Final Summary Report
A Study of the AASHO Road Test Phase 1
Performance of Rehabilitated AASHO Test Road

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16. Abstract

This report summarizes the performance of rigid and flexible pavements of the Rehabilitated AASHO Test Road under regular interstate traffic over a period of twelve years. Presented is a brief problem statement, objectives, conclusions, research approach and implementation. A list of reports with abstracts included in Phase I is given.

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FINAL SUMMARY REPORT OF THE PERFORMANCE OF THE REHABILITATED AASHO TEST ROAD

By

R. J. Little

Final Summary Report
Research Study IHR-28
AASHO Road Test - Phase 1

A Research Study Conducted by
Illinois Department of Transportation
Springfield, Illinois 62764
in cooperation with
U. S. Department of Transportation
Federal Highway Administration

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PROBLEM

The AASHO Test Road research furnished two general pavement performance equations, one applying to flexible and the other to rigid pavements. The equations express performances in terms of the number of axle-load applications required to reduce the serviceability level of the pavement to selected values, and relate this performance to the structural design of the pavement and to the magnitude and configuration of the axle load. These equations are necessarily limited in application to the specific pavements, traffic, soils, materials, and environment at the Test Road and must be further modified for application in the structural design and evaluation of highway pavements in regular service.

OBJECTIVES

The general objective of the Rehabilitated AASHO Test Road study is to develop engineering knowledge that can be used in the design of new pavements, in the evaluation and betterment of existing pavements, in the development of optimum economy between vehicles operating costs and the costs of building and maintaining highways. The specific objectives of research for Phase 1 are as follows:

(a) To evaluate the behavior of the surviving original PCC test sections and the new replicate tests sections under regular mixed traffic loadings.

(b) To determine the effects of subbase type on PCC pavement behavior.

(c) To determine the effect of joint spacing on the behavior of transverse contraction joints and pavement panels.

(d) To evaluate the behavior of the resurfaced original flexible pavement test sections.

(e) To determine the effect of base type on flexible pavement behavior.

(f) To determine the effects of different types of mineral fillers on the physical and strength characteristics, and subsequent behavior of asphalt concrete surface and binder courses.

CONCLUSIONS

Mineral Filler Study

Four mineral fillers in dense-graded bituminous concrete (Class I) under investigation were limestone dust, asbestos fiber (Canadian chrysotile fiber Grade 7M, Quebec Standard Test, Quebec Asbestos Manufacturers Association), hydrated lime (ASTM C207-49 Type N Mason's Lime), and pulverized kaolin clay. The limestone dust, hydrated lime, and kaolin clay were used individually in the mixtures; the asbestos fiber was used in combination with limestone dust.

Laboratory tests of samples of the pavements recovered after 5 years service showed no important differences. All pavement of the experimental project showed acceptable service after 8 years, but by the end of 12 years wheelpath rutting in sections with asbestos fiber filler was approximately one-third less than that for the other filler types.

Vehicle-In-Motion Weighing Experiment

The scale system investigated was Cox and Stevens Traffic Research Scale Model TR-2. The system consisted of 4-ft by 12-ft platforms built directly into the road surface and supported by load cells.

The results of this research indicate that the scale system was not capable of serving to provide either dynamic axle weights or acceptable estimates of static axle weights of vehicles traveling at normal highway speeds.

Induced oscillations of the scale platform that masked the recordings of interest were not removable in the attempts that were made, although a filtering

system to compsensate for their presence showed promise. Whatever relationship that may exist between dynamic loadings and static loadings proved to be too complex for estimating static weights from dynamic weights by procedures in this study.

Three separate modifications were made in the original scale system in an effort to control the oscillations of the platform. The first attempt involved preloading the scale platform with a known force, but this approach produced no apparent benefit. The second revision included hinging one side of the platform while supporting the other side by two load cells. This only served to decrease the natural frequency of the platform instead of achieving the desired increase. The final modification was the addition of an electronic filter to eliminate the effect of the undesirable oscillations. This refinement appeared to have merit. Possibly the use of a more sophisticated filter circuit would improve the scale system to a greater degree. Physical problems with the system prevented further exploration.

The physical resistance of the scale system under study was not sufficient to withstand the pounding of the normal traffic mix on what can be considered to be a typical heavy-duty highway. Constant displacement of the load cells supporting the scale platform proved to be a problem that was never overcome. Deterioration and failure of the electronic equipment and circuitry in the scale pits from water and brine action proved to be another problem that was never coped with successfully.

Contraction Joint Study

The Contraction Joint Study consisted of pavement sections from two age groups. One group was the AASHO Test Road rigid pavement test sections built in 1958, and the second group was sections built in 1962 when the AASHO Test Road

was rehabilitated as a part of Interstate 80. The AASHO Test Road sections had sawed, doweled contraction joints spaced at 15 ft (4.57 m) and 40 ft (12.19 m) with pavement thicknesses of 8.0 in. (203 mm), 9.5 in. (241 mm), 11.0 in. (279 mm), and 12.5 in. (317 mm). The sections containing 15-ft joint spacings were plain concrete while the sections containing 40-ft joint spacings were reinforced with welded wire fabric.

Sections built in 1962 also had doweled contraction joints, but they were sawed at 40 ft (12.19 m) and 100 ft (30.48 m). Sections containing 40-ft joint spacings were either 8.0 in. (203 mm) or 9.5 in. (241 mm) thick and reinforced with welded wire fabric. Sections with 100-ft joint spacings were 10 in. (254 mm) thick and reinforced.

Except for one section which was placed directly on the subgrade all the AASHO Test Road sections had a granular subbase, while the sections built in 1962 had either a granular or stabilized subbase. The stabilized subbase was either Bituminous Aggregate Mixture (BAM) or Cement Aggregate Mixture (CAM). From this study the following conclusions were drawn:

1. The cumulative amount of pavement damage, and the maintenance requirement per unit length of pavement increase directly as the number of joints per mile increase.
2. The amount of damage per joint increased as the joint interval increased.
3. Faulting decreased as slab thickness increased and increased as the joint interval increased. Faulting was reduced on the stabilized subbase.
4. The cumulative amount of faulting per pavement mile is greatest on short panel lengths even though they fault less.
5. Winter joint openings in the 100-ft pavement panels on the BAM subbase were large enough to prevent corrosion from freezing the load transfer dowels in place.

6. The best level of service throughout the life of the experimental rigid pavements was associated with the longest joint interval.
7. Uncontrolled transverse cracking was almost eliminated in the 15-ft pavement panels.
8. The formation of major panel cracks was associated with inoperative joints.
9. Corrosion of the load transfer dowels, rather than dowel misalignment, was the cause of inoperative joints.
10. The formation of transverse cracks was reduced in the pavement panels on the stabilized subbases. The reduction was greatest in the 100-ft panels on the BAM subbase.

Rehabilitated AASHO Test Road Pavement Performance

After 12 years of interstate highway service and the passage of almost 26 million vehicles as normal highway traffic, the experimental pavement sections of the rehabilitated AASHO Test Road have been resurfaced with bituminous concrete. The behavior of the test sections has been regularly documented during this period. Where applicable the pavement serviceability-performance concept has been applied in the analysis of the data as a test of the performance equations and to evaluate the behavior of the pavement designs, materials, and pavement structural elements that were included in the experimentation. From these studies the following conclusions seem to be justified:

1. Pavement performance curves are useful in evaluating the behavior of pavement designs, materials and pavement structural elements such as bases and subbases.
2. The performance equation for rigid pavements predicted with reasonable accuracy the service life expectation of the 8.0-in. and 9.5-in. thick rigid pavement sections in the original AASHO Test Road and the duplicate

rigid sections that were built in 1962, but it tended to predict a greater expectancy for the original 11.0-in. and 12.5-in. thick rigid pavement sections than was actually observed.

3. The revised performance equation for rigid pavements fits the observed behavior of the 11.0-in. and 12.5-in. rigid pavement sections about as well as the original equation fitted the original data.
4. The revised equation increases the service life expectation of the 8.0-in. pavements slightly but reduces the expectation for the 9.5-in., 11.0-in. and 12.5-in. pavements by increasing amounts as slab thickness increases in comparison with the original equation.
5. With respect to performance of the rigid pavement sections, no difference in pavement behavior was observed that could be associated with the kind of granular subbase materials that were used.
6. The stabilized-aggregate subbases (BAM and CAM) were effective in improving the performance of rigid pavements over those on granular materials.
7. The improved performances associated with the BAM subbase was ascribed to a difference in subbase drag, which resulted in fewer transverse cracks and in more uniform winter joint openings, particularly in pavements with 100-ft pavement panels.
8. The most important types of rigid pavement distress with respect to pavement performance were transverse cracking, D-cracking, and spalling at the pavement joints and cracks.
9. Corner breaks and compression cracks occurred only in minor amounts.

10. Pavement pumping occurred only in minor amounts.

11. Only one blow-up occurred in the mainline pavement during the study period, and it was not in an experimental pavement section.

12. The flexible pavement sections on a CAM base had the highest RI, and those on a BAM base had the lowest RI.

13. The flexible pavements on a CAM base developed higher RI's earlier in their service life than those on the crushed stone or the BAM bases.

14. The roughness of the CAM base was associated with tenting of the transverse cracks in the pavement surface.

15. Feathered construction joints in the CAM bases were associated with humps in the pavement surface.

16, The rate of rut formation in the flexible pavements tended to decrease with time on the BAM and CAM bases but continued at a high rate on the granular base.

17. The resurfaced flexible AASHO pavement sections proved to be structurally more than adequate for the interstate highway traffic during the observation period. However, the ruts that formed in the wheelpaths were approximately one-half inch deep.

18. On the granular base course, the rutting was confined to the surface course and the base course. It was not apparent in the subbase.

19. Rut depths were reduced on the portland cement concrete base and on the CAM base.

20. Replacement of part of the mineral filler with asbestos fiber in the surface course mixtures reduced the depth of rutting by approximately one third.

RESEARCH APPROACH

Work in Phase 1 was conducted in general according to recommendations of the AASHO Working Committee given in its "Statement of Fundamental Principles, Project Elements, Specific Directions." Plans and specifications for rehabilitating the test facility were started in the fall of 1961, and construction was completed in December 1962 when the rehabilitated pavement was opened to traffic.

Observations and measurements similar to those of the AASHO Test Road were conducted on the rehabilitated pavement sections to relate the effects of mixed traffic axle loadings and the various design variables on pavement behavior. These observations and measurements were pavement condition surveys, surface smoothness measurements, static deflections, traffic classification counts, loadometer measurements, faulted joint measurements, joint width measurements, rut depth measurements, weather data, and pavement maintenance records. In addition to the routine observations, two doweled contraction joints were removed from the pavement for examination, and four trenches were excavated in the flexible pavement to study wheelpath ruts, tented cracks, and humps in the pavement.

In general analysis was made by comparing average values of the data, and by comparing overall behavior of one design to another. In the 12-year span of observations, trends also were used in establishing characteristics of behavior. From the rigid pavement, enough performance data were available to perform a regression analysis. This resulted in a revision of the AASHO Test Road rigid pavement performance equation.

IMPLEMENTATION

Mineral Filler Study

The results of the study provide a good indication that any of the four mineral fillers included in the experimentation can be expected to perform adequately in dense-graded bituminous concrete under environmental conditions such as exist at the site where the AASHO Road Test was conducted in Illinois. The type selected from among the four included in the experimentation can be left to the discretion of the contractor, and the selection that is made will be dependent on the cost of the delivered material, and on the cost of handling at the job-site.

Vehicle-In-Motion Weighing Experiment

No further use of, or experimentation with, a scale of the specific design and hardware components of that covered in this study is recommended.

Contraction Joint Study

The conclusions drawn from this study were based on an evaluation of twelve years of performance data on the joints included in the rehabilitated AASHO Test Road project. The joint spacing was 15 ft (4.57 m) for nonreinforced pavement and 40 ft (12.19 m) for reinforced pavement in the original AASHO Test Road and 40 ft (12.19 m) and 100 ft (30.48 m) for reinforced pavements in the new pavement. The 100-ft joint spacing was the standard in Illinois and several other States during the study period and has remained so for a number of years. The conclusions indicate that the longer 100-ft joint spacing provided the best overall pavement performance. While the amount and severity of both spalling and faulting per joint increased, the accumulative effects of these per mile of pavement decreased as the joint interval increased. The amount of faulting per mile of pavement, which will ultimately require maintenance, decreased as the joint interval increased. Also, the loss in riding quality with time and traffic tended to decrease as the joint

interval increased. The results tend to substantiate the old theory that problems with conventionally reinforced PCC pavements are at the joints, and the fewer joints one puts in, the less problems one has.

In considering implementation of the findings, it is necessary to look at the limitations placed on these findings by the design of the joints under study in combination with advancement in technology that has been made in the area. All joints included in the study were formed by sawing a 1/8-in. wide groove. The sealing of the joints was accomplished with a cold-applied rubber-asphalt material in the 1/8-in. groove. None of the joints remained sealed, which allowed incompressibles to enter. Since the initiation of this study, considerable advancement has been made in joint-sealant materials and in the shape factor of the reservoir to hold these materials. The concept also has been advanced that joint design spacing should be compatible with the material used for sealing the joints and with the environmental conditions under which the joints will serve.

Thus, for implementation purposes, the findings of this study are being interpreted as indicating that transverse contraction joints should be spaced the maximum distance possible that will still be compatible with the type of sealant used and the anticipated maximum opening that will occur during the cold winter months. The findings from this study, combined with information from other sources, have resulted in the following changes in the Illinois Standard Design for contraction joints in PCC pavements.

(1) Require plastic-coated dowel bars for load transfer at joints.

(2) Seal all contraction joints with neoprene compression seals.

(3) Reduce the spacing between contraction joints from 100 ft (30.48 m) to 50 ft (15.24 m).

(4) Reduce the size of welded wire fabric and bar mat reinforcement to correspond with the reduced joint spacing.

(5) Reinforce only the center 35 ft (10.67 m) of pavement between contraction joints.

(6) Revise the specifications for construction joints to require deformed tie bars in lieu of load transfer dowel bars.

Relative to the first change, the findings from this study reinforced other findings that corrosion at dowel bars can cause joint lockup and prevent the joints from performing satisfactorily during pavement thermal length changes. This was demonstrated in the detailed examination of two joints and by the fact that many of the joints in later years failed to open during the cold winter months. Plastic coatings have been shown to prevent corrosion of dowel bars. The use of plastic coating also eliminates the need for the heavy greasing which, on occasion, has caused early faulting at joints due to voids being formed between the dowel bar and the concrete. The application of a light coating of form oil has been shown to prevent bonding of the plastic coating to the concrete.

Relative to the second change, all literature and available product information indicate that the preformed neoprene compression seal is the best and most effective sealant presently available for contraction joints in the new PCC pavement. This type of sealant can be compressed up to 50 percent of its uncompressed width, and should be maintained at least 20 percent compressed throughout its life.

In the third revision, 50 ft (15.24 m) was selected as the maximum spacing between contraction joints that would be compatible with the neoprene compression-type seal with the environmental conditions that exist in Illinois, and at the same time would not adversely affect the as-constructed riding quality of new pavements. To maintain the 100-ft joint spacings it would require a one-inch-wide reservoir and a two-inch-wide compression seal. This would permit a maximum joint opening of 0.6 in. (15.2 mm) in the winter months, which would be compatible with Illinois

environmental conditions but would adversely affect the riding quality. A 1.6-in. joint opening would ride as an expansion joint and would be felt by the traveling public. The 50-ft spacing requires an initial reservoir width of 0.63 in. (16 mm) and a neoprene compression seal 1.25 in. (32 mm) wide. This will accommodate a maximum opening of 0.38 in. (10 mm) in the winter time and still maintain 20 percent compression in the seal.

The fourth change is a natural outgrowth of the adopted closer joint spacing. Pavement reinforcement is required to hold transverse panel cracks tightly together to provide load transfer by aggregate interlock. With shorter panels, the amount of reinforcement needed for this purpose is reduced. Procedures developed by PCA were used to determine the weight of reinforcement for 50-ft panels.

The fifth change, to reinforce only the center 35 ft (10.67 m) of pavement between contraction joints or 70 percent of the pavement area, was adopted as a cost-reduction measure. The cost savings involved in lighter reinforcement and in utilizing only 70 percent reinforcement in the pavement area would partially offset the added cost of doubling the number of contraction joints, dowel bar assemblies, and the addition of the neoprene compression seal. Data collected from this study, from other studies of pavement condition in Illinois, and from some work done by Minnesota show that cracks in PCC pavements mostly develop within the middle one-third of a panel and rarely occur outside the center two-thirds of a panel. Thus, since the steel reinforcement serves only to hold panel cracks together, it serves no useful purpose in the areas immediately adjacent to contraction joints where transverse cracks do not develop.

The final change, to require deformed tie bars in lieu of load transfer dowel bars at construction joints, was adopted for two reasons. First, it permits maintaining a uniform 50-ft spacing between contraction joints without placing an

undue hardship on construction to place headers at the end of a day's paving exactly at the location of a contraction joint. Secondly, a standard practice has been to place loose dowel bars through drilled headers at the end of a day of paving. This has often resulted in misalignment of the individual dowel bars, and the improper functioning of the construction joint as a contraction joint. By tying construction joints with deformed reinforcement bars in a quantity sufficient to withstand shear stresses and by not edging the joint, it will be unnecessary to seal construction joints and should eliminate the problems that have developed at these joints in the past.

PUBLISHED REPORTS WITH ABSTRACTS

1. "A Field Experiment with Mineral Filler," R. J. Little, Illinois Division of Highways, Research and Development Report No. 34A.

Eight years of service experience with four inert mineral filler types in dense-graded bituminous concrete (Class I) in an experimental project at the site of the former AASHO Test Road facility has shown no important behavioral differences attributable to individual characteristics of the mineral fillers. Laboratory tests of samples of the pavements recovered at age five years also showed no important differences. Mineral fillers included in the investigation were limestone dust, asbestos fiber, hydrated lime, and kaolin clay. The limestone dust, hydrated lime, and kaolin clay were used individually in the mixtures; the asbestos fiber was used in combination with limestone dust. All pavement of the experimental project is showing acceptable service at the age of eight years.

2. "Vehicle-In-Motion Weighing Experiment at Restored AASHO Test Road Facility," Edward J. Kubiak and Floyd K. Jacobsen, Illinois Division of Highways, Research and Development Report No. 32.

During the construction of the AASHO Test Road facility, and in the subsequent restoration of the facility for service as a part of Interstate 80,

electronic scales were installed in the pavements to measure the dynamic weights of axles of vehicles traveling at normal speeds in the regular traffic stream. Calibration tests produced inconsistent results, especially at higher speeds, and showed no simple relationship to exist between dynamic and static loadings. Platform vibrations caused serious interference in the oscillograph recordings of axle loads. Several modifications that were made in the system to overcome the interference were unsuccessful. Insurmountable maintenance problems resulting from poor resistance of the scale system to the normal environmental conditions of the site brought about a termination of the study.

3. "The Rehabilitated AASHO Test Road Part I-Materials and Construction," R. J. Little, L. J. McKenzie, and P. G. Dierstein, Physical Research Report No. 51.

The Working Committee for the AASHO Test Road project recommended extending the study of the AASHO Test Road under mixed traffic at the site nearing Ottawa, Illinois. At the close of controlled testing, new rigid and flexible test sections were added as links between the test tangents of the four major loops and as replacement test sections for those which either had failed or were inadequate by interstate standards. New subbase materials introduced under rigid pavement were crushed stone, gravel, bituminous aggregate mixture and cement aggregate mixture, but only new subbase material used under the flexible pavement was gravel. Except for portland cement concrete, base materials such as salvaged crushed stone-special, crushed stone, bituminous and cement aggregate mixtures were similar to those used in the original AASHO Test Road. As a side study, the bituminous surface was altered in several test sections either by adding asbestos to or by substituting hydrated lime and kaolin clay for limestone dust mineral filler. The new experimental highway, which was opened to traffic in November 1962 as a part of Interstate 80, has 84 rigid and 43 flexible test sections.

4. "Behavior of Contraction Joints In The Rehabilitated AASHO Test Road," L. J. McKenzie, R. J. Little, and P. G. Dierstein, Illinois Division of Highways, Physical Research Report No. 75.

Rehabilitating the AASHO Test Road pavement gave an opportunity to examine the behavior of sawed, doweled contraction joints at 15 ft (4.57 m) in non-reinforced pavement overlying a granular subbase with those sawed at 40 ft (12.19 m) and at 100 ft (30.48 m) in reinforced pavements on both granular and stabilized subbases. Behavior for this study represents a change in spalling, faulting, joint opening, D-cracking, transverse cracking and pavement smoothness. Faulting decreased as a joint interval decreased and as pavement thickness increased. Faulting was reduced where the subbase was stabilized. The cumulative amount of faulting per pavement mile was largest for 15-ft panels even though they had the least fault per joint. This fact partly accounts for pavements with 40-ft joints being smoother than those with 15-ft joints. The amount of spalling per mile of pavement increased as the joint interval decreased, although the number of major spalls per joint tended to increase as joint interval and joint opening increased. Transverse cracking between the joints increased as joint interval increased, but it was reduced over a stabilized subbase. The amount of D-cracking per mile of pavement increased as the number of joints and cracks increased and as the pavement aged. The best overall pavement behavior and the lowest Roughness Index were associated with pavements that had the fewest joints, particularly on the BAM subbase.

5. "Performance of Pavement Test Sections in the Rehabilitated AASHO Test Road," R. J. Little, and L. J. McKenzie, Illinois Division of Highways, Physical Research Report No. 76.

The performance of the original portland cement concrete pavement sections from the AASHO Test Road has been studied. Findings indicate that the original

AASHO peformance equation for rigid pavements predicted a greater service life expectation for the thicker pavement slabs than was being observed. To agree with the observed performance, a modified performance equation that slightly increased the performance expectation for the pavement sections 8.0 in. (203.2 mm) thick and reduced the expectation for the pavement sections 9.5 in. (241.3 mm), 11.0 in. (279.4 mm) and 12.5 in. (317.5 mm) thick was developed. Stabilized aggregate subbases, especially the BAM, improved rigid pavement performance. On the BAM subbase, rigid pavement sections developed fewer major cracks and pavements with joints spaced at 100 ft (30.48 m) had the most uniform winter joint opening. Dowel bar corrosion was the primary cause of joint lockup in the rigid pavement test sections.

Stabilized aggregate mixtures, used as the base course in flexible pavements, had variable effects on pavement behavior. On the BAM base, the flexible pavements were smoothest. On the CAM base, transverse cracks formed which tented in freezing weather. On the granular base, area cracking was the primary form of pavement distress and the deepest ruts formed. Rut formation was reduced on the rigid base and the least rutting developed where asbestos fiber filler was used in lieu of part of the filler.