Use of Foamed Asphalt in Recycling of an Asphalt Pavement

ADRIAAN VAN WIJK AND LEONARD E. WOOD

The recycling of pavement materials is a cost-effective and energy-efficient method of reconstruction. Laboratory studies have demonstrated that foamed asphalt can be used with success as a binder in cold recycling. During the summer of 1981, the Indiana Department of Highways constructed an experimental 9.0-mile (14-km) section in which foamed asphalt was used as a binder in cold recycling. The main purpose was to monitor and evaluate the construction procedures and the performance of such reconstruction. The initial concept was to use in-place cold recycling. Due mainly to the inability of the milling machine to reduce the pavement to a full depth of 5 in. (125 mm), the construction procedure was changed. During actual construction the initial pavement was removed in two 2.5-in. (65-mm) layers and the material stockpiled at a nearby central plant. Some additional aggregate was precoated with 4 percent foamed asphalt and mixed with an additional 1.5 percent of foamed asphalt in a ratio of 1 to 3 to form the final base-course mixture. All mixing was done by a twin-shaft pugmill. The final mixture was placed in two layers with a total thickness of approximately 5.5 in. This new base course was overlaid by 1.25 in. (38 mm) of hot asphalt mixture. Tests were conducted before, during, and after construction to evaluate the properties of the mixture and the performance of the recycled layer. The use of foamed asphalt caused no serious problems during construction. Conventional equipment could be used with only small modifications. The recycled pavement could be opened to traffic soon after compaction without any problems. It was therefore also possible to keep the road open to traffic throughout the construction. Foamed asphalt appears to behave as well as a binder in cold recycling. The initial performance of the recycled layer is satisfactory.

Recycling is widely accepted as a feasible alternative to most highway rehabilitation and reconstruction methods. This is shown by the wide interest in recycling at conferences such as the Annual Meeting of the Transportation Research Board, conferences of the Association of Asphalt Paving Technologists, and international conferences on concrete pavements. In comparison with conventional methods such as overlaying or reconstruction with new material, recycling has obvious advantages in that it saves construction materials, energy, and valuable resources.

McKinney (1, p. 12) indicated at the Purdue Road School in 1979 that 94 percent of all paved roads in the United States have bituminous surfaces. This varies from state to state. For instance, bituminous-surfaced roads make up approximately 83 percent of total paved, hard-surface structures under the jurisdiction of the Indiana Department of Highways (1). In any case, the percentage of bituminous roads remains high. It is therefore obvious that the recycling of bituminous pavements is an alternative to be considered in a large number of maintenance projects.

An important aspect of recycling is the savings in energy, especially liquid fuel. The fuel and energy savings aspect was one of the characteristics of recycling that made it so promising after 1973. During the past few years, the emphasis in highway construction has changed from the major concern of energy conservation to the more effective use of limited funds. Halstead (2, p. 1) indicated in 1979 that highway maintenance consumes a maximum of only 3 percent of the total energy used in the United States. Recycling alone will therefore not solve all the energy problems. Inferior construction practices may lead to excessive maintenance cost and energy use. In other words, although recycling has certain advantages over conventional maintenance methods or new construction, the performance of the pavement must also be taken into consideration. This might create a problem for the designer because recycling of bituminous pavements has been used extensively for only the past few years.

The performance of recycled mixtures has been studied in laboratories and has been reported to give very good results (3; 4, p. 68; 5). The only way to verify this is by actual field application. The positive laboratory results have not been completely verified, because of the relatively few cold-mixed, recycled pavements that have been constructed and in actual use for this short time (6). This does not mean that laboratory studies are not important; on the contrary, they give the basic information regarding the composition, performance, and possible application of new methods or mixtures at a relatively low cost. Less than 0.2 percent of highway dollars is spent on research by states and the federal government in the United States (7, p. 9).

COLD RECYCLING WITH FOAMED ASPHALT

Recycling can be divided into two types based on the mixing procedure: cold and hot mixing. Cold recycling is used mainly to construct base courses. The binders traditionally used in the stabilizing of the cold-recycled material are liquid asphalt cement and emulsified asphalt.

Another binder that shows promise as a stabilizer for virgin aggregate and recycled material is foamed asphalt. Foamed asphalt is the material obtained through the addition of a small amount of cold water (usually around 2 percent by weight of asphalt) to hot asphalt cement [usually at about 330°F (165°C)]. This creates an asphalt foam. The expansion ratio is defined as the ratio of the volume of the foamed asphalt to the volume of the asphalt cement. Unfortunately, the asphalt cement does not stay in the foamed state very long. The half-life is defined as the elapsed time (in seconds) from maximum expansion to the time it takes the foam to be reduced by one-half from the maximum volume. The idea of foaming asphalt was introduced by Csanyi of Iowa State University in the late 1950s (3). This method, which produced foam by means of a steam generator, was altered by Mobil Oil of Australia Ltd. in the late 1960s (2).

Foamed asphalt has been used with success to stabilize virgin aggregate and sands in base courses since the mid-1950s (8-10). To our knowledge, there is no reported use of foamed asphalt as a binder in cold recycling in actual application before 1980.

Laboratory research at Purdue University on foamed asphalt and recycling (11,12; 13, p. 361) showed that foamed asphalt can be used in recycling. Foamed asphalt has the advantage over asphalt cement in that it can be used at a lower mixing temperature and over emulsified asphalt because it does not need extensive curing. The strength of the foamed-asphalt mixture relies heavily on the coating of the fines to form a mastic. Research also provided the necessary information for the design of the foamed-asphalt mixture.

As indicated earlier, research can provide information up to a point. Only field application can evaluate the construction procedure and the per-

Figure 1. Location of test road.

formance under actual traffic loads and environmental conditions.

The remainder of this paper discusses the construction of a recycled layer using foamed asphalt with the cold process in Indiana.

CONSTRUCTION OF RECYCLED PAVEMENT USING FOAMED ASPHALT

During 1980 the decision was made by the Indiana Department of Highways to construct an experimental section in which foamed asphalt and emulsion would be used as a binder in cold recycling. The road selected for this purpose was an 8.8-mile (14-km) segment of SR-16 from the junction with SR-231 to the Jasper-White County line. It was a road that was to be resurfaced during the same year. Figure 1 shows the location of the road. The road section was divided into two approximately equal segments. Foamed asphalt was used as the binder on one segment and emulsion on the other.

The main objectives of this experimental section (14, p. 2) were

1. To determine the feasibility and suitability of the use of cold recycling,
2. To monitor the performance of such a pavement under actual traffic and weather conditions,
3. To determine the cost and time required for the project,
4. To determine the interest and ingenuity of the contractors in the project, and
5. To gain experience in the use of foamed asphalt and emulsion in recycling (particularly foamed asphalt in view of the fact that it had not been used in Indiana).

Conventional construction equipment had to be modified in order to produce and mix the foamed asphalt.

Conditions of Initial Pavement

The initial pavement was 18 ft (5.5 m) wide. It showed a few longitudinal cracks, some rutting, some consolidation, and extensive flushing. The longitudinal cracks appeared mostly along the wheel path closest to the centerline. These cracks could have been caused by the lack of internal friction in the sandy subgrade (15) or excessive bending stresses in the wheel path (16, p. 22) or both. None of these pavement defects caused serious performance problems. The flushing created an unsafe roadway in wet weather and required an improved cross section.

The traffic volume, as determined in 1978, consisted of approximately 550 vehicles/day in both directions, including 18 percent trucks.

Original Construction Concept

The plan was to reconstruct the pavement by using the pulverized in-place pavement material mixed with additional aggregate and foamed asphalt as a base course. It was believed that cold, in-place recycling could provide a low-cost, simple construction procedure.

In order to design the recycled mixture and to determine thickness, tests were conducted on cores obtained from the initial pavement. Approximately 100 4-in. (125-mm) cores were taken over the 8.8-mile section.

At first, 24 core samples from 6 sites were analyzed to determine the grading and the asphalt content. The results are given in Table 1. In a second investigation, 8 cores from 4 different locations were analyzed to determine the penetration and the kinematic viscosity of the asphalt cement in the initial pavement. These results are given in Table 2. The average asphalt penetration was 41, and the average viscosity was 460 cSt. Both the penetration and viscosity values had large variances. The average asphalt content was 6.1 percent with a small variance.

Ten extra 4-in. (100-mm) cores were analyzed to determine the resilient modulus at different temperatures and for the top and bottom 2.5 in. (65 mm). There is no significant difference (at $\alpha = 0.05$) between the resilient moduli obtained from the top and the bottom 2.5 in. The average total thickness was 5.8 in. (147 mm). Visual inspection appeared to indicate that the top half had more asphalt than the bottom half. This was not verified through testing.

The plan was to reconstruct the road to a width of 22 ft (6.7 m) by increasing the width by 2 ft (0.6 m) on each side. Excavations had to be made to a depth of 5 in. (125 mm) to extend the 5-in. base course. The excavated material was to be used on the shoulders. Some additional aggregate had to be added to maintain the 5-in. thickness of the base course. Figure 2 shows a cross section of the proposed final pavement.

A thickness of 5 in. of recycled base course and a 1.25-in. (32-mm) hot-mix asphalt concrete surface appeared to be sufficient to carry the traffic on this road. No structural coefficients were available to be used in the design. The selection of the

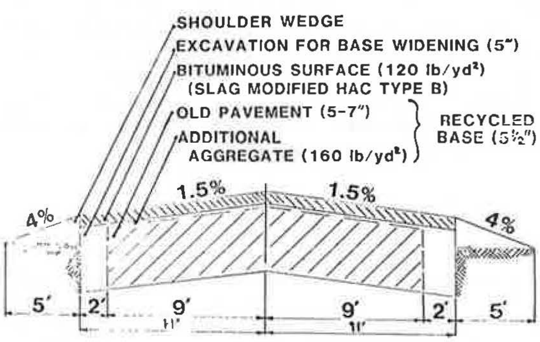
Table 1. Gradation and asphalt content of 24 core samples.

Item	Asphalt (%)	Percentage Retained on Sieve 0.75 in.	0.5 in.	0.375 in.	No. 4	No. 6	No. 200	Percentage Passing No. 200
Avg	6.10	0.83	8.56	16.90	34.50	9.12	25.11	4.39
SD	0.40	1.21	2.89	2.75	2.74	0.89	4.09	0.81
Range	5.06-6.79	0-4.18	4.19-14.72	11.46-21.5	27.39-39.14	7.67-11.14	18.93-37.10	2.39-5.76

Table 2. Penetration and kinematic viscosity of 8 core samples.

Item	Penetration	Kinematic Viscosity (cSt)	Percentage Passing Sieve No. 8	No. 30	No. 40	No. 50	No. 100	No. 200
Avg	41	459.9	28.3	15.1	13.4	11.9	8.6	5.5
SD	12.18	155.47	2.43	1.41	1.09	1.07	0.79	0.41
Range	28-63	195.2-651.4	25.8-33.3	13.4-17.9	11.9-15.0	10.1-12.5	7.3-9.5	4.6-5.9

Figure 2. Pavement cross section.



thickness of the stabilized base was made strictly from a practical viewpoint.

Cold, in-place recycling was specified in the construction proposal. The initial pavement had to be ripped, milled, scarified, or pulverized to a depth of 5 in. to such an extent that 100 percent of the material passed the 3-in. (75-mm) sieve and 90 to 100 percent passed the 1.5-in. (38-mm) sieve. After the excavations on the sides were made, the additional aggregate had to be placed on top of the reduced and shaped material at a rate of approximately 160 lb/yd² (87 kg/m²). The additional aggregate could be crushed stone, crushed blast furnace slag, natural or blast furnace slag, sand, or a combination of these materials that meet a standard specification. A material complying with the specifications of the Indiana Department of Highways for a No. 53 crushed stone would be acceptable, as shown in Figure 3.

The first application of foamed asphalt had to be applied directly to the additional aggregate at a rate of approximately 0.75 gal/yd² (3.5 L/m²) (4 percent by weight of aggregate) and simultaneously shallow-mixed to a depth of not more than 0.5 in. (13 mm) below the additional aggregate layer. A second application of foamed asphalt then had to be applied at 1.0 gal/yd² (5 L/m²) (1.5 percent by weight of material) and mixed to full depth. The hot-mix surface had to be placed on top of the recycled base at a rate of 20 lb/yd² (11 kg/m²). The specifications are summarized in Table 3.

The bid was made on the basis of in-place recycling (14). The unit prices (in 1981) were $0.40 for the shallow mixing, $1.00 for full-depth mixing, and $0.25 for the spreading and compaction of the recycled base. The successful low bidder was A. Metz, Inc. The contractor was given 60 working days to finish the 8.8-mile section. Adjustments to the proportions of the materials could be, and were, made if necessary.

Actual Construction

The construction of the foamed-asphalt section started in August 1981. It was the first experience for the contractor with foamed asphalt.

The contractor got permission to mix the mixed material and the additional aggregate at a central plant instead of in place. The main reasons for this were:

1. The contractor had a mixing plant available approximately 5 to 10 miles (8 to 16 km) from the construction site.
2. The milling machine had difficulty milling to a depth of 5 in. (125 mm) in one pass. The twin-shafted pugmill the contractor originally intended to use was no longer available.
3. The mixing control would be better at a central plant.

During trial runs at the central plant, the proportion of the additional aggregate to be added was changed from 29 percent to approximately 33 percent by weight of reduced material or 25 percent by total weight of material. This small change did not appear to influence the quality of the mixture. No. 53 crushed stone was to be used as additional aggregate. It was readily available to the contractor.

The centerline of the initial pavement was used as reference height. This meant that the transverse slope was measured from the centerline. Thus, the depth of the intended excavation of 5 in. on the sides of the pavement varied because the initial pavement did not have a constant transverse slope.

The construction procedure was changed from cold in-place recycling to cold recycling at a central plant. Figure 4 shows a flow diagram of the construction procedure. The specifications in Table 3 were still valid.

Description of Construction Procedure

The milling was done in two layers in order to keep the road open to traffic during nonwork periods. A CMI rotomill was used. The milling was done by a subcontractor. The pavement also had to be safe for traffic during nonwork periods, and no drop-offs were allowed overnight. First, a 2.5-in. (65-mm) layer was removed. The remaining 2.5 in. of initial pavement was sufficient to sustain traffic during construction. Approximately 8,000 to 10,000 linear ft (2400 to 3000 linear m) of milling of this 9-ft (2.75-m) wide and 2.5-in.-thick pavement layer could be performed in a day. The milling was done to the

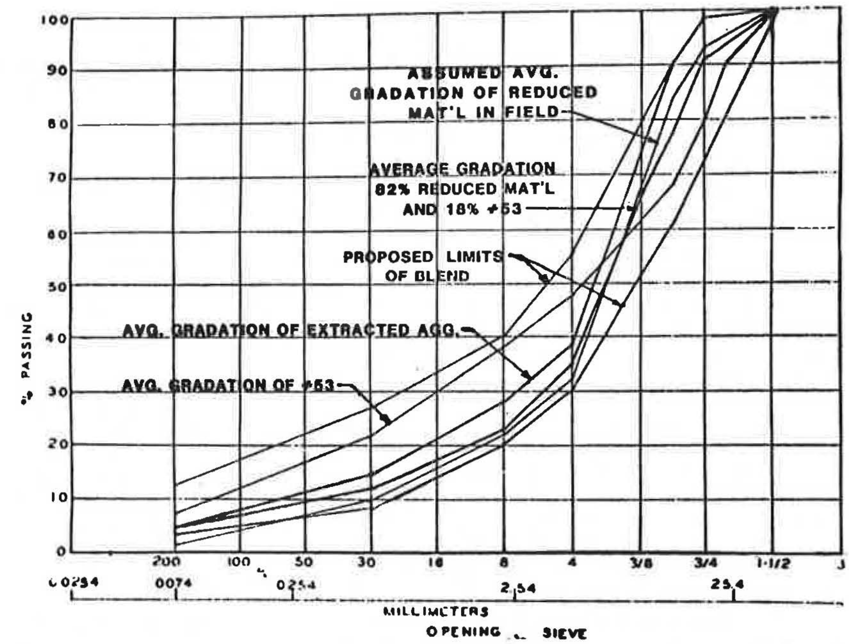


Figure 3. Grading analyses of materials used.

Table 3. Construction and material specifications.

Item	Specification
Foamed asphalt	
Asphalt concrete	AC-5
Mixing temperature	330° ± 15°F
Amount of water	2 percent by weight of asphalt
Expansion ratio[a]	10
Half-life[b]	20 sec
Temperature during processing	>50°F
Milled material	
Maximum size[c]	3 in.
Free moisture during mixing	2.5-3.5 percent
Additional aggregate	
Grading	Meeting Section 903 of ISHC standard specifications
Coarse aggregate	Meeting requirements of class C aggregate
Free moisture during mixing	2.5-3.5 percent
Geometry of pavement	
Minimum thickness of recycled base	5 in.
Construction	Constructed section must be open to two-way traffic during nonwork periods and be graded and compacted

Note: ISHC = Indiana State Highway Commission.

[a]Volume of foamed asphalt/volume of asphalt cement.

[b]Time for volume of foam to reduce from its maximum volume to one-half maximum volume.

[c]90 to 100 percent less than 1.5 in.

width of a lane 9 ft at a time. It was found that the milling was faster and fewer pieces larger than 3 in. (75 mm) were created during cooler weather. The milling was therefore done mainly from early morning (6:30 a.m.) to just after noon (12:30 p.m.). The milled material was hauled to the central plant and stockpiled.

The additional aggregate (No. 53) obtained during the first milling operation was mixed with 4 percent foamed asphalt (by weight of aggregate) and stockpiled. The mixing was done at the central plant with a modified twin-shafted pugmill. Figure 5 shows the process. An old Barber Green twin-shafted pugmill was modified to mix the foamed asphalt. Four large nozzles were installed to spray the foamed asphalt into the mixing chamber. The water was stored in a tank on the ground and pumped under

Figure 4. Construction process.

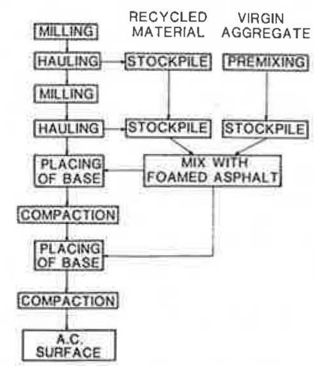
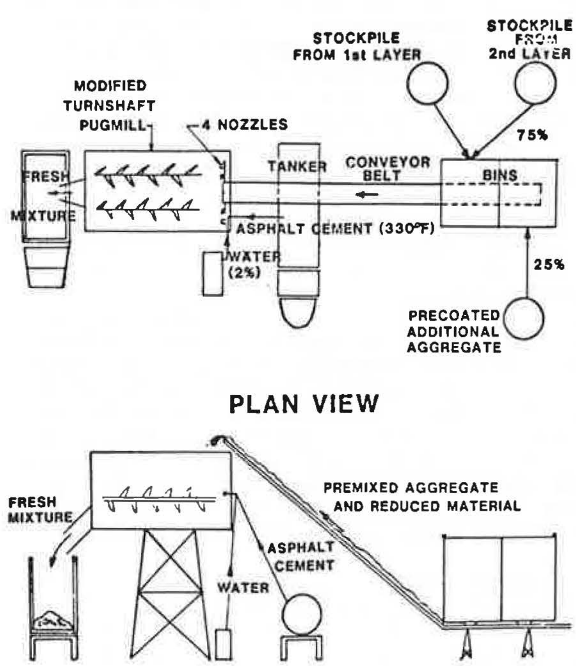


Figure 5. Mixing process.



pressure to the nozzles. The asphalt cement came directly from an asphalt tanker at approximately 330°F (165°C). The asphalt was also pumped to the nozzles, where it came into contact with the water. The mixing time was approximately 45 sec. This modified pugmill can produce up to 240 tons/hr (218 Mg/hr) of a foamed asphalt mixture. The foamed asphalt coated the fines better than the coarse aggregate, as expected, because it relies on the mastic properties of the fines. The premixed stockpile had the color of wet aggregate and not asphalt-coated aggregate.

The second milling operation followed the first one and removed an additional 2.5 in. of initial pavement. An average thickness of 1 in. (25 mm) of initial pavement was left on top of the underlying layers. This protected the subgrade and avoided problems with heavy construction equipment in places where very soft subgrades appeared.

The second milling operation was followed closely, at approximately 1,000 ft (300 m), with the placement of the first 3 in. (75 mm) of the intended 5.5 in. (140 mm) of recycled base course. The placement was done by a conventional asphalt paver to a width of 11 ft (3.35 m), which was the lane width. The 2 ft (600 mm) on the sides was cleared by a motor grader. Because the centerline height was taken as reference height and transverse slope had to be 1.5 percent, no excavations (as originally specified) were made. The paver completed the portion that had been previously milled by the end of the construction day. This provided a graded, compacted, and safe roadway during nonwork periods. Care was taken, through the milling of a few inches at the side of the placed recycled material, to provide a good bond between the recycled material to be placed in the opposite lane and the recycled layer that had already been placed.

The mixture used in the paving operation was mixed in the twin-shaft pugmill at the central plant. The reduced material was mixed with the premixed additional aggregate in the ratio of 3 to 1. The amount of foamed asphalt added was 1.5 percent of the total mixture.

Compaction was started immediately after the placement of the first lift by two passes of a steel roller. This was followed by two passes of a rubber-wheeled roller after a few hours and another two passes of the same roller at the end of the day. Nuclear density tests show that six passes give adequate compaction. Because the road was open to traffic after a few hours, the traffic, and especially the heavy construction trucks traveling to and from the central plant, caused extra compaction.

The placement of the second lift of 2.5 in. to reach a base thickness of 5.5 in. followed the first lift. It was placed and compacted in the same way as the first lift. An uncompacted, placed layer of 4 in. (100 mm) compacted to a thickness of approximately 2.5 in. This is completely different from hot asphalt mixes.

Material from the first and second milling operation was stockpiled in separate piles. Material from both of these stockpiles was used simultaneously in the mixing process to minimize the effect of possible unequal asphalt contents in the top and bottom of the initial bituminous pavement. The mixed material was generally transported directly from the pugmill to the paver to be placed. In a few cases, when some additional aggregate had to be coated, the recycled mixture was stored for a few days.

The placement of the second lift (top) of the base course was followed after about 3 days with an AE-T tack coat of 0.05 gal/yd² (0.25 L/m²) and the hot asphalt surface of 120 lb/yd² (65 kg/m²). A shoulder consisting of one-size material obtained as a byproduct from the production of crushed stone completed the construction. The construction of the foamed-asphalt section, including the milling of the initial pavement, took 20 to 25 days.

Control of Foamed-Asphalt Mixture

The properties of the foamed asphalt were checked before construction, and it was found that a reasonable coating could be obtained by using a half-life of only 12 sec and an expansion ratio of 10. These properties were checked frequently during construction.

It was never necessary to adjust the free moisture content of the material because it was between 2.5 and 3.5 percent most of the time.

Only a small amount of material larger than 3 in. was obtained through the milling operation. No effort was made to remove these pieces because it was assumed that they would be broken down during mixing.

Construction Problems

No serious problems occurred during construction. One minor problem was that, in milling during high pavement temperatures, the milled material stuck together because of the high asphalt content. Another minor problem was that the larger pieces of reduced material were dragged along by the paver and the scars had to be corrected manually.

The biggest problem was raveling during the first few days of placement. Raveling usually appeared on the outside few feet of the pavement. It occurred soon after placement and was initiated by the wheels of the heavy construction vehicles. The reasons for raveling appear to be a low binder content, inadequate compaction for heavy vehicle traffic, and a very soft or improperly prepared subgrade. The existence of some organic material, such as grass, could have prevented proper compaction. The raveling was compacted by the traffic to a distress pattern similar to rutting and was corrected by the placement of either the second lift of base-course material or the surface coat. It was not necessary to remove these sections.

SOME IMPORTANT TEST RESULTS

The main thrust of the research at Purdue University on this project was to determine the structural coefficients of the foamed-asphalt recycled layer. The material properties that were important in such a study were resilient modulus, Poisson's ratio, and tensile strength.

Samples of the mix were taken during construction and were compacted in the laboratory at room temperature by using the California kneading compaction method. Samples were taken at six different positions, and at least six specimens were prepared for each position. All six specimens were cured for 10 days in laboratory conditions [approximately 73°F (21°C)]. Three specimens for each position were subjected to 1-hr vacuum saturation and left under water for 24 hr. Resilient modulus, Hveem R-value, Marshall stability, and flow values were then determined at approximately 73°F for all six specimens by using standard testing procedures. The resilient moduli were also determined for the three unsaturated specimens at 34° and 104°F (1° and 40°C).

After construction, 4-in. (100-mm) cores were taken at 18 positions. Several were taken at each location to obtain a total of 35. It was difficult to get full-sized cores because they tended to crumble or break at the intersection of the two lifts. The cores were cut into three segments: two 2.5-in. (65-mm) specimens representing the first and second lift and one 1.25-in. (32-mm) specimen representing the surface. These specimens were tested in the same way as those prepared from the samples of the mix obtained in the field except that only four were tested under vacuum saturation. It was difficult to get specimens of a proper size from the cores.

Figure 6. Effect of temperature on resilient modulus.

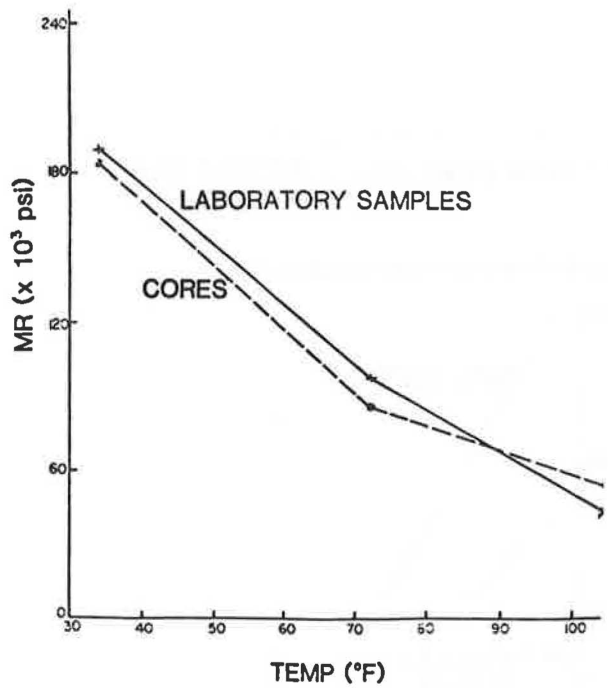
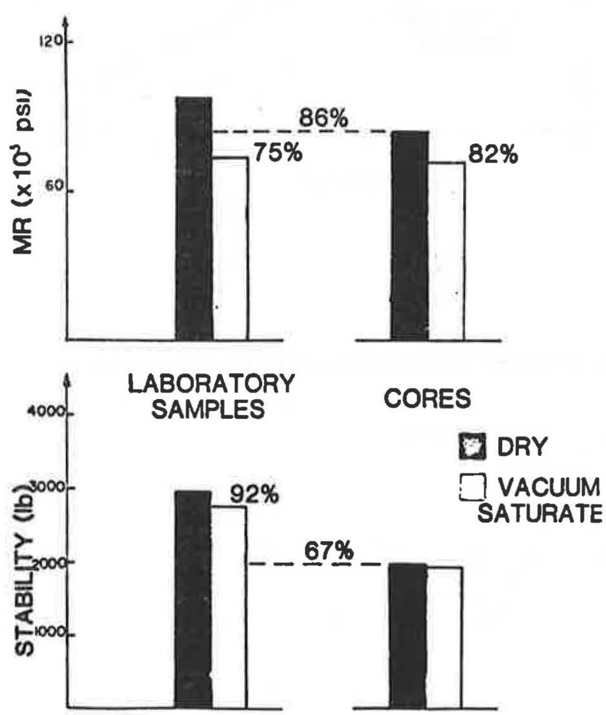


Figure 7. Effect of water on resilient modulus and Marshall stability.



The resilient modulus and Marshall stability values showed no statistical difference at $\alpha = 0.05$ between the two lifts and the position on the pavements for both the laboratory samples and the cores. There is a difference between the resilient modulus of the laboratory-compacted samples and the cores, as shown in Figure 6. This is also true of the Marshall stability. The main reason for this is the difference between the densities of the laboratory samples and the cores, given below:

	Density (lb/ft^2)	
Item	Range	Average
Samples	143-149	147.5
Cores	132-150	138.6

The cores are expected to have lower densities because the Hveem compaction method simulates the pavement densities approximately 4 to 6 weeks after construction and testing 4 weeks thereafter. It was also observed that resilient modulus (stiffness) decreases with an increase in temperature.

Figure 7 shows the effect of water on resilient modulus and Marshall stability. The resilient modulus is reduced significantly (at $\alpha = 0.05$) with the introduction of water. The effect is less pronounced on the Marshall stability of the mixture but is still present. It is therefore important to keep water out of the foamed-asphalt recycled layer through proper side drainage and surface protection.

Another important factor in the stability of the mixture is the compaction moisture content. A definite optimum compaction moisture content exists. The effect of moisture content on the compacted unit weight for the laboratory-compacted samples is shown in Figure 8, which shows an optimum moisture content of 2.4 percent.

Curing time and method have a marked influence on the resilient modulus (stiffness) and the tensile strength of the foamed-asphalt recycled material, as shown in Figures 9 and 10. Maximum curing is intended to represent the condition of the pavement after some time in use under favorable conditions. This was simulated by air curing for 10 days and curing for 50 hr at 140°F (60°C). The 10-day air curing represents the condition of the pavement after a few weeks in use and the 1-day air curing the condition immediately after construction. The results shown in these figures were obtained by testing an extra 18 specimens from a mixture sample taken during construction.

Deflection measurements were taken with a Dynaflect before, during, and twice after construction. The first set of deflection measurements was taken only 12 days after construction and the second approximately 250 days thereafter. Figure 11 shows the Dynaflect maximum deflections before and during construction (on the foamed-asphalt base course). The values have been adjusted for temperature (17). There were no statistically significant differences among the average deflections, but the newly constructed pavement had a higher average deflection than the initial pavement. Based on the maximum deflections, the initial pavement was structurally sound, as was the newly constructed pavement. The laboratory study on the effect of the curing on stiffness (resilient modulus) indicates that stiffness will increase and deflections will therefore decrease over time. This was what happened during the first 250 days after construction (see Figure 12). The deflections decreased and were essentially the same as those before construction. It is not possible at this stage to predict how long this consolidation phase will continue.

Figure 8. Effect of compaction moisture content on Marshall stability.

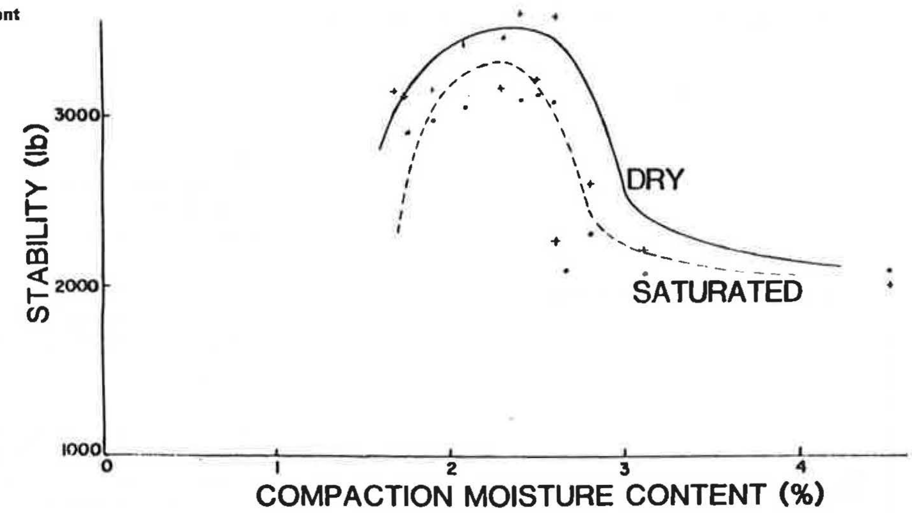


Figure 9. Effect of curing time on resilient modulus.

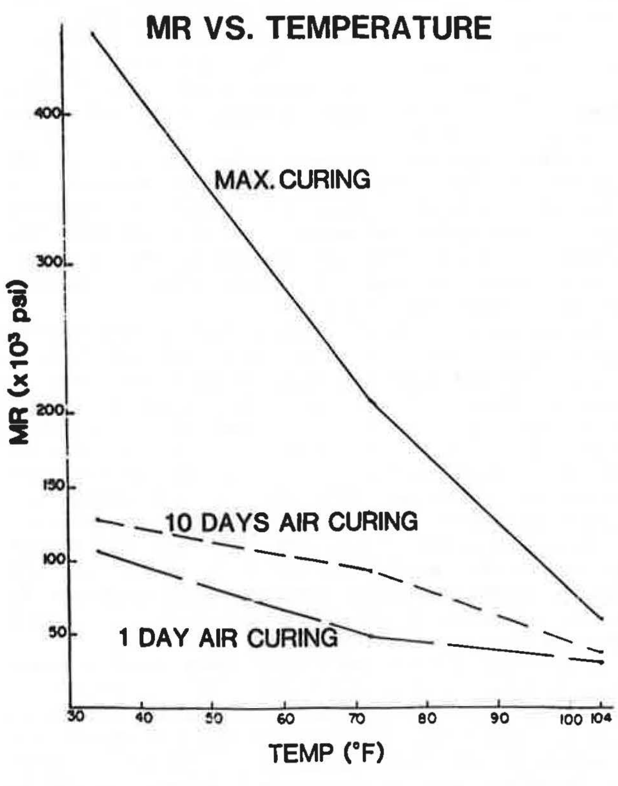


Figure 10. Effect of curing time on tensile strength.

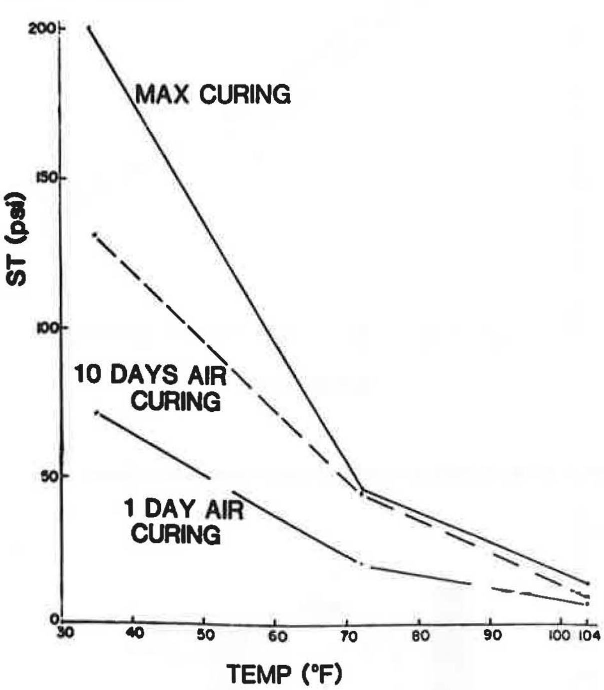


Figure 11. Maximum Dynaflect deflections 12 days after construction.

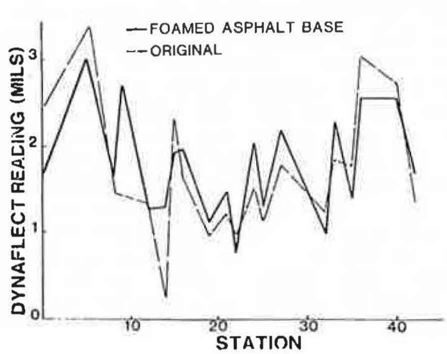
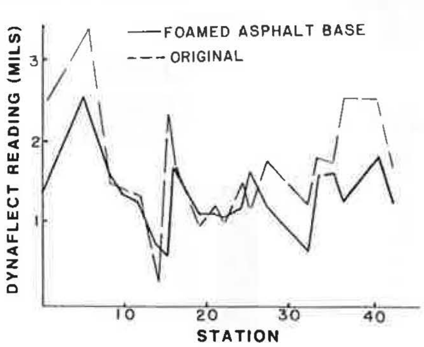


Figure 12. Maximum Dynaflect deflections 250 days after construction.



CONCLUSIONS

Foamed asphalt appears to be an acceptable binder in cold recycling. No major equipment changes had to be made during construction to accommodate the foamed asphalt. Conventional equipment could be used with only minor modifications. The construction procedure could also be kept simple and progress maintained at an acceptable rate. The construction crew adjusted well to the placement of the new material, although they remarked that it was easier to place hot asphalt concrete.

The pavement could be opened to traffic soon after construction and it performed well. Even the heavy construction vehicles had no detrimental effect on the recycled layer.

The importance of the correct moisture content during compaction and the detrimental effect of water on the recycled material must be kept in mind in design and construction.

Test results indicate that the initial and short-term performance of the foamed-asphalt recycled layer is satisfactory. The pavement was still in good condition after 8 months. The surface layer showed some thin cracks at the centerline of the lanes. These cracks appear to be in the surface layer only and not to be caused by the recycled layer. Results from tests show that there is reason to believe that it will behave well in the future, but, as mentioned in the introduction to this paper, this can only be verified by monitoring future and ultimate performance in actual use.

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