implementation status of the Superpave mix design and are summarized in Figure 3. The results suggest that only four states are not sure when Superpave will be implemented. Thirteen states indicated that the Superpave mix design is in the implementation stages and will be implemented at slow rate. The remaining states have implemented the Superpave mix design.

In general, it can be stated that most of the SHAs have implemented Superpave volumetric mix design and the remaining states are making slow and steady progress towards it. Alaska, Hawaii, and Wyoming have either started smaller projects or have asked for Superpave bids and hope to fully implement Superpave mix designs in all of their constructions by 2004. Texas has implemented Superpave mix design for high volume roads; however, it has no intention of becoming 100% Superpave state in the near future. The four states with minimal or no implementation plans are Rhode Island, Idaho, Nevada, and California. Rhode Island and Idaho are skeptical about Superpave, however, have placed a couple of Superpave mixes in summer 2002. Both states are waiting for fine-tuning of Superpave mix design before fully implementing it in their states. Apparently, in both states local agencies attempted to place Superpave mixes and damaged base layer and drainage pipes due to over compaction. To achieve specified densities, the contractor made too many roller passes and damaged the base layer or the drainage pipes. Nevada had performed some preliminary evaluations and decided not to implement until all the questions have been answered. California is the only state with no implementation plans.

Based on the literature search and survey results, it was identified that the number of Superpave projects has been consistently increasing over the years (Figure 4). The number of

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Figure 4 - Number of Superpave Projects Awarded
Superpave projects awarded has increased from 95 projects in 1996 to 4726 projects in 2001. In addition, the percentage of Superpave projects has also increased in comparison to conventional projects. The survey results indicate that more than 60% of awarded projects will be Superpave in 2002 (Figure 5).

The assessment of 100% Superpave mix design implementation is a difficult task because of the following reasons:

- Some states have decided to use Superpave mixes for high volume roads and are performing research or have decided not to use it for low or medium volume roads.
- Some states have selected portions of Superpave mix design and are using them but have not yet made up their mind for full implementation.
- Some states have not set up any specific target date but are implementing it at a slower rate than previously anticipated.
- Some states do allow contractors to come up with the design based on specified criteria and the contractor has a choice of using conventional or Superpave mix design.
- Some states specify Superpave for surface course but do allow contractors to use conventional mix for base courses.

The discussion suggests that most SHAs are willing and have implemented Superpave and remaining states have a conservative approach towards implementation. Therefore, 100% implementation of Superpave mix design is a growing system.

**Superpave Concerns**

Although most of the states have implemented Superpave mix design, concerns with Superpave mixes are abundant and do vary from state to state. Based on discussions with SHAs and Superpave centers, a list of common concerns was developed in a questionnaire form and was sent out to quantify the concerns. A target group of 84 agencies was identified for this survey. The target group included 52 state highway agencies (including District of Columbia, and Puerto Rico). The survey was also sent to 5 User Producer groups (UPGs), 5 Superpave centers (SCs), and 22 hot mix asphalt contractors. The questionnaire was divided in three components: asphalt binder, aggregates, and asphalt concrete mixture. In addition, the numbers of questions in the questionnaire were different for different agencies to make sure that the questions asked are relevant to the surveyed agency. All of the Superpave centers and 47 SHAs out of 52 responded to the questionnaire. Only 8 contractors and 2 UPGs responded to the survey. Overall response to the survey was extremely good because more than 70% of
the target group provided their input. The survey data was stored and analyzed in an Excel sheet and the results of the analysis are discussed in the following paragraphs.

Although SHAs are satisfied and have implemented PG binder specifications, many states do have a problem with modified binders. To satisfy temperature, loading, and reliability requirements of PG specifications, SHAs specify PG grades that can only be produced by adding modifiers to the asphalt binder. Based on the experience, SHAs have identified that some modifiers work better than others. However, all of them pass the PG specifications tests. SHAs believe that PG grade is transparent to modifiers and needs to have new specifications for the asphalt consisting of modifiers.

According to the survey, 18 highway agencies, 1 UPG and 2 SCs indicated (Figure 6) that current PG specifications are adequate for specifying asphalt binder consisting of modifiers. The remaining state highway agencies (39) either specify a specific modifier (17) or additional tests (23) or both to eliminate poor performing modifiers. In addition, 4 SCs indicated that PG specifications are not applicable for modified binders. Discussions with some of the SHAs identified that PG grade specifications work well for asphalt binder consisting of smaller quantities of modifiers. However, PG specifications are not able to discriminate between well and poor performing modifiers when behavior of asphalt binder is dominated by modifier (i.e., usage of large quantity of modifiers). This discussion suggests that PG specifications for modified asphalt binder need to be developed. A study conducted by Brown et al. (9) also identified that there is a need for new modified binder specifications.

Another concern raised by the SHAs was the gradation control points. The main concern with gradation limits and control points now is that it allows design of coarse mixes. The coarse mix design allows placement of mixes that are highly open. An open mix allows more water to infiltrate and reduces the durability of Superpave mixes in the long run.

The survey results suggest that 23 SHAs, 1 SC, and 2 UPGs indicated that there is no need to modify control points (Figure 7). On the other hand, 8 SHAs and 3 SCs indicated that requirements should be modified while 16 SHAs
and 1 SC indicated that it may need to be modified. The combination of “yes” and “may be” makes a total of 28 respondents (24 SHAs and 4 SCs) interested in further evaluation of Superpave gradation control points.

Another concern raised was the voids in mineral aggregates (VMA) requirements of Superpave design. Some SHAs indicated that higher VMA requirements produce open mixes and reduces the durability of Superpave mixes. In addition, few SHAs indicated that VMA requirements should be different for coarse and fine graded mixes.

According to the survey, more than 60% of the respondents (Figure 8) indicated that the requirements are adequate while 31% of the respondents indicated that either they are low (13%) or high (18%). 7% of respondents did not have enough experience to suggest either way. The results suggest that majority of agencies feel that VMA requirements are adequate for producing and placing good quality Superpave mixes.

The discussion and literature review suggested that Superpave mixes have less asphalt content due to the higher design number of gyrations. SHAs’ experience suggests that higher number of gyrations in conjunction with open gradation parameters allow design of lower asphalt content mixes. The lowered asphalt content reduces the durability of mixes. In the survey, both questions were asked separately and the results are summarized in the following paragraphs.

According to the survey, more than 50% of the respondents (Figure 9) indicated that Superpave mixes can be adequately compacted in the laboratory and no major impact of N_{des} on the quality of mix could be identified. However, 44% of the respondents indicated that N_{des} requirements are either too low (11%) or too high (33%) and quality of mix is significantly affected by them. Only 4% of the respondents indicated that they did not have enough experience to suggest either way. The discussion with some of the highway agencies identified that few of the agencies have already modified the Superpave compaction table while others feel comfortable with it.

In response to the question of asphalt content of Superpave mixes, 31 SHAs, 2 contractors, 2 UPGs, and 2 SCs indicated that Superpave mixes have lower asphalt content than conventional mixes (Figure 10). Meanwhile, 11 SHAs, 6 contractors and 2 SCs indicated that asphalt content is adequate in the Superpave mixes while 5 SHAs were not sure about it.
Some SHAs have already solved the problem of less asphalt content by reducing number of gyrations and/or by specifying minimum asphalt content or film thickness.

Another common concern expressed by SHAs is the openness of Superpave mixes. An open mix reduces the durability of Superpave mixes because it allows water to infiltration and provides air for binder oxidation.

According to the survey, 20 SHAs, 3 contractors, 3 SCs, and 1 UPG indicated that Superpave mixes are not necessarily open in comparison to conventional mixes. Meanwhile, 14 SHAs, 4 contractors, and 2 SCs indicated that Superpave mixes are more open (Figure 11). 13 SHAs, 1 contractor and 1 UPG were not sure either way. Response of contractors and Superpave centers is pretty much split on this issue.

Since gradation control points, VMA requirements, and N_{des} influence the openness of mixes, the results of the survey suggest that they should be further evaluated.

The discussion with SHAs suggested that Superpave mix design may not be for low or medium volume roads. Therefore, a question was asked about the adequacy of Superpave mixes for low and medium volume roads. According to the survey, 41 SHAs, 4 SCs, and 2 UPGs suggested that Superpave mixes are for all types of roads. On the other hand, 2 SHAs indicated that Superpave is for higher volume roads only (Figure 12) while 4 SHAs were not sure about it. The results clearly indicate that majority of agencies believe Superpave is for all volume roads.

Abundant construction issues have propped up after implementation of Superpave. One of the major issues has been that contractors and SHAs did not have training or experience to place good
quality Superpave mixes. In addition, it should be recognized that issues related to construction might have been more visible because of the fact that new equipments are available to identify the problems and everybody is using similar mixes. Better Roads (7) published results of the survey conducted to get contractor viewpoints of Superpave. In response to the question of difficulty to work with the Superpave, more than 83% felt that it was difficult to work with.

According to the survey of this study, 44% of the respondents have either solved the compaction problem or never had compaction problem with Superpave mixes (Figure 13). On the other hand, 36% of the respondents indicated that the compaction is still a problem; however, they rated the difficulty of compaction as moderate while 3% agencies rated level of difficulty as low. Only 5% of the respondents had high levels of difficulty in achieving compactions.

In response to the question of regional training, 21 SHAs, 7 contractors, 3 SCs, and 1 UPG indicated that there is a need for regional level training. On the other hand, 13 SHAs indicated that regional level training is not needed while 13 SHAs were not sure about it (Figure 14).

The results of the survey indicate that compaction is still an issue and more regional training is needed for better implementation of Superpave. This step is essential because poorly placed Superpave mixes will have a lower life cycle, and the benefits of research would not be fully reaped.

Although most of the SHAs agree that Superpave mixes are less prone to rutting in comparison to conventional mixes, SHAs still feel that accelerated rut test equipment and specifications are required. This requirement is essential for the southern states because they experience higher levels of rutting. Some agencies have started using Asphalt Pavement Analyzer (APA) or Hamburg Wheel Tracking Device (HWTD) to identify rutting potential of the mix. However, the usage and specifications of APA or HWTD do vary from state to state. In addition, some states require that mix pass the specified rut criteria while other states only require passing rut criteria if mix gradation passes through the restricted zone.
According to the survey, more than two thirds of the respondents indicated that there is a need for rut test equipment and specifications (Figure 15). On the other hand, 6 SHAs and 1 UPG indicated that there is no need for accelerated rut testing equipment. Meanwhile, 9 SHAs, 1 UPG, and 1 SC were not sure about it.

In general, SHAs feel that accelerated rut test specifications and equipment are needed because APA or HWTD simulates field conditions. Also, tests can be conducted in relatively shorter time frame.

Based on the discussions with SHAs, a list of common missing components was developed and included in the survey. The objective of this exercise was to identify what components could be added in the mix design to accelerate the implementation of Superpave.

According to the survey, 38% of the respondents indicated that a performance test is missing while 28% identified that a moisture susceptibility test is needed (Figure 16). 20% of the respondents indicated that PG specifications for modified binder should be developed and 9% of the respondents indicated that specifications for Reclaimed Asphalt Pavement (RAP) are needed. NCHRP has already sponsored projects for the development of a SPT and moisture susceptibility test. Therefore, the discussion indicates that a PG specification for modified asphalts is the main concern.

Cost/Benefit of Superpave Implementation

In general, it is extremely difficult to perform cost/benefit analysis of highway infrastructure because of the amount of material used and the exposure to the uncontrolled environment. An added difficulty with Superpave projects is the fact that they have not been placed long enough to compare their performance with conventional Marshall or Hveem mix. An attempt is made in this study to document the current cost of Superpave mixes and the benefits of Superpave. In the end, the cost/benefit analysis performed by Texas Transportation Institute (TTI) and University of Reno, Nevada is presented.
Cost

With the exception of Ohio and New York DOTs, none of the SHAs have documented and compared the cost of Superpave mixes with the conventional mixes. The main reason cited for not documenting is the fluctuation of binder prices. Ohio DOT developed a data base system to document the cost and performance of the Superpave projects. A study published by Abdulshafi and Kedzierski (8) suggested that cost of Superpave projects was 12 to 30% higher than conventional Marshall mixes. However, it should be noted that the data comes from projects built in 1996, during the initial years of Superpave implementation.

NYSDOT began Superpave implementation in 1996 and documented the cost of Superpave projects (9) in 1998. The study indicated that prices of Superpave projects were 5% higher in comparison to conventional mixes. For example, PG 58-28 binder was $32.65 per ton while for AC 20 Marshall mix was $31.10 per ton, a difference of only 5%. The study also suggested that price of Superpave mixes is higher for mixes consisting of higher-grade spread (between high and low temperatures) binders.

In August 2001, Utah DOT published a Position Statement on Superpave and identified that the cost of modified PG binder ranged from about 10 to 15% more than the neat asphalts (unmodified). Their best estimate places the increased cost per ton of HMA as high as 10% during the first year or so. Currently, the cost of Superpave mixes is 2 to 4% higher than conventional mixes. This happened after the materials testing labs purchased the required new equipment and the contractors and consultants labs gained some experience working with Superpave mixes.

Annual Superpave Implementation and Needs Assessment report published by NYSDOT (5) suggested that the average price per ton of conventional mix in 2000 was $36.04 per ton and $37.03 per ton for Superpave (a less than a dollar per ton difference). The report also suggested that on an average the cost for a ton of Superpave mixes is 3% higher in comparison to conventional mix.

The above discussion indicates that the cost of Superpave mixes is not significantly higher than the conventional mixes and has dropped with the increase of Superpave projects being built. The discussion also indicates that the prices will be higher when the higher-grade spread is specified because of higher percentage of the costly modifier.

Benefits

One of the reasons for Superpave implementation is the fact that Superpave mixes improve the performance of asphalt concrete pavements. However, Superpave mix design system offers additional benefits. Based on discussion with SHAs, a list of direct and indirect benefits was prepared and opinions of surveyed agencies were sought. The results of the survey are discussed in the following paragraphs.

-11-
SHAs were given seven choices to identify the major benefits of Superpave and the results are shown in Figure 17. Approximately 39% of the respondents indicated that binder and mix tests are accurate in comparison to conventional tests. 23% of the respondents indicated that performance has increased with the usage of Superpave and 10% indicated that new design system increased the life of pavements; therefore, reduced the life cycle cost. About 9% indicated that Superpave allowed them access to resources while 8% indicated that field testing can be performed quickly using Superpave tests.

In response to the question of indirect benefits, knowledge sharing came out to be the most valuable indirect benefit of Superpave. Approximately, one third of the respondents indicated that the knowledge sharing (Figure 18) is very helpful in successfully implementing Superpave and learning from each other’s mistake. The second major benefit is the faster transfer of technology for which 21% of the respondents indicated that new technology is implemented faster in comparison to the previous technologies. The next indirect benefit came to be better communications between local, state and federal agencies (19%). Another outcome is the availability of accurate tools for quality control and quality assurance of the placed material (19%). The last benefit identified is the optimized usage of resources (8%).

Cost/Benefit Analysis

An extensive review revealed that a national level study was conducted by the University of Reno, Nevada, and Texas Transportation Institute (TTI) (1) to identify economic benefits of Superpave implementation. To predict the potential savings, nine criteria were established; however, only a few of them are discussed here for the sake of brevity. For in-depth review of the criteria, authors are encouraged to read reference (1). A 40-year life-cycle cost, a 5% discount rate, and an annual traffic growth rate of 2.1% was used in this study. The study assumed a 6.7% increase in cost of Superpave projects in comparison to conventional mixes.
This included the cost of implementation, which consisted of the equipment and personal training. The study also included benefits derived from reductions in vehicle operating costs because of smoother pavements, reductions in costs associated with fewer overlays and repairs needed during life of the pavement. The study was performed for three levels of implementation: slow (100% after 10 years), moderate (100% after 5 years), and fast (100% within a year). Based on these criteria, TTI performed analyses and the results are presented in Table 1 (reproduced from Report No. FHWA-SA-98-012).

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Based on an estimated 20-year research, development, and implementation cost of $230 million

* Totals may not add up because of rounding.

The Cost-Benefit ratios mean that for each dollar spent on research, development, and implementation, the public highway agencies can expect a return of $26 at a slow implementation rate, $34 at a moderate implementation rate and $43 at a fast implementation rate. Since the fast and moderate implementation rates have not been achieved, the savings expected could be 22.5 billion dollars.

Although an attempt for the cost/benefit analysis was made in the study conducted by TTI, many of the assumptions may not be valid in the field. A study conducted by Noureldin indicated that the overall pavement performance life might be significantly affected when the specified asphalt content, aggregate gradation, and degree of compaction are not achieved in the field. In addition, the study does not account for a less than 100% implementation. However, it was identified in this study that not all SHAs are going for 100% Superpave implementation.

Ohio DOT and the Rocky Mountain Asphalt User-Producer Group (RMAUPG) are maintaining a database of Superpave projects and could be used to perform an analysis to identify benefits of Superpave based on procedures suggested by Epps and Noureldin. NCAT is also planning to perform cost benefit analysis of Superpave projects in near future.
Conclusions

Based on the information presented, it can be concluded that Superpave binder and aggregate selection implementation efforts have been extremely successful. More than 85% of states have implemented PG grade specifications and more than 75% of the states have adopted consensus aggregate properties. The implementation of Superpave mix design has been achieved with mixed success. In general, most of the states have either implemented or are in the process of implementation. However, the goal of 100% Superpave mix design will take longer than anticipated.

The results of the survey identified that SHAs are overall satisfied with Superpave; however, feel that more research is needed to resolve concerns like gradation control points, openness of mixes, asphalt content, and Nadj. In addition, most of the agencies feel that specifications for modified asphalt binder are essential for eliminating poor performing modifiers. The study also suggests that there is a need for rut test equipment and specifications.

The initial cost of Superpave mixes was higher than conventional mixes. The cost has come down considerably and right now Superpave mixes cost is approximately 3% higher than conventional mixes. The study also identified direct and indirect benefits of Superpave implementation. The major direct benefit turned out to be the accuracy of binder and asphalt concrete tests while knowledge sharing turned out to be the major indirect benefit.

A future study is needed to identify implementation status of Superpave. However, the scope of the study should be modified to include the evaluation of Superpave projects that have been in service for more than five years. The data collected by various highway agencies and User-Producer groups should be gathered and a cost benefit analysis proposed by Epps (1) and Noureldin (10) should be performed.

References


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SUPERPAVE Practices: Adoption, Issues and Benefits

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### SUPERPAVE Practices: Adoption, Issues and Benefits

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**Abstract:**
Asphalt concrete pavements have been failing prematurely throughout the nation. The premature failure can mainly be attributed to an increase in traffic loads and adverse environmental factors. The failure reduces pavement smoothness and requires frequent maintenance and rehabilitation. To overcome premature failure problems and improve the nation’s highways, a five year 150 million dollar Strategic Highway Research Program was initiated in 1987. A major component of this research was a 50 million dollar asphalt program that led to the development of Superpave.

At the end of Strategic Highway Research Program, the Federal Highway Administration assumed responsibility for further development and validation of Superpave systems. It also initiated a national program to encourage the adoption of the system by all state highway agencies. The American Association of State Highway and Transportation Officials Task Force on Strategic Highway Research Program implementation developed the concept of Lead States for uniform implementation of Superpave. Although initial implementation progress and state highway agency needs were documented by the Lead States, the implementation status and needs beyond 2000 are not identified. This information is essential for future implementation planning and allocation of resources. The gathered information can also be used to demonstrate the major benefits of the new Superpave system and current costs of Superpave mix in comparison of conventional mixes. To identify Superpave implementation status, benefits and concerns, a review of existing literature was performed and state highway agencies were contacted. Based on the gathered information, a survey was developed and state highway agencies, Superpave centers, User Producer groups, and hot mix asphalt contractors were surveyed. The literature review information and results of the survey along with conclusions are presented in this report.

**Key Words:** Superpave, Implementation, Asphalt, Binder, Mix Design, PG Grade, SHRP

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Abstract

Asphalt concrete pavements have been failing prematurely throughout the nation. The premature failure can mainly be attributed to an increase in traffic loads and adverse environmental factors. The failure reduces pavement smoothness and requires frequent maintenance and rehabilitation. To overcome premature failure problems and improve the nation's highways, a five year 150 million dollar Strategic Highway Research Program was initiated in 1987. A major component of this research was a 50 million dollar asphalt program that led to the development of Superpave.

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To identify Superpave implementation status, benefits and concerns, a review of existing literature was performed and state highway agencies were contacted. Based on the gathered information, a survey was developed and state highway agencies, Superpave centers, User Producer groups, and hot mix asphalt contractors were surveyed. The literature review information and results of the survey along with conclusions are presented in this report.
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Chapter 1
Introduction
Problem Statement

Asphalt concrete pavements have been failing prematurely throughout the nation. The premature failure can mainly be attributed to an increase in traffic loads and adverse environmental factors. The failure reduces pavement smoothness and requires frequent maintenance and rehabilitation. The frequent rehabilitation also increases chances of traffic hazard.

To overcome premature failure problems and improve the nation's highways, a five year 150 million dollar Strategic Highway Research Program (SHRP) was initiated in 1987. A major component of this research was a 50 million dollar asphalt program that led to the development of Superpave. Superpave involves improving performance of flexible pavements through greater understanding of fundamental chemical and physical properties of asphalt binders and mixes.

At the end of SHRP, the Federal Highway Administration (FHWA) assumed responsibility for further development and validation of Superpave systems. It also initiated a national program to encourage the adoption of the system by all State highway agencies. The American Association of State Highway and Transportation Officials (AASHTO) Task Force on SHRP implementation developed the concept of Lead States for uniform implementation of Superpave. The Superpave Lead State Team has done an excellent job of assisting and documenting the Superpave implementation; however, the team was scheduled to sunset in 2000. Further information is needed to provide a current assessment of Superpave implementation and for future implementation planning. The gathered information can also be used to demonstrate the benefits of the new Superpave system.
Study Objectives and Approach

The objective of this study was to identify and document implementation status, issues that need to be resolved, and benefits of the Superpave system. To achieve these objectives, a literature search was performed to assess current state highway agencies (SHAs) practices for the selection of asphalt materials and mix design, in particular related to the adoption and use of the Superpave system. In addition, an attempt was made to contact SHAs, User Producer Groups, Superpave Centers (SCs), and asphalt contractors to determine current Superpave implementation status and future planned activities. Based on information gathered, questionnaires were prepared and sent to identified agencies. The gathered information is presented in the next chapter. Results of the survey are reported in Chapter Three. Conclusions and recommendations for future research are included in Chapter Four.
Chapter 2

Literature Review and Information Gathered

Of the approximately $110 billion spent each year on our nation’s highways, about $15 billion is spent on hot mix asphalt concrete (5). Despite this large expenditure on asphalt concrete, coupled with the fact that more than 90% of our paved highways are surfaced with this material, little is spent on asphalt research and development (6). The result is that asphalt concrete pavements have been failing prematurely throughout the nation. To improve performance of asphalt concrete pavements, the Strategic Transportation Research Study in 1984 identified asphalt as one of six-priority areas for research and development (5). As a result, asphalt became one of the key areas in SHRP established by Congress in 1987. A major product of the SHRP research is the development of the Superior Performing Asphalt Pavements (Superpave) system for the comprehensive design of asphalt concrete pavements (5). The objective of the Superpave mix design system is to design an economical blend of asphalt binder and aggregate, which results in a paving mixture having sufficient workability, and satisfactory performance characteristics over the service life of the pavement (7).

Superpave system consists of four elements: a) performance based specifications for selecting asphalt binder, b) laboratory procedures for optimizing the volumetric mix design system, c) mixture analysis tests, and d) a performance prediction system that includes computer software, a weather database, and environmental and performance model. Although various types of distresses have been documented, the Superpave system primarily addresses six causes of failure: aging, permanent deformation (rutting), fatigue (structural) cracking, low (thermal) temperature cracking, moisture sensitivity, and adhesion failure.

The research is always performed under controlled laboratory environment and on limited factorial basis. To identify problems associated with the newly developed technology and to identify the influence of unaccounted field factors, it is essential that the Superpave mixes be placed on the nation’s highways. The placement of Superpave mixes required new equipment, additional testing and data analyses, and training of contractors as well as state highway agencies. In addition, SHAs and contractors needed encouragement and convincing that Superpave is a good mix design system and will
improve performance of flexible pavements. Therefore, implementation of Superpave became a challenging task and required significant levels of efforts.

**Implementation Efforts**

To successfully implement Superpave, various organizations pooled in the resources together and FHWA took the lead for implementation at the national level. To achieve this objective, various activities were identified, committees were formed and centers were created. Various actions taken for implementation are discussed in the following sections (5, 8).

**Office of Technology Application (OTA)**

FHWA through its OTA formed the following teams/groups:

- **Superpave Technology Delivery Team**: To expedite Superpave implementation efforts and to improve coordination between SHAs
- **Asphalt Technical Working Group**: To provide guidance on ways to encourage the adoption of the Superpave system by the highway industry
- **Binder Expert Task Group**: To provide specialized guidance on the testing and adoption of the Superpave asphalt binder specification
- **Mix Expert Task Group**: To assist Asphalt Technical Working Group on the implementation of Superpave mixes and provide recommendations to the AASHTO subcommittee on Materials to improve the standards
- **Superpave Models/Software Expert Task Group**: To advise on development and distribution of the Superpave software and refinement of the Superpave performance prediction model

**Centers**

Since most of the products were developed at universities which have resources for training, five regional Superpave University centers were formed. The Superpave centers are located at Texas Transportation Institute, Purdue University, Auburn University, University of Nevada at Reno, and Pennsylvania State University. The goals of the Superpave centers are to: a) evaluate Superpave products through applied research, b) be an information resource for management level personnel, c) provide training in Superpave technology, and d) provide testing and technical assistance related to the Superpave system.

**Equipment**

One major implementation hurdle was the cost of equipment needed for the Superpave mix design system. To overcome this problem, SHAs created pooled funds to facilitate acquiring of test equipment for asphalt binder and Superpave gyratory compactor (SGC) for volumetric mix design.
FHWA also developed two mobile asphalt concrete laboratories for demonstration and training of Superpave technology. The mobile asphalt concrete laboratories also allowed access to various constructions sites throughout the nation.

Training

Asphalt Institute (AI) and National Center for Asphalt Technology (NCAT) received a contract from FHWA to offer Superpave training courses and technical assistance to SHAs’ paving contractors, asphalt suppliers, etc.

To further reach out the regional paving community, the asphalt user-producer groups played an important role in terms of developing a well-planned strategy for adopting the Superpave system on regional basis.  

Field Validation

For Superpave validation, various controlled test sites were constructed and these sites are continuously monitored through Long Term Pavement Performance (LTPP) program. In addition, West Track facilities in Nevada, Test track at NCAT, and accelerated loading facility of Turner-Fair Banks Highway Research Center have been performing accelerated testing and collecting Superpave mix performance data. The data from these sites has been utilized in the development of performance prediction models at the University of Arizona.

Lead States

For uniform implementation of Superpave, the AASHTO Task Force on SHRP implementation developed the concept of Lead State for various SHRP technologies, including Superpave. The Lead State teams for Superpave technology with New York serving as a team leader include; Florida, Indiana, Maryland, Texas, and Utah. Each Lead State in turn is available for assistance to their neighboring “partner” states. Their mission was to assist in uniform implementation of the SUPERPAVE system by documenting and sharing experiences, furthering development, and providing guidance related to practical implementation of this technology.

Asphalt User Producer Groups

Asphalt User Producer Groups played an important role in implementation of Superpave at the regional level by encouraging common standardized specifications, binder grade selection, and acceptance plans. The following is the list of regional Asphalt User Producer groups:

a. Northeast Asphalt User Producer Group
b. North Central Asphalt User Producer Group
c. South East Asphalt User Producer Group
d. Rocky Mountain Asphalt User Producer Group (RMAUPG)
e. Pacific Coast User Producer Group
Web Sites

Numerous web sites have been set up by FHWA, TRB, Superpave Centers, AASHTO, and other regional organizations. The purpose of these web sites is to provide easy access to public, private, and academic implementers or decision makers about Superpave.

The implementation process started at the end of the SHRP project and is still continuing. To resolve some of the issues identified during implementation process, National Cooperative Highway Research Program (NCHRP) and SHAs have sponsored new research projects. Also, more research projects are expected in the future.

Superpave Mix Design System Implementation

To identify the impacts of various implementation efforts, a review of literature was performed and various SHAs were preliminarily contacted and the results of the findings are summarized in the following sections.

Performance Grade Asphalt Binder Specifications

One of the major achievements and widely accepted SHRP products is the Performance Grade (PG) specifications of asphalt binder. To eliminate deficiencies in the existing asphalt binder grading system, new test equipments and a grading system were developed. Existing systems specified a set of test temperatures in order to perform testing regardless of the temperature a particular pavement will experience. The PG specifications suggested testing of asphalt at a temperature that will be experienced by the in-service pavements. A discussion on the concept is presented by Jester (7) and is reproduced in the following paragraph.

The selection of PG is based on the average seven-day maximum pavement design temperature and the minimum pavement design temperature. A unique feature of the Superpave specification is that the specified criteria remains constant, but the temperature at which the criteria must be met changes for the various PG grades. An important aspect of the Superpave binder specification is its reliance on testing asphalt binders in conditions that simulate the three critical stages during the binder’s life. Tests performed on the original binder represent the first stage of transport, storage, and handling. Aging of the binder in the rolling thin film oven is used to simulate the effects of mix production and construction on asphalt binder. The pressure-aging vessel, which follows the rolling thin film oven procedure, is used to simulate years of in-service binder aging.

The PG specifications have been adopted by almost all the SHAs as shown in Figure 1. Full implementation has been accomplished by 47 states and District of Columbia. Two states, Nevada and Massachusetts, have started implementing PG specifications by specifying them in new projects. CalTrans specifies Performance Based Asphalts (PBA) and do not have any plans to switch to PG specifications.
In general, it can be a fair statement that PG specifications are in place and have been implemented. SHAs and local agencies are satisfied with the PG specifications and some states have subdivided the state in different binder groups. For instance, Washington DOT sponsored a research project that established three binder groups as shown in Figure 2. Nevada DOT decided to subdivide the state in the North and South. It has identified PG76-22NV for Southern region and PG 64-28NV for Northern region.

Although SHAs are satisfied and have implemented PG specifications, many states do have a problem with modified asphalt binders. To satisfy temperature, loading, and reliability requirements of PG specifications, SHAs specify PG grades that can only be produced by adding modifiers to the asphalt binder. Based on the experience, SHAs have identified that some modifiers work better than others; however, all of them pass the PG specifications tests. SHAs believe that PG specifications are transparent to modifiers and needs to have new specifications for the asphalt consisting of modifiers. To avoid future modifier problems, SHAs either specify a modifier in their bidding process and/or specify additional tests to eliminate problem modifiers.
A survey conducted by FHWA division office identified that more than one-third of the SHAs have adopted a modified version of PG specifications (Figure 3) to eliminate usage of poor modifiers in construction projects.

Figure 2 – Guidelines for PG Use for the State of Washington (9)

Figure 3 – Modified Versus AS-IS PG Grade Specifications Usage by States
The level of modification varies from using AASHTO MP1 table to specifying additional tests. For example, Arkansas and Florida use MP1 table while Nevada specifies to perform ductility, toughness, and tenacity tests in addition to PG specifications tests. On the other hand, New Jersey limits the usage of modifiers to Styrene-butadiene plus an elastic recovery tests. According to a survey conducted by Brown et al. (10), more than 40% of the respondents used modified asphalt binder to satisfy the PG specifications.

The above discussion suggests that PG specifications have been fully implemented (except California) and many states have modified the specifications to account for modifiers used to meet the PG specifications criteria. The discussion also indicates that there is a need for the development of PG specifications for the asphalt binder consisting of modifiers.

Aggregate

Aggregate is one of the major components of the mix design and a poor or marginal aggregate may significantly reduce the service life of the pavement. However, hauling cost of aggregates from sources farther away from construction sites prohibits implementation of national level aggregate specifications. In addition, SHAs have already developed and implemented specifications to eliminate poor and marginal aggregates being used in pavements. Therefore, a list of consensus aggregate tests was developed that can further improve the performance of mixes. The consensus aggregate tests are: fine aggregate angularity (FAA), coarse aggregate angularity (CAA), flat and elongated (F&E) particles, clay content, and new gradation parameters. The objective of FAA and CAA is to limit the usage of round and fine materials in the mix and increase the requirements for crushed aggregate faces for better internal friction. The F&E requirement limits the usage of aggregate that can easily be broken during compaction process. The amount of clay content limits the amount of deleterious material present in the mix. The gradation parameters restrict usage of fine mixes and will be discussed in the mix design section.

A discussion with various SHAs indicated that consensus properties are a good tool to reduce or eliminate poor or marginal performing aggregates. The results of the discussion are shown in Figure 4 and are based on responses of 39 state highway agencies. Twenty-three states have implemented the requirements and six of them have modified the requirements to allow for usage of local aggregate sources. Only ten SHAs have not specified the consensus aggregate properties. However, this does not mean that these SHAs are not interested in implementing them. Seven out of ten SHAs performed a preliminary investigation and identified that their existing specifications satisfy the consensus aggregate properties. Therefore, it can be stated that thirty states have specified the consensus aggregate properties. Additionally, some SHAs have specified usage of rut testing machines (like APA or HWTD) to reduce or minimize the rutting potential of mixes consisting of aggregates not meeting consensus aggregate properties.
Superpave Mix Design

The Superpave mix design system is based on the volumetric proportioning of asphalt binder and aggregate materials, and laboratory compaction of trial mixes using the Superpave gyratory compactor (SGC). At the end of SHRP, three levels of mixture design were identified: Level 1, Level 2, and Level 3 based on traffic loads (Equivalent Single Axel Loads). However, this terminology has been changed and now Level 1 is considered to be the Superpave volumetric mix design procedure while Level 2 and 3 are considered to be mix analysis tools rather than mix design procedures. The scope of this study is limited to the volumetric mix design; therefore, issues associated with mix analysis procedure will not be discussed herein.

In the Superpave volumetric mix design, specimens are prepared using SGC and the following volumetric properties need to be specified: gradation parameters, number of gyrations \( N_{\text{init}}, N_{\text{design}} \) and \( N_{\text{max}} \), air voids levels associated with number of gyrations, voids in mineral aggregates, and voids filled with asphalt binder. The number of gyrations \( N \) depends on the service temperature and traffic load, while gradation parameters depend on the size of the aggregate used.

Superpave volumetric mix design has not been as widely accepted as PG specifications. There are three schools of thought on this issue. One school of thought is that we have previous experience with well performing conventional mixes; therefore, there is no need to change to the new design system. The second school of thought believes in letting other states implement the Superpave system, identify all the problems associated with the new mixes, and find solutions to those problems. These states will implement the Superpave mix design system when all the bugs have been removed. The third school of thought believes that it is a good design system and it should be implemented. Therefore, implementation of Superpave mix design is a growing system. In next paragraphs, an attempt is made to summarize all the information gathered in this study.
Surveys conducted in this study, by NYSDOT, and FHWA division office identified implementation status of the Superpave mixes design and is summarized in Figure 5. The results suggest that four states are not sure when Superpave will be implemented. Thirteen states indicated that the Superpave mix design is in implementation stages and will be implemented at slow rate. The remaining states have implemented the Superpave mix design.

![Superpave Mix Design Implementation Status Map](image)

**Figure 5 – Superpave Mix Design Implementation Status**

In general, it can be stated that most of the SHAs have implemented Superpave volumetric mix design and the remaining states are making slow and steady progress towards it. Alaska, Hawaii, and Wyoming have either started smaller projects or have asked for Superpave bids and hope to fully implement Superpave mix designs in all of their constructions by 2004. Texas has implemented Superpave mix design for high volume roads; however, it has no intention of becoming 100% Superpave state in the near future. The four states with minimal or no implementation plans are Rhode Island, Idaho, Nevada, and California. Rhode Island and Idaho are skeptical about Superpave, however, have placed couple of Superpave mixes in summer 2002. Both states are waiting for fine-tuning of Superpave mix design before fully implementing it in their states. Apparently, in both states local agencies attempted to place Superpave mixes and damaged base layer and drainage pipes due to over compaction. To achieve specified densities, the contractor made too many roller passes and damaged the base layer or the drainage pipes. Nevada had performed some preliminary evaluations and decided not to
implement until all the questions have been answered. California is the only state who
does not have any implementation plans.

FHWA also conducted a survey in 2000 and the results of the survey are shown in Figure
6. The question used for this survey was “Are the highway projects in your state based
on Superpave mix specifications?” In total, 42 states indicated that they are specifying
and using some form of Superpave mix specifications.

![Bar Chart]

As Is | Modified
--- | ---
22 | 20

**Figure 6 – Superpave Mix Design Implementation Status (FHWA Survey)**

The assessment of 100% Superpave mix design implementation is a difficult task because
of the following reasons:

- Some states have decided to use Superpave mixes for high volume roads and are
  performing research or have decided not to use it for low or medium volume
  roads.
- Some states have selected portions of Superpave mix design and are using them
  but have not yet made up their mind for full implementation.
- Some states have not set up any specific target date but are implementing it at a
  slower rate than previously anticipated.
- Some states do allow contractors to come up with the design based on specified
  criteria and the contractor has a choice of using conventional or Superpave mix
  design.
- Some states specify Superpave for surface course but do allow contractors to use
  conventional mix for base courses.

The discussion suggests that most SHAs are willing and have implemented Superpave
and remaining states have a conservative approach towards implementation. A 2000
survey conducted by NYSDOT (11) identified that more than 53% of placed hot mix was
designed using Superpave. Therefore, 100% implementation of Superpave mix design is
a growing system.
Superpave Concerns

Issues with Superpave are abundant and do vary from state to state. Based on discussions with SHAs, a list of common issues was prepared and is presented in Figure 7. A brief discussion on each issue is presented in the following paragraphs.

Figure 7 – Common Superpave Issues to be Addressed

The most common concern expressed by the highway agencies was a lack of strength test after a mix meets volumetric requirements. Although SHAs have fully implemented Superpave, they would like to have a strength test like Simple Performance Test (SPT) to evaluate strength of the mix. NCHRP has sponsored several projects to identify and in the process of selecting a simple performance test to reliability estimate properties of Superpave mixes.

Although most of the SHAs agree that Superpave mixes are less prone to rutting in comparison to conventional mixes, SHAs still feel that accelerated rut test equipment and specifications are required. Even if a SPT test will be available in near future, SHAs still feel that accelerated rut test specifications are needed because APA or HWTD simulate field conditions and tests can be conducted in relatively shorter time frame.

The third most common concern expressed is the openness of Superpave mixes due to gradation control points specified by the Superpave. The main concern with gradation limits and control points now is that it allows design of coarse mixes. The coarse mix design allows placement of high permeability mixes.

The fourth most common concern expressed was poor reliability of moisture susceptibility tests. A research project was sponsored by SHRP to identify and develop a
moisture susceptibility test; however, the developed test was not implemented. Instead, the existing AASHTO T-283 test was selected in the Superpave design system. States experiencing moisture damage problem are especially interested in the development of a new test because existing test does not consistently identify moisture susceptible mixes. A research project has been recently sponsored by NCHRP to develop a moisture susceptibility test.

The fifth and sixth problems are less asphalt content and less number of gyrations, respectively. Such problems are interrelated and should be addressed together. SHAs experience suggests that higher number of gyrations in conjunction with open gradation parameters allow design of mixes with lower asphalt content. The lowered asphalt content reduces the durability of mixes. The suggested solutions to this problem are different:

- Reduce Number of Design Gyrations
- Specify minimum amount of asphalt content
- Specify minimum film thickness requirements

Some states have implemented these suggestions while other states are waiting for Superpave experts to propose new specifications.

Although voids in mineral aggregates (VMA) has been specified in the Superpave design system, some SHAs feel that higher VMA requirements produce open mixes and reduces the durability of Superpave mixes. In addition, some SHAs feel that VMA requirements should be separate for coarse and fine graded mixes. VMA that is too difficult to achieve is a construction issue and is discussed in the next section.

In addition, some states expressed concern over the reproducibility of SGC, difficulty in achieving density, consistency of angle of gyrations, usage of RAP in Superpave mix design, and training.

Based on the above-discussion, it can be concluded that most of the highway agencies have implemented Superpave mix design and remaining agencies are moving in that direction.

**Construction Issues**

Abundant construction issues have emerged after implementation of Superpave. One of the major issues has been that contractors and SHAs did not have enough training or experience to place good quality Superpave mixes. In addition, it should be recognized that issues related to construction might have been more visible because of the fact that new equipments are available to identify the problems and everybody is using similar mixes.

Better Roads\(^{(12)}\) conducted a survey to get contractor viewpoints of Superpave. The results of the survey are summarized in Figure 8. 75% of the contractors feel that Superpave is the way to go and only 16% feel that it was a waste of time. In response to
the question: “Is Superpave mix of better quality than conventional mix?,” 43% said it was better while 25% said it was much superior. In total, 68% feel that Superpave is better than conventional mixes. However, in response to the question of difficulty to work with Superpave, more than 83% feel that it was difficult to work with. The answer to the last question confirms that good experience and training is essential for successful placement of Superpave.

In general, the concerns of tender mixes and difficulty in achieving the specified densities have been identified as main problems. Various surveys and reports have pointed out problems with tender zone and problems associated with achieving specified densities. A good discussion related to tender zone and compaction has been presented by Chuck Deahl (14) and is summarized in the following paragraphs.

Superpave mixes are coarser than conventional mixes and SGC compaction efforts are different from Marshall compaction efforts. Therefore, it is essential to understand that the techniques used for conventional mixes may not work for Superpave mixes. Deahl identified four primary components in productively achieving specified density with the Superpave mixes:

- **Communication-Process Control**: Communication between foremen, quality control engineer, and roller operator is essential for good quality of placed asphalt concrete.
- **Selection of Compaction Equipment**: a break down roller with tandem vibratory just following the asphalt paver to allow for maximum compaction at higher temperature (285 to 300 °F), no compaction in tender zone (200 to 250° F), and finish rolling from 120 to 170 °F.
- **Testing and establishing rolling zones and rolling patterns**: it is a good idea to establish rolling zones and rolling patterns by constructing a test strip.
- **Training for foremen, quality control engineers and roller operators**: It is essential that all the personal responsible for placing a good quality hot mix asphalt have been properly trained because their training is critical in establishing rolling patterns, changing procedures on the job, maintaining roller patterns, and rolling zones to maximize production and gain density.

Deahl suggested that Superpave mixes can be produced, laid, and compacted productively with good field management, communication on the job, continued evaluation of results, utilization of individual talents, and a commitment to quality hot mix asphalt pavements.

A survey conducted by RMUPG (13) also indicated that poor performance of Superpave mixes is not necessarily an issue of the mix design. For example:

- In one Arizona project, pavement failed prematurely and showed signs of segregation and raveling. This poor performance of Superpave mix was traced back to the placement of the material in marginal weather conditions.
a) Response to the question: "Is Superpave Really the Way to Go?"

b) Response to the question: "Is Superpave Mix of Better Quality than Conventional Mix?"

c) Response to the question: Degree of Difficulty of Working with Superpave

Figure 8 – Contractors’ View of Superpave
In another Arizona project, lack of experienced quality control personnel on job site resulted in inconsistent densities.

In one Colorado project, compaction problems occurred but they were related to improper construction equipment and practices rather than mix design.

The above-discussion suggests that a good quality control, training, and engineering judgment are essential for placement of durable Superpave pavements.

Cost/Benefit Analysis

One of the objectives of this study was to identify increase in construction cost due to usage of Superpave projects and the benefits of Superpave implementation. A survey indicated that none of the SHAs have performed cost/benefit analysis. One of the reasons cited for no analysis was the fact that it is very difficult to perform since the cost of asphalt binder fluctuates and Superpave projects have been relatively recently placed.

Only two SHAs have documented and compared the cost of Superpave mixes with the conventional mixes. Ohio DOT developed a data base system to document the cost and performance of the Superpave projects. A study published by Abdulshafi and Kedzierski (15) suggested that cost of Superpave projects was higher than conventional Marshall mixes. The cost data was collected for Superpave projects built in 1996 and is summarized in Table 1. The data suggests that a Superpave project costs more than a conventional mix and the cost increase varied between 12 to 30%. However, it should be noted that the data comes from projects built in 1996, during the initial years of Superpave implementation.

<table>
<thead>
<tr>
<th>Type of Mix</th>
<th>Cost of Superpave Mix ($/m³)</th>
<th>Cost of Marshall Mix ($/m³)</th>
<th>Percent Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>78.18</td>
<td>69.95</td>
<td>11.8</td>
</tr>
<tr>
<td></td>
<td>72.60</td>
<td>55.85</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>61.85</td>
<td>51.09</td>
<td>21.1</td>
</tr>
<tr>
<td>Leveling</td>
<td>75.35</td>
<td>66.06</td>
<td>14.1</td>
</tr>
<tr>
<td></td>
<td>67.50</td>
<td>54.00</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>58.25</td>
<td>51.45</td>
<td>13.2</td>
</tr>
</tbody>
</table>

NYSDOT began Superpave implementation in 1996 and documented the cost of Superpave projects (16) in 1998. The bid prices for Superpave projects are included in Table 2. The table shows number of projects and bid prices tabulated based on binder grade used. The data shows an increase in bid prices as the binder grade increases. The study suggested that the increase of bid prices is typical in NY from North to South (top
to bottom in the Table) and the increase was comparable to conventional mixes. For example, the prices of Superpave project PG 58-28 binder was $32.65 per ton while for AC 20 Marshall mix was $31.10 per ton, a difference of 5% (for Top Course). However, Sines (16) cautioned that the comparison is based on limited number of projects. In addition, some of the projects required modifiers for the binder, and restriction on the use of some of the locally available material. According to Sines' (16) experience, the cost of Superpave projects is similar to that of conventional mixes.

Table 2 - Average Cost Data Generated from Limited Number of Projects (16)

<table>
<thead>
<tr>
<th>Binder Grade</th>
<th># of Projects</th>
<th>Top Course</th>
<th>Binder Course</th>
<th>Base Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 58-34</td>
<td>6</td>
<td>$29.97</td>
<td>$28.24</td>
<td>-</td>
</tr>
<tr>
<td>PG 58-28</td>
<td>18</td>
<td>$32.65</td>
<td>$31.95</td>
<td>$33.11</td>
</tr>
<tr>
<td>PG 64-28</td>
<td>19</td>
<td>$33.63</td>
<td>$31.92</td>
<td>$32.60</td>
</tr>
<tr>
<td>PG 64-22</td>
<td>2</td>
<td>$43.80</td>
<td>$44.39</td>
<td>$43.00</td>
</tr>
<tr>
<td>PG 70-22</td>
<td>14</td>
<td>$47.93</td>
<td>$51.40</td>
<td>$47.60</td>
</tr>
<tr>
<td>AC 20</td>
<td>-</td>
<td>$31.10</td>
<td>$31.10</td>
<td>$31.67</td>
</tr>
</tbody>
</table>

In August 2001, Utah DOT published a Position Statement on Superpave and identified that the cost of modified PG binder ranged from about 10 to 15% more than the neat asphalts (unmodified). Their best estimate places the increased cost per ton of HMA as high as 10% during the first year. Currently, the cost of Superpave mixes is 2 to 4% higher than conventional mixes. This happened after the materials testing labs purchased the required new equipment and the contractors and consultants labs gained some experience working with Superpave mixes.

Annual Superpave Implementation and Needs Assessment report published by NYSDOT (11) suggested that the average price per ton of conventional mix in 2000 was $36.04 per ton and $37.03 per ton for Superpave (a less than a dollar per ton difference). The report also suggested that on an average the cost for a ton of Superpave mixes is higher than 3% in comparison to conventional mix.

The above discussion suggests that the cost of Superpave is not significantly higher than conventional mixes and has dropped with the increase of Superpave projects being built. The discussion also indicates that the prices will be higher when the higher-grade spread is specified because of higher percentage of costly modifier.

In general, it is extremely difficult to perform a cost/benefit analysis for highway infrastructure because of the amount of material used and the exposure to the uncontrolled environment. An added difficulty is that Superpave projects have not been placed long enough to compare them with conventional Marshall or Hveem mix performance.
An extensive review revealed that a national level study was conducted by the University of Reno, Nevada, and Texas Transportation Institute (TTI)\(^5\) to identify economic benefits of Superpave implementation. To predict the potential savings, nine criteria were established; however, only a few of them are discussed here for the sake of brevity. For in-depth review of the criteria, authors are encouraged to read reference\(^5\). A 40-year life-cycle cost, a 5 \% discount rate, and an annual traffic growth rate of 2.1 \% was used in this study. The study assumed a 6.7 \% increase in cost of Superpave projects in comparison to conventional mixes. This included the cost of implementation, which consisted of the equipment and personal training. The study also included benefits derived from reductions in vehicle operating costs because of smoother pavements, reductions in costs associated with fewer overlays and repairs needed during life of the pavement. The study was performed for three levels of implementation: slow (100 \% after 10 years), moderate (100 \% after 5 years), and fast (100 \% within a year). Based on these criteria, TTI performed analyses and the results are presented in Table 3 (reproduced from Report No. FHWA-SA-98-012).

**Table 3 - Twenty-Year Cost-Benefit Ratio\(^*\) and Cost Saving (Billion $) for SHRP Asphalt Research\(^5\)**

<table>
<thead>
<tr>
<th>Implementation Rate</th>
<th>Slow</th>
<th>Moderate</th>
<th>Fast</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ratio(^+)</td>
<td>Savings</td>
<td>Ratio(^+)</td>
</tr>
<tr>
<td>Agency Savings</td>
<td>26</td>
<td>6.0</td>
<td>34</td>
</tr>
<tr>
<td>User Savings</td>
<td>72</td>
<td>16.5</td>
<td>94</td>
</tr>
<tr>
<td>Total</td>
<td>98</td>
<td>22.5</td>
<td>129</td>
</tr>
</tbody>
</table>

*Based on an estimated 20-year research, development, and implementation cost of $230 million

\(^{+}\) Totals may not add up because of rounding

The Cost-Benefit ratios mean that for each dollar spent on research, development, and implementation, the public highway agencies can expect a return of $26 at a slow implementation rate, $34 at a moderate implementation rate and $43 at a fast implementation rate. Since the fast and moderate implementation rates have not been achieved, the savings expected could be 22.5 billion dollars.

Although an attempt for the cost/benefit analysis was made in the study conducted by TTI, many of the assumptions may not be valid in the field. A study conducted by Noureldin\(^17\) indicated that the overall pavement performance life might be significantly affected when the specified asphalt content, aggregate gradation, and degree of compaction are not achieved in the field. In addition, the study does not account for a
less than 100% implementation. However, it was identified in this study that not all SHAs are going for 100% Superpave implementation.

Ohio DOT and the Rocky Mountain Asphalt User-Producer Group (RMAUPG) are maintaining a database of Superpave projects that could be used to perform an analysis to identify benefits of Superpave based on procedures suggested by Epps (5) and Noureldin (17). NCAT is also planning to perform cost benefit analysis of Superpave projects in near future.

Indirect Benefits of SUPERPAVE

Cost/benefit analysis performed by TTI showed savings directly derived from implementation of Superpave. The Superpave system has allowed integration of SHAs, FHWA, Academia, and Regional User Producer groups that was not possible before Superpave. This integration could be termed as a indirect benefit of Superpave implementation. In addition, Superpave allowed for better quality control of hot mix that was also not feasible with conventional mix design systems. Similarly, there are other factors that can improve Superpave mix performance and could be the indirect benefit of Superpave implementation process. Based on feedback from SHAs, the following indirect benefits were identified:

- Before Superpave, states did not have similar specifications and individual states had to resolve problems on their own. In addition, the identified solution might not be applicable to another state because of specification differences. Superpave system allowed all states to have similar specifications for binder and mix design. Therefore, a solution developed in one state can be implemented in another state with minimum effort, i.e. knowledge sharing.
- Since inception of the Superpave system, various regional groups have been formed for information sharing. For example, a combined state binder group (IA, MN, NE, ND, SD and WI) is formed to share the experiences with PG graded binders. All six states use same procedures for accepting PG graded binders.
- Managers of SHRP had visited various European transportation laboratories and agencies to identify new technologies and to gain knowledge about their highway infrastructure. This step opened communication between two unions and allowed academia and state highway agencies to share knowledge.
- Various research efforts either have been completed or are in progress to monitor Superpave performance and to identify the implementation issues of Superpave. The SHAs/organizations conducting research are shown in Figure 9. The database developed, issues identified, and solutions documented can be evaluated by any SHA to resolve issues within their states because the design specifications are similar.
- Superpave implementation has allowed SHAs to pool their resources to resolve common problems. A very good example is the restricted gradation zone. A national level effort was made to resolve the issue and all of the agencies can now reap the benefits.
- Another benefit of Superpave is that it allows for better quality control. SHAs indicated that the developed equipments are more precise and accurate than the
ones previously used. In addition, the new equipments are portable and can be taken to the field for quicker evaluation in the field. The field-testing allows for early detection of problem areas and better quality control of hot mix placed in the field.

- Superpave is being used by various local agencies and benefits reaped from local roads can be termed as an indirect benefit because the initial focus of implementation efforts was to implement Superpave mix design for state designed and maintained roads.
- Local airports of Illinois have developed implementation plans for adopting Superpave for airports.

![Figure 9 – Superpave Studies](image-url)
Chapter 3

Results of Survey

Although agencies were initially contacted to identify concerns and benefits of Superpave implementation, the questions asked varied from agency to agency. The change in type and number questions was intrinsic due to the fact that knowledge gained by discussion with one agency influenced discussion with agencies contacted afterwards. This meant that discussion with first agency contacted was quite different from discussion with agency contacted last. Therefore, it became essential to perform survey of all agencies with similar questions to quantify concerns and benefits of Superpave implementation in a coherent manner.

Based on discussion presented in Chapter 2, a list of common concerns and benefits of Superpave implementation was developed and transformed into a questionnaire form. In addition, the questions regarding quantity of Superpave projects planned and the ratio of Superpave versus conventional mixes were included as well. To perform this survey, the hot mix asphalt contractors were also included in the list. In total, 84 agencies were targeted for the survey. The target group included 52 state highway agencies (including District of Columbia, and Puerto Rico), 5 User Producer groups (UPGs), 5 Superpave centers (SCs), and 22 hot mix asphalt contractors. The questionnaire was divided in three components: asphalt binder, aggregates, and asphalt concrete mixture. In addition, the numbers of questions in the questionnaire were different for different agencies to make sure that the questions asked are relevant to the surveyed agency (Appendix A, B, and C). All of the Superpave centers and 47 SHAs out of 52 responded to the questionnaire. Only 8 contractors and 2 UPGs responded to the survey. Overall response to the survey was extremely good because more than 70% of the target group provided their input. The survey data was stored and analyzed in an Excel sheet and the results of the analysis are discussed in the following paragraphs.

Superpave Projects

Superpave Lead State Team(11) had previously documented a number of Superpave projects awarded and percentages of Superpave awarded projects in comparison to
conventional mix designs. The combined results are included in the Figures 10 and 11. The results suggest that the number of Superpave projects have been consistently increasing over the years (Figure 10). The number of Superpave projects awarded has increased from 95 projects in 1996 to 4726 projects in 2001. In addition, the percentage of Superpave projects has also increased in comparison to conventional projects. The survey results predict that more than 60% of awarded projects will be Superpave in 2002 (Figure 11).

![Figure 10 - Number of Superpave Projects Awarded]

![Figure 11 - Percentage of Superpave Projects Based on Total Asphalt Concrete Projects]
Superpave Concerns

Although SHAs are satisfied and have implemented PG binder specifications, many states do have a problem with modified asphalt. To satisfy temperature, loading, and reliability requirements, SHAs specify PG grades that can only be produced by adding modifiers to the asphalt binder. Based on the experience, SHAs have identified that some modifiers work better than others; however, all of them pass the PG specifications tests. SHAs believe that PG grade is transparent to modifiers and needs to have new specifications for the asphalt consisting of modifiers.

According to the survey, 18 highway agencies, 1 UPG and 2 SCs indicated that current PG specifications are adequate for specifying asphalt binder consisting of modifiers (Figure 12). The remaining state highway agencies (39) either specify a particular modifier (17) or additional tests (23), or both, to eliminate poor performing modifiers. In addition, 4 SCs indicated that PG specifications are not applicable for modified binders. Based on the discussions with highway agencies, it was identified that PG grade specifications work well for asphalt binder consisting of small quantity of modifiers. However, PG specifications are not able to discriminate between well and poor performing modifiers when behavior of asphalt binder is dominated by modifier (i.e., usage of large quantity of modifiers). The discussion with SHAs indicates that PG specifications for modified asphalt binder need to be developed. Brown et al. (10) have also identified that there is a need for new specifications for modified binders.

Another concern raised by the SHAs was the gradation control points. The main concern with gradation limits and control points now is that it allows design of coarse mixes. The coarse mix design allows placement of mixes that are highly open. An open mix allows more water to infiltrate and reduces the durability of Superpave mixes in the long run.

The survey results suggest that 23 SHAs, 1 SC, and 2 UPGs indicated that there is no need to modify control points (Figure 13). On the other hand, 8 SHAs and 3 SCs indicated that requirements should be modified while 16 SHAs and 1 SC indicated that it may need to be modified. The combination of “yes” and “may be” makes a total of 28
agencies (24 SHAs and 4 SCs) interested in further evaluation of Superpave gradation control points.

Another concern raised was the voids in mineral aggregates (VMA) requirements of Superpave design. SHAs indicated that higher VMA requirements produce open mixes and reduces the durability of Superpave mixes. In addition, some SHAs indicated that VMA requirements should be different for coarse and fine graded mixes.

According to the survey results, more than 60% of the respondents (Figure 14) indicated that the requirements are adequate while 31% of the respondents indicated that either they are low (13%) or high (18%). 7% of the respondents did not have enough experience to suggest either way. The results suggest that majority of agencies feel that VMA requirements are adequate for producing and placing good quality Superpave mixes.

The discussion and literature review suggested that Superpave mixes have less asphalt content due to the higher design number of gyrations. SHAs experience suggests that higher number of gyrations in conjunction with open gradation parameters allow design of lower asphalt content mixes. The lowered asphalt content reduces the durability of mixes. In the survey, both questions were asked separately and the results are summarized in the following paragraphs.

According to the survey, more than 50% of the respondents (Figure 15) indicated that Superpave mixes can be adequately
compacted in the laboratory and no major impact of $N_{as}$ on the quality of mix could be identified. However, 44% of the respondents indicated that $N_{as}$ requirements are either too low (11%) or too high (33%) and they significantly affect quality of mix. Only 4% of the respondents indicated that they did not have enough experience to suggest either way. The discussion with some of the highway agencies identified that few of the agencies have already modified the Superpave compaction table while others feel comfortable with it.

In response to the question of asphalt content of Superpave mixes, 31 SHAs, 2 contractors, 2 UPGs, and 2 SCs indicated that Superpave mixes have lower asphalt content than conventional mixes (Figure 16). Meanwhile, 11 SHAs, 6 contractors and 2 SCs indicated that asphalt content is adequate in the Superpave mixes while 5 SHAs were not sure about it.

Some SHAs have already solved the problem of less asphalt content by reducing number of gyrations or/and by specifying minimum asphalt content or film thickness.

Another common concern expressed by SHAs is the openness of Superpave mixes. An open mix reduces the durability of Superpave mixes because it allows water to infiltration and provides air for binder oxidation.

According to the survey, 20 SHAs, 3 contractors, 3 SCs, and 1 UPG indicated that Superpave mixes are not necessarily open in comparison to conventional mixes. Meanwhile, 14 SHAs, 4 contractors, and 2 SCs indicated that Superpave mixes are more open (Figure 17). 13 SHAs, 1 contractor and 1 UPG were not sure either way. Response of contractors and Superpave centers is pretty much split on this issue.

Since gradation control points, VMA requirements, and $N_{as}$ influence the openness of mixes, the results of the survey suggest that they should be further evaluated.
The discussion with SHAs suggested that Superpave mix design might not be for low or medium volume roads. Therefore, a question was asked about the adequacy of Superpave mixes for low and medium volume roads. According to the survey, 41 SHAs, 4 SCs, and 2 UPGs suggested that Superpave mixes are for all types of roads (Figure 18). On the other hand, 2 SHAs indicated that Superpave is only for high volumes roads while 4 SHAs were not sure about it. The results clearly indicate that majority of agencies believe Superpave is for all volume roads.

As previously mentioned, abundant construction issues have emerged after implementation of Superpave. One of the major issues has been that contractors and SHAs did not have training or experience to place good quality Superpave mixes. In addition, it should be recognized that issues related to construction might have been more visible because of the fact that new equipments are available to identify the problems and everybody is using similar mixes. Better Roads (7) published results of the survey conducted to get contractor viewpoints of Superpave. In response to the question of difficulty to work with the Superpave, more than 83% felt that it was difficult to work with.

According to the survey of this study, 44% of the respondents have either solved the compaction problem or never had compaction problem with Superpave mixes (Figure 19). On the other hand, 36% of the respondents indicated that the compaction is still a
problem; however, they rated the
difficulty of compaction as
moderate and 3% of the
respondents rated level of difficulty
as low. Only 5% of the
respondents had high levels of
difficulty in achieving compactions
while 12% the respondents are not
sure about it.
In response to the question of
regional training, 21 SHAs, 7
contractors, 3 SCs, and 1 UPG
indicated that there is a need for
regional level training (Figure 20).
On the other hand, 13 SHAs
indicated that regional level training is not needed while 13 SHAs were not sure about it.

The results of the survey indicate that compaction is still an issue and more regional
training is needed for better implementation of Superpave. This step is essential because
of the fact that poorly placed Superpave mixes will have lower life cycle, and the benefits
of research would not be fully reaped.

Although most of the SHAs
agree that Superpave mixes are
less prone to rutting in
comparison to conventional
mixes, SHAs still feel that
accelerated rut test equipment
and specifications are required.
This requirement is essential
for the southern states because
they experience higher levels
of rutting. Some agencies have
started using Asphalt Pavement
Analyzer (APA) or Hamburg
Wheel Tracking Device
(HWTD) to identify rutting
potential of the mix. However,
the usage and specifications of
APA or HWTD do vary from
state to state. Some states
require that mix pass the
specified rut criteria while other states only require passing rut criteria if mix gradation
passes through the restricted zone.
According to the survey, more than two thirds of the respondents indicated that there is a need for rut test equipment and specifications (Figure 21). On the other hand, 6 SHAs and 1 UPG indicated that there is no need for accelerated rut testing equipment. Meanwhile, 9 SHAs, 1 UPG, and 1 SC were not sure about it.

In general, SHAs feel that accelerated rut test specifications and equipment are needed because APA or HWTD simulates field conditions. Also, tests can be conducted in relatively shorter time frame.

Based on feedback from SHAs, a list of common missing components was developed and included in the survey. The objective of this exercise was to identify what components could be added in the mix design to accelerate the implementation of Superpave. According to the survey, 38% of the respondents indicated that simple performance test (SPT) is missing while 28% identified that moisture susceptibility test is needed (Figure 22). The 20% of the respondents indicated that PG specifications for modified binder should be developed and 9% of the respondents indicated that specifications for Reclaimed Asphalt Pavement (RAP) are needed. NCHRP has already sponsored projects for the development of a SPT and moisture susceptibility test. Therefore, the discussion indicates that a PG specification for modified asphalts is the main concern.
Benefits

One of the reasons for Superpave implementation is the fact that Superpave mixes improve the performance of asphalt concrete pavements. However, Superpave mix design system offers additional benefits. Based on previous discussion with SHAs, a list of direct and indirect benefits was prepared and opinions of surveyed agencies were sought. The results of the survey are discussed in the following paragraphs.

SHAs were given seven choices to identify the major benefits of Superpave and the results are shown in Figure 23. Approximately 39% of the respondents indicated that binder and mix tests are accurate in comparison to conventional tests. The 23% of the respondents indicated that performance has increased with the usage of Superpave and 10% of the respondents indicated that the new design system increased the life of pavements, thus reducing the life-cycle cost. About 9% of the respondents indicated that Superpave allowed them access to resources while 8% of the respondents indicated that field-testing can be performed quickly using Superpave tests.

![Figure 23 - Major benefits of Superpave Implementation](image)

In response to the question of indirect benefits, knowledge sharing came out to be the most valuable indirect benefit of Superpave. 29% of the respondents indicated that the knowledge sharing (Figure 24) is very helpful in successfully implementing Superpave and learning from each other’s mistake. The second major benefit is the faster transfer of technology for which 21% of the respondents indicated that new technology is implemented faster in comparison to the previous technologies. The next indirect benefit came to be better communications between local, state and federal agencies (19%). Another outcome is the availability of accurate tools for quality control and quality assurance of the placed material (19%). The last benefit identified is the optimized usage of resources (8%).

30
Figure 24 - Indirect Benefits of Superpave Implementation
Chapter 4

Closure

Asphalt concrete pavements have been failing prematurely throughout the nation. The premature failure can mainly be attributed to an increase in traffic loads and adverse environmental factors. The failure reduces pavement smoothness and requires frequent maintenance and rehabilitation. To overcome premature failure problems and improve the nation's highways, a five year 150 million dollar Strategic Highway Research Program was initiated in 1987. A major component of this research was a 50 million dollar asphalt program that led to the development of Superpave.

At the end of SHRP, the Federal Highway Administration (FHWA) assumed responsibility for further development and validation of Superpave systems. It also initiated a national program to encourage the adoption of the system by all State highway agencies. The American Association of State Highway and Transportation Officials (AASHTO) Task Force on SHRP implementation developed the concept of Lead States for uniform implementation of Superpave.

Although initial implementation progress and state highway agency needs were documented by the Lead States, the implementation status and needs beyond 2000 are not identified. This information is essential for future implementation planning and allocation of resources. The gathered information can also be used to demonstrate the major benefits of the new Superpave system and current costs of Superpave mix in comparison of conventional mixes. To identify Superpave implementation status, benefits and concerns, a review of existing literature was performed and state highway agencies were contacted. Based on the gathered information, a survey was developed and state highway agencies, Superpave centers, User Producer groups, and hot mix asphalt contractors were surveyed.

Based on the results of this study, it was identified that Superpave implementation efforts have been successful. More than 85% of the states have implemented PG grade specifications and more than 75% of the states have adopted consensus aggregate
properties. The implementation of mix design has been achieved with mixed success. In general, most of the states have either implemented or are in the process of implementation. However, the goal of 100% Superpave mix design will take longer than anticipated.

The results of the survey identified that SHAs overall are satisfied with Superpave; however, they feel that more research is needed to resolve concerns like gradation control points, openness of mixes, asphalt content, and N_d. In addition, most of the agencies feel that specifications for modified asphalt binder are essential for eliminating poor performing modifiers. The study also suggests that there is a need for rut test equipment and specifications.

Initially, the cost of Superpave mixes was higher than conventional mixes. However, the cost has come down and now Superpave mixes cost approximately 3% more than conventional mixes. The study identified the following major benefits of Superpave implementation:

- accurate binder and AC tests,
- moderate to high improvement in performance,
- access to resources, and
- reduction in life cycle costs.

The study also identified following indirect benefits of Superpave implementation:

- knowledge sharing,
- improved communication between local, state, and federal agencies,
- faster implementation of new technology,
- availability of better tools for quality control and quality assurance of placed pavements, and
- optimization of resources.

A future study is needed to identify implementation status of Superpave. However, the scope of the study should be modified to include the evaluation of Superpave projects that have been in service for more than five years. The data collected by various highway agencies and User-Producer groups should be gathered and a cost benefit analysis as proposed by Epps (5) and Noureldin (17) should be performed. Future research directions could then be developed using the results of the study.
References


Appendix A

Questionnaire Sent to SHAs
Asphalt Binder

1. Is it a fair statement that PG grade specifications are applicable to the modified asphalt binder?
   - Yes
   - No
   - May be

   a. If answer is No or May be, how are you controlling modifiers usage in asphalt binders?
      - i. By specifying a particular modifier
      - ii. By additional testing (please specify)
      - iii. Both i and ii

Aggregate

2. Is there a need for modifying SUPERPAVE gradation control points?
   - Yes
   - No
   - May be

Asphalt Concrete

3. Are Voids In Mineral Aggregates (VMA) requirements of SUPERPAVE Mixes:
   - Too high
   - Too low
   - Just right

4. Do you think that VMA requirements should be different for coarse and fine gradations?
   - Yes
   - No
   - May be

5. Is number of design (Ndes) gyrations:
   - Too high
   - Too low
   - Just right

6. Is it a fair statement that SUPERPAVE mixes have less asphalt content in comparison to conventional mixes?
   - Yes
   - No
   - Not sure

7. Is it a fair statement that SUPERPAVE mixes are highly permeable?
   - Yes
   - No
   - Not sure

8. Is it a fair statement that an accelerated rut testing equipment and specifications are needed?
   - Yes
   - No
   - Not sure

9. Is it a fair statement that SUPERPAVE mixes are difficult to compact?
   - Yes
   - Identified a Solution
   - No
   - Not sure

   If answer is yes, please rate the level of difficulty
   - High
   - Moderate
   - Low
10. Is it a fair statement that more regional level training is needed to resolve construction issues?
   Yes   No   Not sure

11. Is it a fair statement that some premature failures of SUPERPAVE mixes are due to poor construction practices rather than mix design issues?
   Yes   No   Not sure

12. Is it a fair statement to say that SUPERPAVE is only applicable for high-volume roads?
   Yes   No   Not sure

13. In your opinion, what are the major benefits of SUPERPAVE (Circle all that apply)?
   i.  Accurate and precise testing of asphalt binders
   ii. Accurate and precise testing of asphalt concrete
   iii. Field testing can be performed in relatively short time
   iv.  Significant improvement in performance
   v.   Moderate improvement in performance
   vi.  Access to resources
   vii. Earlier opening to traffic
   viii. Overall reduction in life-cycle cost of pavements
   ix.  Others:_________________

14. In your opinion what are the indirect-benefits of SUPERPAVE (Circle all that apply)?
   i.  Knowledge sharing
   ii. Faster technology transfer
   iii. Optimized utilization of resources
   iv.  Availability of reliable tools for better quality control and quality assurance
   v.   Improved communication between state, local, and federal agencies
   vi.  Implementation of SUPERPAVE by local and airport agencies

15. In your opinion, what are the most urgently needed tests/specifications in the SUPERPAVE Mix Design System? (Circle all that apply)
   i.  Modified PG Binder Specifications
   ii. Simple Performance test
   iii. Moisture susceptibility analysis tests
   iv.  Specifications for Reclaimed Asphalt Concrete Usage
   v.   Others_________________
Quantity of Placed Hot Mix Asphalt Concrete

16. How many asphalt concrete projects were built in your State in 2001?  
   
   Projects

A. What percentage of placed asphalt concrete was SUPERPAVE?  
   10%  25%  50%  75%  100%

B. What percentage of placed asphalt concrete was modified SUPERPAVE?  
   10%  25%  50%  75%  100%

C. What percentage of placed asphalt concrete projects could be specified as  
   Low Volume Roads  
   Medium Volume Roads  
   High Volume Roads

D. What percentage of 2002 planned projects will be SUPERPAVE?  
   10%  25%  50%  75%  100%
Appendix B

Questionnaire Sent to User Producer Groups
Asphalt Binder

1. Based on your experience, how successful would you say that the SUPERPAVE PG grade specifications have been in reducing pavement distress in your region?
   - Highly
   - Moderately
   - Less

2. Is it a fair statement that PG grade specifications are applicable to the modified asphalt binder?
   - Yes
   - No
   - May be

   a. If answer is No or May be, how are you controlling modifiers usage in asphalt binders?
      i. By specifying a particular modifier
      ii. By additional testing
      iii. Both i and ii

Aggregate

3. Is there a need for Aggregate consensus properties?
   - Yes
   - No
   - Not sure

4. Is Fine Aggregate Angularity (FAA) requirement implemented in your Region?
   - Yes
   - No
   - In modified form

   a. If yes, does fine aggregate angularity requirement improves rutting resistance of asphalt concrete?
   - Yes
   - No
   - May be

5. Is Coarse Aggregate Angularity (CAA) requirement implemented in your Region?
   - Yes
   - No
   - In modified form

   a. If yes, does coarse aggregate angularity requirement improves rutting resistance of asphalt concrete?
   - Yes
   - No
   - May be

6. Is Flat and Elongated (F&E) requirement implemented in your Region?
   - Yes
   - No
   - In modified form

   a. If yes, does Flat and Elongated requirement improve rutting resistance of asphalt concrete?
Yes No May be

7. Is clay content requirement implemented in your Region?
   Yes No In modified form

   a. If yes, does clay content requirement improves performance of asphalt concrete?
      Yes No May be

8. Is there a need for modifying SUPERPAVE gradation control points?
   Yes No May be

Asphalt Concrete

9. Are Voids In Mineral Aggregates (VMA) requirements of SUPERPAVE Mixes:
   Too high Too low Just right

10. Do you think that VMA requirements should be different for coarse and fine gradations?
    Yes No May be

11. Is number of design ($N_{des}$) gyrations:
    Too high Too low Just right

12. Is it a fair statement that SUPERPAVE mixes have less asphalt content in comparison to conventional mixes?
    Yes No Not sure

13. Is it a fair statement that SUPERPAVE mixes are highly permeable?
    Yes No Not sure

14. Is it a fair statement that an accelerated rut testing equipment and specifications are needed?
    Yes No Not sure

15. Is it a fair statement that SUPERPAVE mixes are difficult to compact?
    Yes Identified a Solution No Not sure

   a. If answer is yes, please rate the level of difficulty
      High Moderate Low

16. Is it a fair statement that more training at regional level is needed to resolve construction issues?
    Yes No Not sure
17. Is it a fair statement that some premature failures of SUPERPAVE mixes are due to poor construction practices rather than mix design issues?  
   Yes  No  Not sure

18. Is it a fair statement to say that SUPERPAVE is only applicable for high-volume roads?  
   Yes  No  Not sure

19. In your opinion, what are the major benefits of SUPERPAVE (you can select more than one option)?
   i. Accurate and precise testing of asphalt binders
   ii. Accurate and precise testing of asphalt concrete
   iii. Field testing can be performed in relatively short time
   iv. Significant improvement in performance
   v. Moderate improvement in performance
   vi. Access to resources
   vii. Earlier opening to traffic
   viii. Overall reduction in life-cycle cost of pavements
   ix. Others: ___________________

20. In your opinion what are the indirect-benefits of SUPERPAVE?
   i. Knowledge sharing
   ii. Faster technology transfer
   iii. Optimized utilization of resources
   iv. Availability of reliable tools for better quality control and quality assurance
   v. Improved communication between state, local, and federal agencies
   vi. Implementation of SUPERPAVE by local and airport agencies

21. In your opinion, what are the most urgently needed features for SUPERPAVE? (Circle all that apply)
   i. Modified PG Binder Specifications
   ii. Simple Performance test
   iii. Moisture susceptibility analysis tests
   iv. Specifications for Reclaimed Asphalt Concrete Usage
   v. Others ___________________
Appendix C

Questionnaire Sent to Hot Mix Asphalt Contractors
Aggregate

1. Is there a benefit of specifying gradation control points for SUPERPAVE mixes?
   Yes  No  May be

Asphalt Concrete

2. Are Voids In Mineral Aggregates (VMA) requirements of SUPERPAVE Mixes:
   Too high  Too low  Just right

3. Is number of design (N_{des}) gyrations:
   Too high  Too low  Just right

4. Is it a fair statement that SUPERPAVE mixes have less asphalt content in comparison to conventional mixes?
   Yes  No  Not sure

5. Is it a fair statement that SUPERPAVE mixes are highly permeable?
   Yes  No  Not sure

6. Is it a fair statement that SUPERPAVE mixes are difficult to compact?
   Yes  Identified a Solution  No  Not sure

   a. If answer is yes, please rate the level of difficulty.
      High  Moderate  Low

7. Is it a fair statement that more regional level training is needed to resolve construction issues?
   Yes  No  Not sure

8. Is it a fair statement that some premature failures of SUPERPAVE mixes are due to poor construction practices rather than mix design issues?
   Yes  No  Not sure

9. In your opinion, what are the major benefits of SUPERPAVE (you can select more than one option)?
   x. Field testing can be performed in relatively short time
   xi. Significant improvement in performance
   xii. Moderate improvement in performance
   xiii. Access to resources
   xiv. Earlier opening to Traffic
   xv. Others: ____________________________
10. In your opinion what are the indirect-benefits of SUPERPAVE?

vii. Knowledge sharing
viii. Faster technology transfer
ix. Optimized utilization of resources
x. Availability of reliable tools for better quality control and quality assurance
xi. Improved communication between state, local, and federal agencies
xii. Implementation of SUPERPAVE by local and airport agencies

Quantity of Placed Hot Mix Asphalt Concrete

11. How many asphalt concrete projects did your firm build in 2001?
   
   ____ Projects

   A. What percentage of placed asphalt concrete was SUPERPAVE?
      10%  25%  50%  75%  100%

   B. What percentage of placed asphalt concrete was modified SUPERPAVE?
      10%  25%  50%  75%  100%