Cold Recycling

K. J. Kercher, P.E.
Research Engineer
Research and Training Center, IDOH

The Department of Highways has attempted only two cold recycling projects. The first was constructed in 1978 on SR-32 in Fountain County. The road was rehabilitated with an in-place stabilized base using an emulsified asphalt.

The pavement was ripped with a dozer, windrowed, and crushed in place. Virgin aggregate, 150 lb./sq. yd., was added and 2.3% AE-150 was applied with a distributor. The materials were mixed in place with a rotary mixer. The stabilized material was leveled to a uniform cross section with a grader and compacted. A bituminous coated coarse aggregate base was placed over this and a seal coat was added for a wearing course.

From all the information I have, the project was a success. The roadway was rehabilitated with a minimum of expense and provides satisfactory service for the traffic loads it carries.

The second project was constructed this past summer. The impetus came from some groundwork laboratory investigations conducted at Purdue on the use of foamed asphalt in recycled pavement layers. As an extension of this work the Department of Highways selected a secondary road scheduled for resurfacing during 1981 for a cold recycling project to compare field performance with the laboratory results.

Rehabilitation of the road was divided into two experiments. The east half of the project consisted of a recycled base using emulsified asphalt and the west half a recycled base using foamed asphalt. Details of the emulsion stabilized base follow.

The five main objectives of this project were to:

1. Determine the feasibility and suitability of the foamed asphalt process and cold mix recycling to rehabilitate a roadway.
2. Compare the performance of pavement recycled with different bituminous binders under actual conditions of weather and traffic.
3. Determine the costs of and time required to construct a pavement section by cold recycling.
4. Determine the interest and ingenuity of contractors to accomplish the work.

5. To gain experience in cold recycling of bituminous pavements.

The site selected for the project was an 8.8 mile section on SR-16 in Jasper County, from US-231 to the Jasper-White County line. This is a straight, relatively flat secondary road with a directional ADT of 250 vpd. The road was rutted and bleeding in the wheelpath and badly in need of an improved cross section. The pavement was, however, structurally sound.

A series of cores were taken to determine the composition of the existing pavement. The average asphalt content was 6.1% and very uniform throughout the length of the section. The asphalt residue had an average penetration of 41 but this was quite variable, ranging from 28 to 63. The kinematic viscosity was 460 cSt and again quite variable, ranging from 195 to 650, and the average pavement thickness was 5 in.

Based on an average subgrade CBR of 22, the asphalt institute thickness design procedure called for a 9-in. pavement. This was felt to be excessive since the existing 5-in. pavement had successfully carried the traffic loads for a number of years.

The typical section ultimately chosen called for 5-1/2 in. of stabilized base topped with 120 lb./sq. yd. of dense graded surface. This would give a total pavement thickness of about 7 in. The depth of the stabilized base was arrived at strictly from a practical point of view. It was anticipated the No. 53's would be used for the virgin aggregate. If the existing pavement was pulverized and spread to a 22-ft. width it would provide 4 in. of depth. The minimum thickness that the 53's could be applied was the top-sized aggregate or 1-1/2 in. adding these gives a 5-1/2 in. depth.

The project was let under Contract No. RS-13064 and bid on the basis of in-place recycling. The proposed procedure was to excavate the widening trenches, pulverize and spread the existing pavement across the new width and add 160 lb./sq. yd. of virgin aggregate. AE-150 would be applied at the rate of 1/8 gal./sq. yd. to the surface and shallow mixed with the virgin aggregate. This would be equivalent to adding 4% asphalt to the aggregate. An additional AE-150 of 1% would be applied and mixed full depth. The material was then to be leveled and compacted.

The successful low bidder was A. Metz Inc. of Rensselaer. Just prior to construction the contractor learned that the twin-shafted travelling pugmill he intended to use for in-place mixing was no longer available. Additionally the subcontractor performing pavement reduction could not supply a milling machine capable of reducing 5 in. in one pass. The contractor proposed, and the state agreed to remove the pavement in two layers and haul it to his central batch plant about 5 mi. from the jobsite for mixing.

Since the materials were to be batch mixed, mix proportions needed to be determined. Adding 1-1/2 in. of aggregate amounted to a 3:1 blend of reduced pavement to virgin material.

On the assumption that the central plant pugmill would produce more efficient mixing than in-place, all of the AE-150 was allowed to be added in a single mixing operation. The total asphalt content of the resultant mix would be about 6-1/2%. It was assumed the several percent of the original asphalt had oxidized and hardened and that the effective asphalt content was around 4%. Since 4% asphalt was added to the virgin aggregate and another 1% to the total mix, we assumed an effective asphalt content of from 4 to 4-1/2% in the final product. This is consistant with what is specified for a dense graded hot mix base under traffic.

This project was changed from in-place to central plant recycling due to circumstances which were unforeseen prior to construction.

The pavement was pulverized and removed with a CMI rotomill, transported to the central mix plant and stockpiled. The milling machine had no difficulty in producing a well graded material with a 1-1/2 in. top size. There was a noticeable difference in the gradation between early morning and midday. The machine produced a finer gradation when the pavement was cool. By midday the pavement was heated and had softened considerably and tended to break off in slightly larger chunks. The speed of the milling machine varied with the heat of the pavement but averaged about 40 ft./min.

The contractor was not allowed to leave a drop off between lanes overnight since traffic was maintained on the road all during construction. To accomplish this the top 2-1/2 in. was removed from both lanes for several miles. The bottom 2-1/2 in. was then removed from one lane, only as far ahead as the paver could catch up to by the end of the day. The milling machine could remove material much faster than it could be paved.

Each day the milling crew would start removing the bottom layer at 6 a.m. The paving crew would start placing the recycled mix at 8 a.m. By midmorning the milling crew would have removed enough bottom material for that day and could resume removing the top layer in equal lengths from both lanes.

The one major mistake made on this project concerned stockpiling the reduced pavement. Since in-place recycling was to be used originally, the idea of stockpiling the reduced pavement wasn't considered until the 11th hour. The fact that the asphalt content in the top layer was much higher than the bottom layer, wasn't immediately recognized as a major concern. As a consequence no provisions were made to stockpile the top cut separately from the bottom cut.

In any given day the milling crew removed a considerable amount of both top and bottom layers. This material was all placed in one gigantic stockpile at the plant. The different layers were not randomly spread throughout the pile, however, but were grouped in large areas.

As the mix was produced the chances were great that it would be composed of material from only one layer. If the recycled pavement was to have a uniform asphalt content, equal parts of both layers would be needed in each batch. In retrospect it seems rather simple, but at the time we agonized over the inconsistency of the mix until someone had the good sense to recognize what the problem was.

Unforunately most of the emulsion mix had been placed by the time we caught the mistake and not much could be done except to start stockpiling the layers separately from that point. The one consolation was that the foamed asphalt portion of the project, which could be considered the more important part, was done after the emulsion section was completely finished, and by that time the problem was corrected.

The central plant pugmill was used for mix production. The material were loaded into the cold bins from stockpiles. The contractor was forced to keep one man at the reduced pavement bin constantly, as the material tended to arch over the opening and stop flowing.

This bin had to be filled very slowly so that the material would not compact together. A tremendous amount of abuse was heaped on this particular bin with a sledge hammer throughout the project. A much shallower bin slope coupled with a strong vibrator would be needed in order for the material to feed properly.

The individual bin feeds were set for a 3:1 blend the first day, and verified twice a day thereafter by sampling the belt. Samples were taken twice a day to check asphalt content and gradation.

A 2-1/2-in. scalping screen was placed in the tower to remove oversized material, however, very little oversized material was encountered and these were probably caused by the material clumping together in the cold bin.

Although there was a good deal of rain during construction, no moisture problems were encountered in the stockpiles.

The reduced pavement and virgin aggregate were dry mixed for 5 sec. and wet mixed for 40 sec. The recycled mix was placed with a paver in the same manner as a hot mix. The only difficulty encountered was a tendency for the material to stick to the screed when the paver stopped for more than a few minutes.

Each time the paver restarted a number of tears were made at the surface. This may have added to the unevenness of the final product, but more than anything was a constant annoyance to the paving foreman who also happened to be the company president. Attempts were made to remedy the problem by heating the paver screed, but this was never resolved.

One noticeable difference between this material and a hot mix was that it was quite fluffy when placed. About 4 in. loose were required to get 2-1/2 in. compacted depth. We tried using a pneumatic roller for compaction, but the mix continually picked up on the tires and this was abandoned. All compaction was done with a steel wheeled roller.

The first day the mix was placed, a nuclear gauge was used to determine the number of rolling passes necessary for maximum density. No increase in density was realized after six passes and this pattern was used for the remainder of the work. To get an idea of the uniformity of the material the nuclear gauge was used throughout the job to compare the density obtained.

The biggest problem encountered with the mix was ravelling and rutting. There were a number of isolated areas where the mix really just disintegrated. There were also several areas when this occurred across the entire pavement width for several hundred feet. A number of possible explanations have been suggested for these failures. The real cause was probably a combination of all of them:

1. The haul trucks caused some of the rutting by running on the mix before it was properly cured.
2. When the haul trucks were ordered off the fresh mix they damaged the exposed subgrade in spots and subsequent lays over these areas failed.
3. The mix took several days to cure and develop strength, to the point where traffic would not harm it.
4. Some of the mix produced with the bottom cut was too lean to hold together under loads.

Several steps were taken to remedy these failures, and although not completely successful, did reduce the problem:

1. Haul truck traffic was restricted on the mix until it was several days old.
2. The mix was produced and stockpiled at the plant for several days to allow partial curing before placement. This was a suggestion from a gentleman with the Wisconsin Department of Highways who happened to visit the project.
3. The mix was allowed to lay open behind the paver for as long as possible before compaction.
4. The material was stockpiled more carefully to avoid the inconsistant asphalt content.

The failed areas were all removed and replaced before the surface was applied. In the several areas where the pavement failed across the full width a third 2-1/2-in. layer of recycled mix was placed in order to bridge over the soft subgrade, as this was felt to be the cause of the problem. A dense graded slag surface was placed over the stabilized base material and granular shoulders were added.

In the nearly 9-lane miles place, only one surface failure occurred after construction. In this area the base material sheared apart causing several wide cracks in the surface. Cores were taken every 0.1 mi. in both lanes after the surface was in place. It was difficult to get good full depth samples. No tack coat was placed between the two base layers and the bottom layer tended to stay in the core hole. Attempts to remove the bottom layer generally damaged them beyond repair. From these cores we were able to cut 16 good specimens of the top layer and ten good specimens of the bottom layer. From these samples, density, Hveem stability and asphalt content were determined. Although the sample size was relatively small some interesting differences were noted between the layers. The average density of the bottom layer was 3 pcf more than the top layer. Also the Hveem stability averaged five higher than the top. The asphalt content was 1.3% less than the top layer irrespective of the layer. The average density of the material was 141.7 pcf but was quite variable ranging from 133 to 151 pcf. The average stability was 21 but again ranged widely from 10 to 40. The average asphalt content was 5.92%. The samples taken at the plant during construction showed an average asphalt content of 6.2%.

The gradation of the recycled mix is slightly more dense than the original pavement. From the No. 4 through the No. 200 sieve the gradation falls almost exactly on Fuller's maximum density curve. Comparing the recycled mix gradation to a No. 5-D base, which is the denest hot mix base specified by the department of highways, shows fairly close agreement. The recycled mix has a slightly less 3/8 to 3/4 in. fraction and a slight excess of No. 4 to 3/8 in. fraction.

The strength of the recycled mix was compared to the original pavement with dynaflect tests. A dynaflect test consists of applying a 1000 lb. dynamic force to the pavement at 8 cycles/sec. and measuring the deflection at 1-ft. intervals away from the point of load application. From these measurements, pavement stiffness, the ability of the pavement to distribute loads to the subgrade, and the subgrade support can be evaluated. Both before and after construction, dynaflect tests were performed every 0.1 mi. in both lanes.

Figures one through three depict the results of the dynaflect tests. The shaded areas of these graphs represent where the recycled pavement was an improvement compared to the original pavement. Figure one, the recycled pavement yielded smaller deflections over approximately 75 percent of the project. Pavement stiffness was also improved over 75 percent of the project, as seen in Figure two. Figure three depicts the spreadability or the percent of the load that is distributed to the subgrade. Typically, spreadability ranges from 40 to 60 percent for bituminous pavements. This is generally the case for the measurements on both the original and recycled pavement.

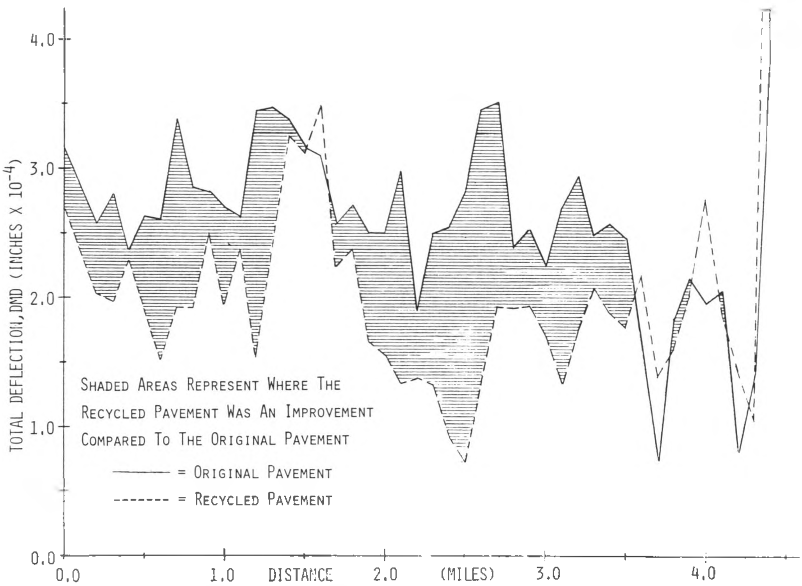

Fig. 1. Total Deflection of Recycled Pavement versus Original Pavement from Dynaflect Tests

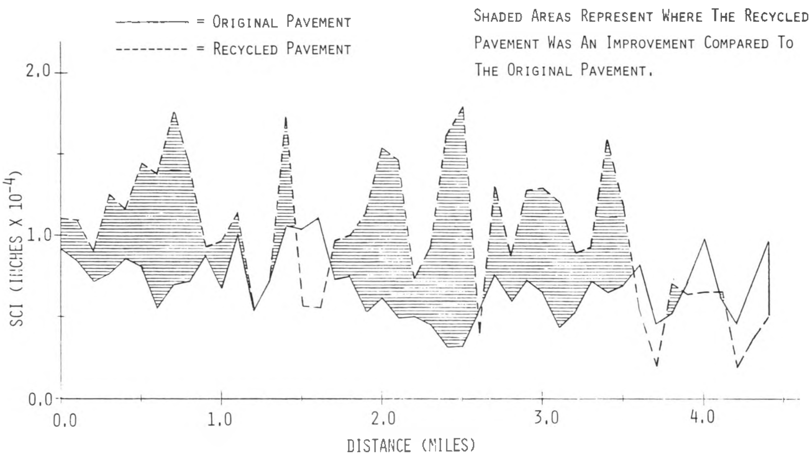

Fig. 2. Pavement Stiffness of Recycled Pavement versus Original Pavement from Dynaflect Tests

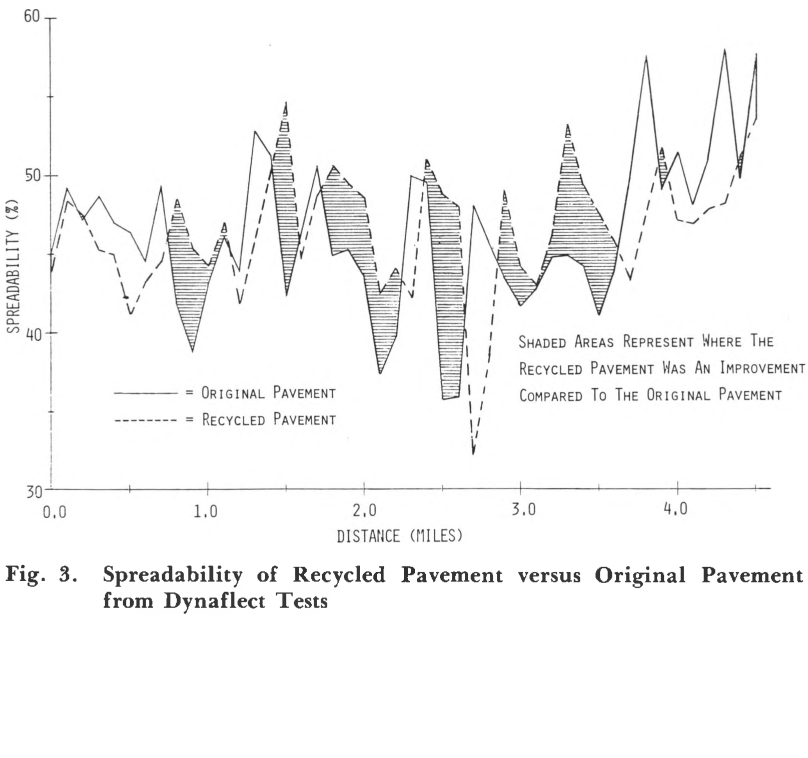

Fig. 3. Spreadability of Recycled Pavement versus Original Pavement from Dynaflect Tests