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National Cooperative Highway Research Program

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Minimizing Premature Cracking in Asphaltic Concrete Pavement

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 9-4, "Minimizing Premature Cracking of Asphaltic Concrete Pavements," by F. N. Finn, K. Nair, and J. Hilliard, Materials Research & Development, Oakland, Calif.

THE PROBLEM AND ITS SOLUTION

Cracking of the surface course is generally considered to be the most significant manifestation of asphaltic concrete pavement distress. Many factors, such as asphalt properties, mix design, construction procedures, aggregate properties, subgrade support, environmental conditions, and traffic loading, influence the ability of a pavement to resist cracking. Premature cracking (that cracking occurring at an early life or after less accumulated traffic than anticipated during design) often results in large expenditures of funds to maintain the intended level of serviceability. Methods are needed for modifying current design and construction procedures that will result in the minimizing of this type of cracking.

Based on an extensive review and analysis of available information from previous research and field experience pertaining to premature cracking in asphaltic concrete pavements, Materials Research and Development, Inc., has prepared a series of recommendations dealing with material specifications, mix design, structural materials selection, and construction requirements that are intended to reduce the possibility of premature cracking of asphaltic concrete pavement. The principal constraint applied to preparation of the recommendations is that development of improved methods of structural design is not one of the techniques to be considered because development of more rational structural design procedures is the objective of other research efforts, such as NCHRP Project 1-10B, "Development of Pavement Structural Subsystems." Specifically, the Project 9-4 recommendations assume that the pavement designer is using a suitable design method for selecting the thickness of various pavement layers to provide structural adequacy for the particular traffic, subgrade support, and climatic conditions. The report also reviews possible procedures for verification of the recommendations for minimizing premature cracking and suggests an approach for a more extensive future verification program. The recommendations are suitable for immediate implementation, at least on a trial basis, for the reasons that (a) they are based on a thorough evaluation by knowledgeable researchers of available information from both previous research and field experience, (b) they have been subjected to limited case history and analytical verification, and (c) they appear to confirm and quantify recent trends in the field of asphaltic concrete pavement design.

FINDINGS

The initial task was identification of the types of cracking that are reported to occur extensively, reduce pavement serviceability, and require extensive maintenance. Of the cracking identified, specific recommendations are made which, if implemented, should tend to minimize premature fatigue cracking, low-temperature cracking, and reflection cracking. Because of a general lack of definitive information, the recommendations for minimizing reflection cracking are somewhat general.

Project findings are listed and discussed by type of cracking as follows:

Fatigue Cracking

1. Increasing the proportion of asphaltic concrete will reduce the potential for fatigue cracking. Analytical studies indicate that increasing the proportion of aspahltic concrete to provide for approximately 50 to 75 percent of the total structural requirements will reduce potential for fatigue cracking. It should be noted that a significant improvement in performance can be achieved by increasing the density of the untreated aggregate base course. Therefore, it is important to evaluate this possibility concurrently with the possibility of increasing the proportion of asphaltic concrete. Also, use of cement-treated materials will virtually eliminate the possibility of fatigue cracking in the asphaltic concrete surface, but the problems of reflection cracking from fatigue and shrinkage of the treated base must be considered.

2. Increasing asphalt content and reducing void content will minimize fatigue cracking. Research has indicated that increasing the asphalt content will tend to improve fatigue life of asphaltic concrete but too much asphalt in the surface course can produce an unstable mix and bleeding or flushing, which could lead to rutting problems and slippery-when-wet conditions. The desired objective is mix design requirements that minimize fatigue cracking without incurring other forms of distress. Tables 7 and 8 provide recommendations for accomplishment of this objective.

3. Conflicting viewpoints exist regarding influence of asphalt consistency on fatigue cracking. It is apparent from the information available that different recommendations on asphalt consistency could be made, depending on the failure criteria used in analysis. Table 6 summarizes the recommendations of the project researchers with regard to asphalt consistency in relation to temperature and thickness of asphaltic concrete, and in consideration of other types of distress, such as rutting and low-temperature cracking.

4. Specify maximum realistic density for untreated aggregate base course. Analytical studies indicate that the moduli of resilience of untreated aggregates increase with density and decrease with moisture. Maximum attainable density should be based on previous experience or special tests per project. Where appropriate, some positive drainage system should be provided.

5. Use of cement-treated bases reduces fatigue cracking of asphaltic concrete surface but may increase reflection cracking. A series of recommendations for cement-treated bases is included in Table 10.

6. Inclusion of subsurface drainage as a design and construction requirement. There is a limited amount of quantitative information available to describe the role of subsurface drainage in fatigue cracking. However, when climate and landforms suggest that water could enter the pavement structure, positive drainage design requirements should be investigated.

Low-Temperature Cracking

7. Use a softer asphalt if premature low-temperature cracking is being observed. This type of cracking manifests itself through transverse cracking beginning in the surface of the asphaltic concrete and progressing through the pavement structure. At present, the most viable designer-controlled factor related to low-temperature cracking is the asphalt cement grade. Table 6 provides reasonable recommendations for asphalt grades, considering both fatigue and low-temperature cracking.

Reflection Cracking

8. It is not possible at present to formulate specific recommendations for minimizing reflection cracking. General techniques currently being used are: (a) Increase the ability of the overlay to withstand the stresses and strains that cause cracking; (b) Place an intermediate stress-relieving layer; and (c) Prepare the underlying pavement. Table 12 contains some reasonable suggestions.

APPLICATIONS

The report suggests the following approaches to implementation of the recommendations for minimizing premature cracking of asphaltic concrete pavement:

1. Individual highway agencies can evaluate the recommendations against current practice and adopt any changes that are judged to be adequately verified in the report. Future observations of performance would indicate the effect of the changes.
2. Individual highway agencies can initiate field experiments to verify, modify, or expand specific recommendations.
3. Initiate a nationwide verification investigation based on Bayesian decision statistics, as recommended in the report.

The generally accepted approach to verification on a regional or national scale has been to design a factorial experimental program and monitor performance, using statistical analysis for evaluation of the variables. An alternate approach has been to verify an analytical model using a small experimental program and case histories of in-service pavements. The model can then be used to evaluate the influence of a larger number of variables. These two approaches are discussed in the report, with the determination that they do not represent feasible approaches for verification of the project recommendations because the cost, time, and scope required for such a program to reach definitive conclusions would be excessive. The approach proposed for nationwide verification and updating of project recommendations represents a new philosophy to the highway field, which uses the cumulative experience of engineers working in the areas of design, evaluation, construction, and maintenance of pavements, together with data from laboratory studies, special test sections, new construction, and analytical studies. Using the Bayesian approach, it is possible to extract the past experience of engineers in a meaningful statistical format for combining with experimental data and experience gained from observation of field performance of new construction. Such an approach, although new in the highway field, is well established for decision-making in other fields and areas of transportation engineering. The general methodology is presented in simplified form in Figure 23.

The suggested program for verification of recommendations for minimizing premature cracking of asphaltic concrete pavements provides the following advantages:

1. Research data, analytical techniques, and practical field experience can be used in a theoretically sound and consistent manner for verifying and updating the recommendations.
2. The time and cost required for conduct of a factorial experimental program are greatly reduced.
3. Because of the utilization of field experience, the likelihood of acceptance and implementation is increased.
4. The methodology provides a means for updating practice as new information becomes available.
5. It includes an information feedback system that will be extremely useful in the total pavement design and management process which goes well beyond the problem of minimizing premature cracking of asphaltic concrete pavement.

The study recommendations dealing with (a) asphalt content and void content of asphaltic concrete, (b) density of untreated aggregate base courses, and (c) subsurface drainage where accumulation of water is a problem, appear to be well documented and suitable for immediate implementation. Plans have not been developed as yet for any nationwide program for verification or modification of the recommendations. However, test sections in new construction might be used by an individual highway department to evaluate specific recommendations, such as increasing proportion of asphaltic concrete, use of softer asphalt to reduce low-temperature cracking, and various techniques for reducing reflection cracking.

TABLE 6
RECOMMENDATIONS FOR SELECTION OF ASPHALT CEMENT

Thickness of Asphaltic Concrete, in. [a]	Climate [b]	Asphalt Cement Grade		Western States [c]
		AASHO M20	AASHO M226	
≦3	Cold [d]	200-300	AC - 5	AR-1000
	Moderate [e]	85-100	AC - 10	AR-4000
	Hot [f]	85-100	AC - 10	AR-4000
4-6	Cold [d]	120-150	AC - 5	AR-2000
	Moderate [e]	85-100	AC - 10	AR-4000
	Hot [f]	60-70	AC - 20	AR-8000
≧7	Cold [d]	120-150	AC - 5	AR-2000
	Moderate [e]	60-70	AC - 20	AR-8000
	Hot [f]	40-50	AC - 40	AR-16,000

[a] Total thickness of asphaltic concrete; surface plus base.
[b] From U. S. Weather Bureau climatological reports.
[c] As reported in Western Construction Magazine (Oct. 1972).
[d] Normal minimum daily temperature of 10F or less; for extremely low temperatures special studies are recommended.
[e] Normal maximum daily temperature of 90F or less.
[f] Normal maximum daily temperature greater than 90F.

TABLE 7
RECOMMENDATIONS FOR MIX DESIGN OF ASPHALTIC CONCRETE [a]

Stability	Void in Mineral Aggregate Based on Maximum Sized Aggregate (%)			Total Voids in Mix [b] (%)
	1/2-in. max.	3/4-in. max.	1 1/2-in. max.	
No change from current practice for upper 6 inches of asphaltic concrete.	15	14	12	3 to 6
Reduce stability in lower layers by addition of asphalt according to traffic, but tentatively not less than 30 by Hveem stability [c] or 500 lb by Marshall stability. [d]	15	14	12	2 to 5

[a] For conventional dense-graded mixes: local experience to be used for special mix types, such as sand-asphalt, open-graded, or asphalt emulsion mixes.

[b] ASTM Designation D2041-64T or AASHO Designation T209-64 Maximum Specific Gravity of Bituminous Paving Mixtures (or equivalent).

[c] ASTM Designation D1560, Resistance to Deformation and Cohesion of Bituminous Mixtures by Means of Hveem Apparatus.

[d] ASTM Designation D1556, Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus.

TABLE 8
RECOMMENDATIONS FOR MAXIMUM AIR VOIDS REQUIREMENTS TO BE INCLUDED IN CONSTRUCTION SPECIFICATIONS

Asphaltic Concrete Layer	Recommended Max. Air Voids (%)	
	Light Traffic	Moderate to Heavy Traffic
Surface, 1 1/2 to 2 in.	8	7
Base	7	6

Notes:
1. Determined from cores in accordance with ASTM Designation D2041-64T or AASHO Designation T209-64.
2. Construction specifications should be written such that not more than 15 percent of the areas would be expected to have air voids exceeding the specified amount. If the specifications are based on average air voids, the construction specification requirements noted in Table 7 should be reduced by one percentage point each.
3. Light traffic is defined as 10 equivalent daily 18-kip single-axle loads; moderate to heavy traffic refers to equivalent daily 18-kip single-axle loads in excess of 10.

TABLE 10
RECOMMENDATIONS TO MINIMIZE CRACKING IN CEMENT-TREATED BASES

Designer-Controlled Activity	Designer-Controlled Recommendations
Design	1. Extend cement-treated layer at least 1 ft into shoulder zone. 2. Minimum design thickness of 0.5 ft. 3. Protection of foundation material against exposure to free water by providing subsurface drainage or membrane protection. 4. Minimum thickness of asphaltic concrete surface of 0.25 ft.
Materials specification	1. Use Type II cement. 2. Cement-treated materials should be capable of meeting ASTM wet-dry and freeze-thaw criteria. 3. Limitation on clay content (approximately 10 to 15 percent depending on clay mineralogy).
Mix design	1. Cement content sufficient to meet wet-dry and freeze-thaw criteria (see also "Materials specification"). 2. Sufficient cement content to provide 500- to 750-psi compressive strength after 7-day cure at density expected in 95 percent of area. 3. Additional cement requirement to compensate for non-uniform mixing (suggested increase of 0.5 percent).
Construction	1. Mixing and compaction completed within 2 hr after water added to cement-aggregate mixture. 2. Minimum density compatible with mix design (suggested minimum of 95 percent of AASHO T180 or equivalent). 3. Layer thickness no less than 0.05 ft thinner than design section. 4. Provision for adequate curing.

TABLE 12
RECOMMENDATIONS FOR PROCEDURES TO MINIMIZE REFLECTION CRACKING IN ASPHALTIC CONCRETE OVERLAYS ON PORTLAND CEMENT CONCRETE PAVEMENTS

Condition of Underlying Surface	Designer-Controlled Recommendations
Essentially sound; some rocking slabs and faulted joints with minor cracking.	1. Repair or replace expansion joint sealant. 2. Subseal with asphalt or pressure grout with portland cement mortar as required. 3. Place bond breaker (e.g., stone dust, membrane) at joints and cracks. 4. Construct asphalt-treated aggregate cushion course minimum 4 in. thick with 3- to 4-in. leveling and surface layers. 5.[a] Modify properties of asphaltic concrete: (a) Use of fillers, such as asbestos or carbon black, which increase strain at break and reduce temperature susceptibility. (b) Use of asphalt modifiers, such as rubber, which increase strain at break and reduce temperature susceptibility.
Moderately cracked; rocking slabs and faulted joints.	1. Repair or replace expansion joint sealant. 2. Subseal with asphalt or pressure grout with portland cement mortar as required. 3. Seat by heavy rolling, with hammering as necessary to initiate cracking. 4. Construct asphalt-treated aggregate cushion course minimum 4 in. thick with 3- to 4-in. leveling and surface layers. 5.[a] See Item 5 under "Essentially sound" category.
Badly broken	1. Seat by heavy rolling, with hammering as necessary to initiate cracking. 2. Construct asphalt-treated aggregate cushion course minimum 4 in. thick with 3- to 4-in. wearing course. 3. See Item under "Essentially sound" category.

[a] Have not been not been documented by field experience; would require further investigation, but appear to be reasonable.

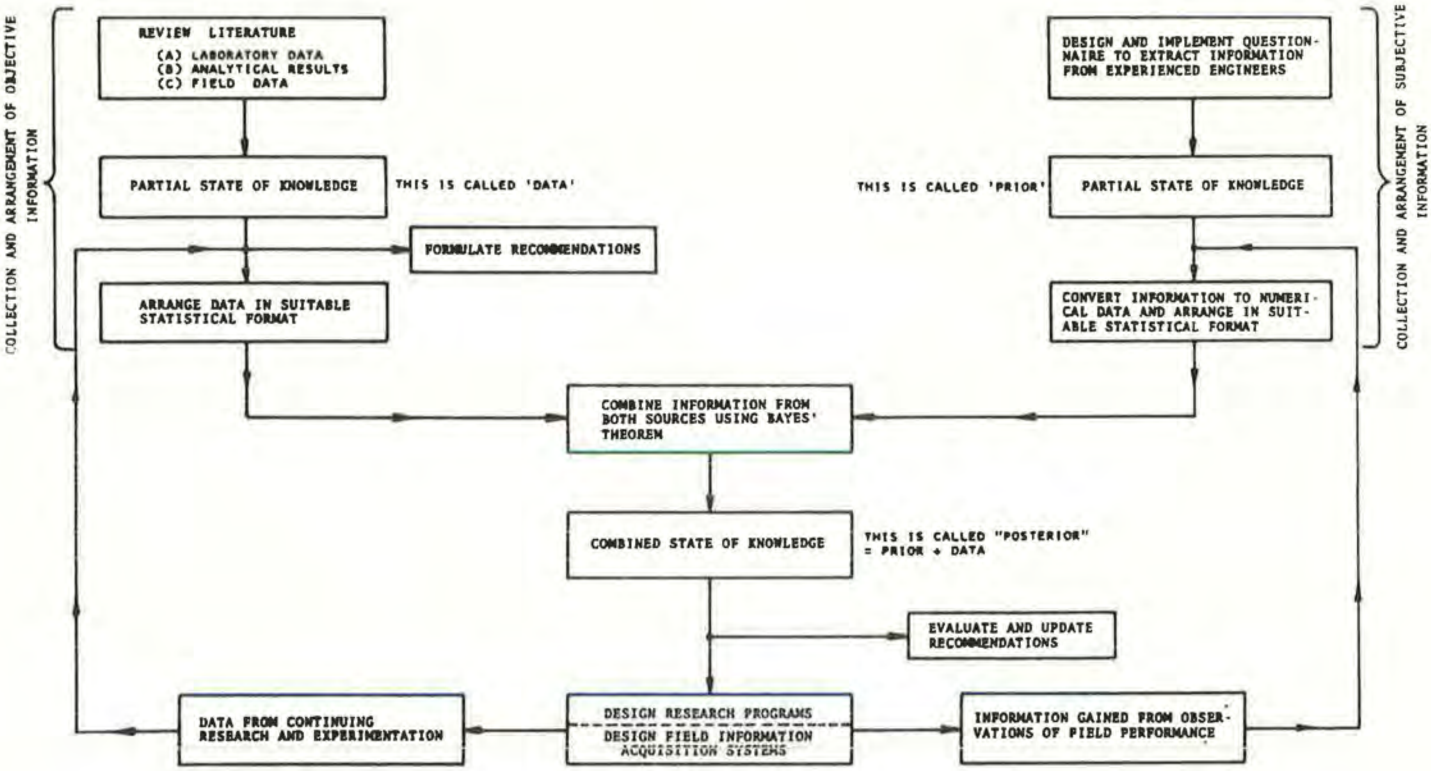

Figure 23. General methodology for combining subjective and objective information to represent current state of knowledge.

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