Cold In-Place Recycling for Rehabilitation and Widening of Low-Volume Flexible Pavements in Indiana

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A rural road in Indiana was selected for rehabilitation and widening in 1986. The project was carried out as a study to investigate the feasibility of using cold in-place recycling in the state of Indiana. The highway selected was a 20-ft-wide low-volume road. One-half of the 9.85-mi project was cold in-place recycled and widened to 24 ft, and the other half was widened in the conventional way by adding 2-ft-wide strips on each side of the existing roadway. The entire pavement was then overlaid with hot mix bituminous mixture. An evaluation after 5 years in service indicates that the recycled half of the highway is performing better than the conventionally treated half. Field investigations indicate less distress and an absence of widening cracks on the recycled pavement. Laboratory tests on the field cores also indicate a generally better pavement condition in the recycled half. The other half of the pavement is showing serious distress in the form of widening cracks reflected upward and some alligator cracking. This half of the pavement will need rehabilitation much earlier than the recycled part.

A cold in-place recycling project was carried out in 1986 on SR-38 in Indiana as part of a widening and resurfacing procedure. The project involved recycling the base layer while widening it from the existing width of 20 ft to 24 ft and topping the surface with hot mix asphalt. An adjacent section of the same highway was widened and resurfaced the conventional way. Two-ft-wide strips of bituminous mix were added on each side of the pavement before resurfacing the entire surface with hot mix asphalt. This paper reports on the performance of the two pavement sections after 5 years in service.

The recycled pavement has performed well and is in better condition than the highway section that received the conventional treatment. The project indicates that cold in-place recycling is a feasible alternative for rehabilitation of low- to medium-volume roads.

PROJECT DESCRIPTION

A 9.74-mi section of SR-38 in Indiana was selected for rehabilitation using cold in-place recycling in 1986. The Research Division was called in to study the pavement after the contract had been let. The section was due for rehabilitation work, which was to include widening and resurfacing the entire length from the existing 20 ft to 24 ft. SR-38 was a two-lane, low-volume rural highway with about 1,500 vehicles per day in 1981, which has since increased to about 1,900 vehicles per day. The location of the site is shown in Figure 1 (*1*).

The section was divided into halves of 4.87 mi each; the western half received the standard widening treatment, which included adding 2-ft-wide strips of bituminous mixture on each side of the existing 20-ft-wide roadway. The strips were laid in a prepared trench and then compacted flush with the existing pavement edge. The eastern half of the pavement section was milled to a depth of about 6 in. and recycled in place on the road surface as a 24-ft-wide base layer. The entire pavement was then resurfaced with hot mix bituminous mixtures. The cross sections of both treatments are shown in Figure 2. An initial report about the project was first published in 1988 (*1*), from which further details can be obtained.

The comparisons made and conclusions drawn here refer to the composite pavement sections rather than individual layers because of the differences in cross sections. It was believed that this comparison would be useful in helping the department choose between the two rehabilitation strategies. The total depths of the two pavement sections are approximately the same, although they are composed of different materials. The deflection data, discussed later, indicated that the pavements were roughly equivalent in structural strength at the time of construction.

The purpose of this study was to evaluate the efficiency of cold in-place recycling and the structural strength and performance of the resulting pavement structure compared with the conventional widening and resurfacing treatment used in Indiana.

EVALUATION TECHNIQUE

The evaluation was carried out in two stages. The first was the nondestructive testing in the field. The field tests formed the basis for selecting the good and bad sites and characterizing the performance of the pavement. The second stage was the destructive testing of the field cores, which was carried out entirely in the laboratory to determine the characteristics of the materials that made up the pavements.

A technique had to be selected to obtain the optimum information to perform an effective evaluation. The choice was between randomly testing the entire pavement in the study and taking samples from representative locations of the pavement. It was decided to select a good and bad pavement section from each half of the project and conduct the eval-

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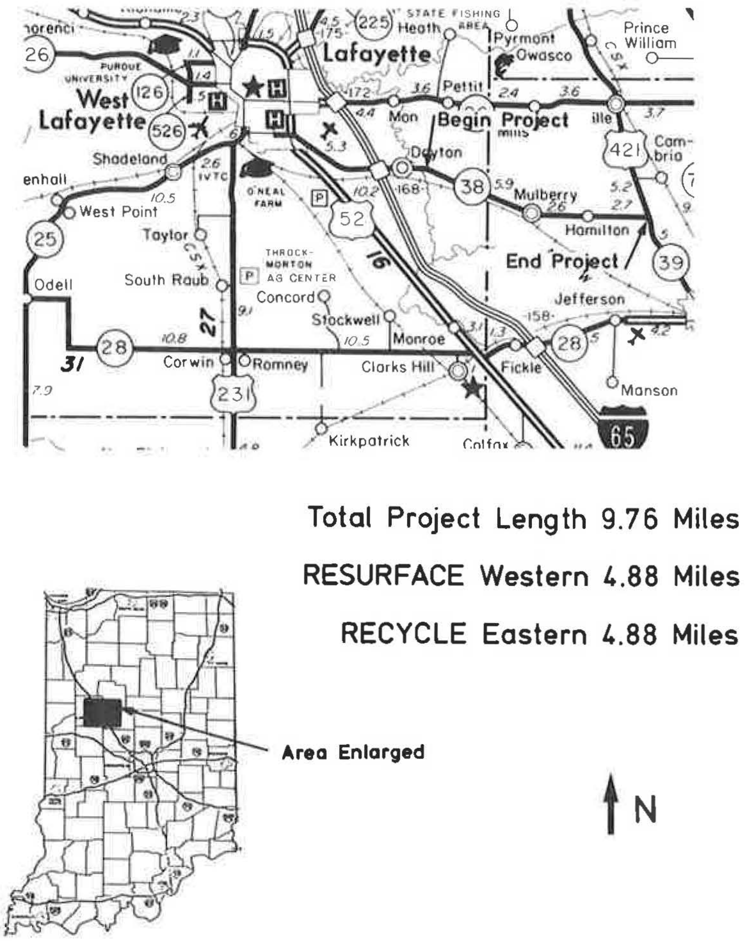

FIGURE 1 Location map.

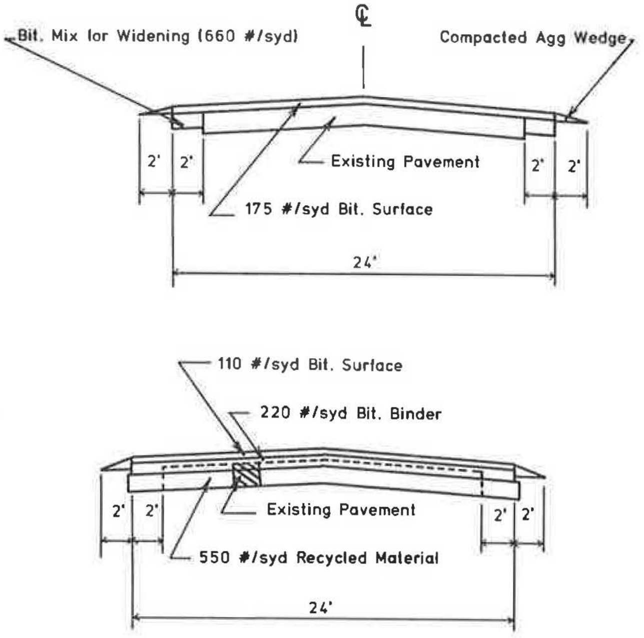

FIGURE 2 Typical cross sections: *top*, resurfaced pavement; *bottom*, recycled pavement.

uation on them only. In this way it was thought that the entire pavement would be represented within the best- and worst-performing pavement sections that were selected, and thus a more meaningful comparison could be made between the recycled and nonrecycled halves of the project. The question that remained was what criteria to use to select these sections.

Since the whole pavement was Dynaflect tested every year as part of the monitoring activity by INDOT, these data were readily available to be used as a criteria for identifying the best- and worst-performing sections. Dynaflect tests are nondestructive and reveal the structural integrity of the pavement system and its support layers. The deflection basin W1 (*2*) was used as a basis in this selection because that reflects the pavement support conditions relevant to this study.

A summary of the 10 best and worst Dynaflect W1 values for tests carried out in 1990 is presented in Table 1. The table indicates that there are good as well as bad representative sections in both halves of the pavement in the study. Thus the likelihood of having biased or skewed the data by selecting exceptionally good or bad sections in that particular half is minimized. The entire Dynaflect data set was tested for normality using the chi squared test, and the coefficients of kurtosis and skewness obtained indicated a normal distribution.

TABLE 1 SUMMARY OF 10 BEST AND WORST DYNAFLECT SECTIONS

	RECYCLED SECTIONS				RESURFACED SECTIONS			
	E-BOUND STATIONS	W1	W-BOUND STATIONS	W1	E-BOUND STATIONS	W1	W-BOUND STATIONS	W1
WORST	177	154	182	139	95	153	62	186
	186	139	157	132	100	145	63	167
	173	136	167	131	62	134	92	149
	182	134	164	128	61	134	100	145
	164	132	181	122	92	129	94	145
	168	128	154	120	93	128	61	143
	184	124	160	118	69	123	95	139
	143	124	178	118	111	121	99	134
	136	123	138	115	63	120	26	128
	135	112	173	115	89	118	93	126
BEST	140	58	168	64	98	66	65	64
	224	56	202	64	19	66	24	63
	206	56	204	64	101	64	20	57
	227	55	132	63	45	64	7	56
	130	53	201	61	36	57	34	54
	155	51	219	58	7	57	4	53
	131	51	130	56	34	56	1	52
	204	48	245	55	3	56	3	51
	226	48	223	48	6	52	5	49
	129	46	131	48	4	51	6	46

SAMPLING

Another factor included in the study was wheel location. Samples were taken from the wheelpath and from outside the wheelpath. This factor was included to investigate the effect of wheel load on the strength and material characteristics of the pavement.

Thus there were three factors in the study: pavement type (recycled or resurfaced), condition (good or bad), and location (wheelpath or outside). Each was present at two levels, resulting in a 2^3 factorial design of experiment. A layout of the design of experiment is given in Table 2. At each location that was selected, at least six 4-in.-diameter cores were obtained; three cores were taken from the wheelpath and three more from outside the wheelpath. The cores were sliced into their respective pavement layers before testing. A complete analysis was carried out on all the cores obtained.

FIELD EVALUATION

A plot of the Dynaflect values at the selected test locations is shown in Figure 3. The best and worst Dynaflect data (W1) for the recycled half are much lower than those from the nonrecycled half. Lower deflection values indicate better pavement strength. When tested shortly after construction, the deflection values on the recycled section were only slightly lower than the values on the resurfaced section (*1*), indicating that the two pavement structures are roughly structurally equivalent.

TABLE 2 LAYOUT OF SAMPLING DESIGN

TYPE / CON-DITION	RECYCLED		CONVENTIONAL	
	W/PATH	O/WPATH	W/PATH	O/WPATH
GOOD	A	C	E	G
BAD	B	D	F	H

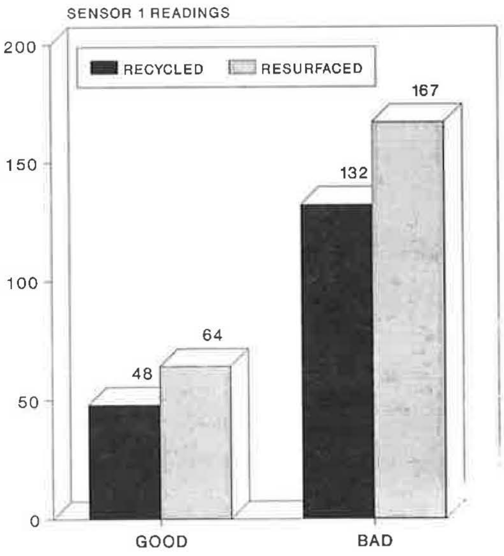

FIGURE 3 **Dynaflect values of test sections.**

A pavement condition survey was also carried out at each of these locations using the method of the U. S. Army Corps of Engineers (*3*). This survey takes into account every visible distress and quantifies them according to a standard that yields an index called the Pavement Condition Index, or PCI. The PCI is measured on a scale of 1 to 100, where the higher number represents a better pavement. The results of this survey are given in Table 3, and a plot of the PCI values is shown in Figure 4. Figure 4 shows that the recycled pavement on the whole is performing better. The PCI value on the bad section of the recycled pavement is slightly higher than the good section, which can be attributed to variations in measuring distress, since only the selected sites were surveyed. Also, the PCI is a surface performance rating, which does not necessarily correspond to the Dynaflect measurements of structural strength. The major distresses in the recycled sections were low levels of transverse and longitudinal cracks and rutting, whereas in the nonrecycled section the predominant distresses were medium to low levels of widening cracks along the joint, transverse and longitudinal cracks, and rutting. Some low levels of alligator cracking were also observed in the latter. Visually, the nonrecycled section is showing more prevalent and more severe distress.

LABORATORY EVALUATION

In the laboratory, several tests were conducted to obtain characteristics of the pavement and its materials and to evaluate them with regard to performance. The tests included bulk specific gravity of cores (ASTM D2726-89), Marshall stability (ASTM D1559-89), maximum Rice specific gravity (ASTM D2041-90), quantitative extraction of bitumen from bituminous paving mixtures (ASTM D2172-88), recovery of asphalt from solution by Abson method (ASTM D1856-79), pene-

TABLE 3 TEST RESULTS

Core #	Dynfl	Ave. Marsh	Pen.	KinV	Rut Depth	% Air Void	Asph. %	PCI	RICE Sg	Ave. Bsg
A31	48	1035	18.0	814	0.25	7.9	5.91	70	2.501	2.3031
B31	132	1029	20.0	772	0.25	6.3	6.10	75	2.469	2.3141
C31	48		19.5	831	0.25	7.6	6.65	70	2.484	2.2937
D31	132	748	23.0	685	0.25	7.7	6.07	75	2.481	2.2897
E31	64	631	21.0	669	0.25	5.5	5.57	59	2.514	2.3753
F31	167	703	25.5	576	0.25	4.4	5.42	57	2.506	2.3960
G31	64	548	21.0	676	0.25	7.6	5.16	59	2.517	2.3252
H31	167	711	25.0	581	0.25	5.7	5.43	57	2.513	2.3701
A32	48	1151	18.0	874	0.25	3.4	4.59	70	2.477	2.3928
B32	132	1043	27.0	594	0.25	3.1	5.09	75	2.503	2.4241
C32	48	1131	20.5	832	0.25	1.6	5.32	70	2.445	2.4059
D32	132	1396	21.0	727	0.25	2.8	4.51	75	2.490	2.4206
E32	64	720	14.5	1121	0.25	8.1	4.77	59	2.450	2.2509
F32	167	493	20.0	739	0.25	7.8	5.19	57	2.457	2.2639
G32	64	603	15.0	915	0.25	7.9	4.92	59	2.463	2.2687
H32	167	459	22.0	808	0.25	7.4	5.74	57	2.445	2.2631
A33	48	575	27.0	701	0.25	7.9	7.28	70	2.427	2.2347
B33	132	525	33.5	591	0.25	7.1	6.88	75	2.451	2.2757
C33	48	519	29.5	688	0.25	6.2	6.34	70	2.416	2.2656
D33	132	477	27.0	709	0.25	8.3	6.09	75	2.470	2.2641

tration of bituminous materials (ASTM D5-86), and kinematic viscosity of asphalts (ASTM D2170-85). The test results are summarized in Table 3. The base layer of the recycled pavement was analyzed and not the base of the nonrecycled pavement, because that was the old pavement. Only the average results are given for each test, which was conducted in duplicate or triplicate according to the ASTM test methods mentioned. Appropriate plots have been made to elucidate the superior performance of the recycled pavement given in the next section.

ANALYSIS OF RESULTS

The test results obtained in this study are in agreement with previously published reports (*4,5*) that cold in-place recycled pavements perform well and are viable for medium- to low-traffic-volume highways. In addition, they are stiffer and hence perform better than conventional pavements (*5,6*). Figures 3 and 4 show plots of Dynaflect and PCI data, respectively, confirming these findings. The higher PCI values also point to a more structurally sound pavement system.

A plot of penetration values of recovered asphalt from the surface, binder, and base layers is shown in Figures 5, 6, and 7, respectively. A comparison is also made for samples from the wheelpath and from outside the wheelpath. The general trend is for the bad sections to have higher penetration values in the surface and binder layers. Soft asphalt in these areas may contribute to greater rutting there. There is no obvious trend in the base layer. The asphalt from outside the wheel-

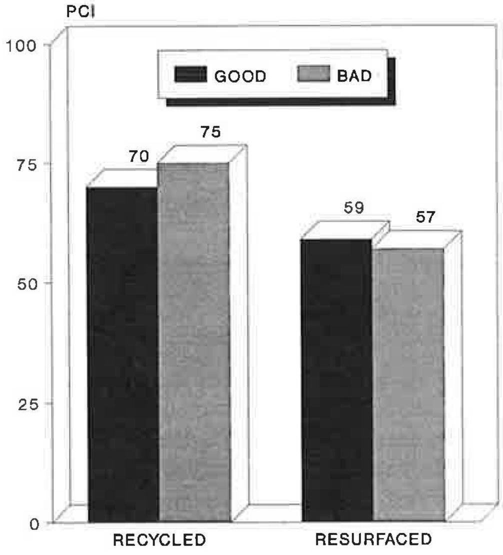

FIGURE 4 PCI values of test sections.

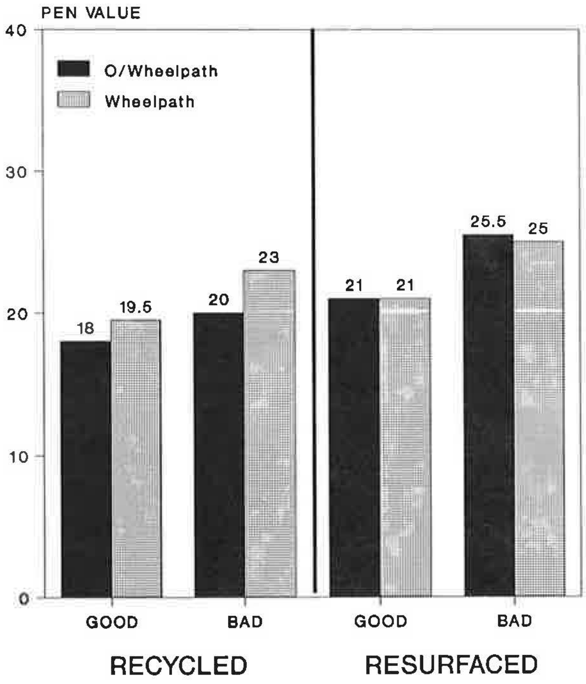

FIGURE 5 Penetration of surface.

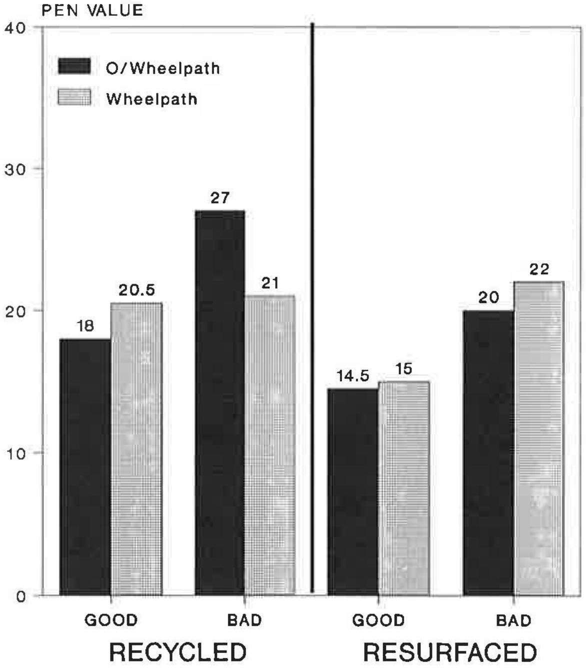

FIGURE 6 Penetration of binder.

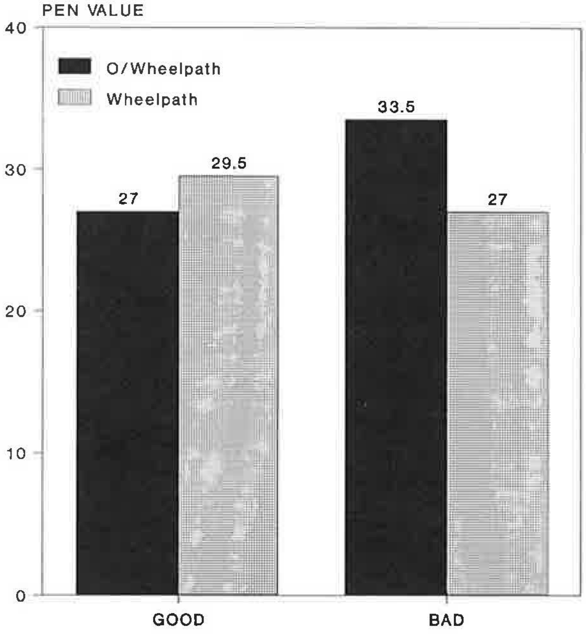

FIGURE 7 Penetration of base.

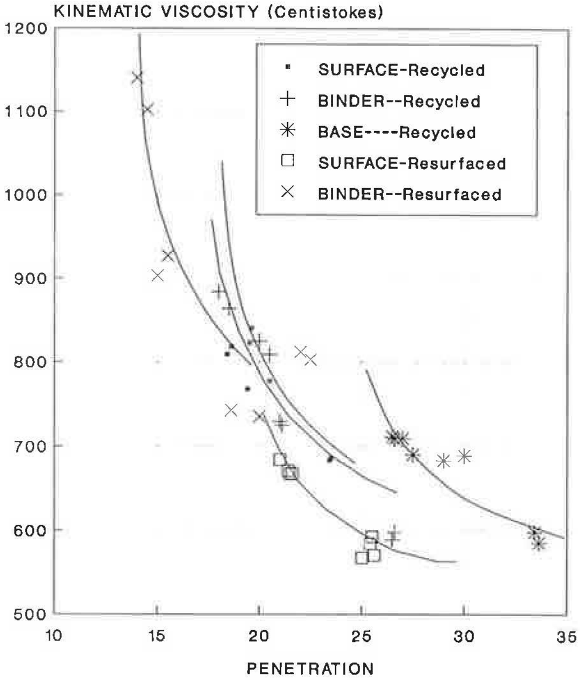

FIGURE 8 Penetration versus kinematic viscosity of recovered asphalt.

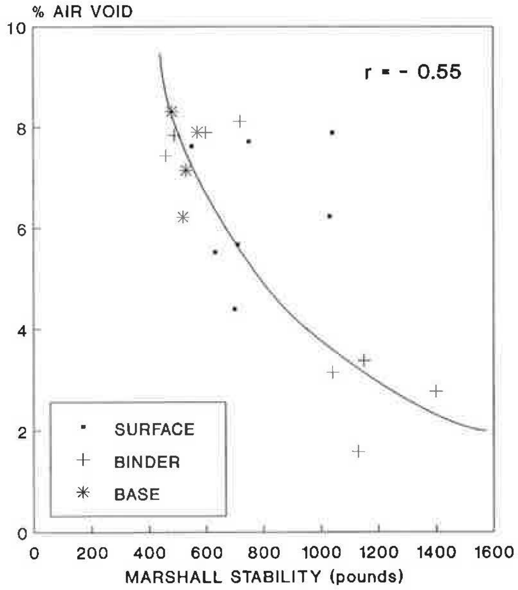

FIGURE 9 Relationship between Marshall stability and air void content.

path generally has lower penetration values, perhaps because it is less traveled and hence has more air voids that allowed more oxidation to occur. Figure 8 shows the predictable result of penetration versus kinematic viscosity, and the relationship for each layer is similar, forming almost parallel curves.

A plot of Marshall stability versus percentage of air voids in Figure 9 shows another expected result. Lower air void content corresponds to higher Marshall stability, because the pavement is more compact and dense. The higher Marshall values also correspond to the recycled half of the pavement, where distress is lower. A plot of the Marshall values is shown in Figures 10 through 12 for the different locations. Figure 13 shows the relationship of penetration versus Marshall stability, where higher penetration, hence softer asphalt, produces lower Marshall stabilities. All these plots verify earlier expectations for recycled pavements and conform with field evaluation.

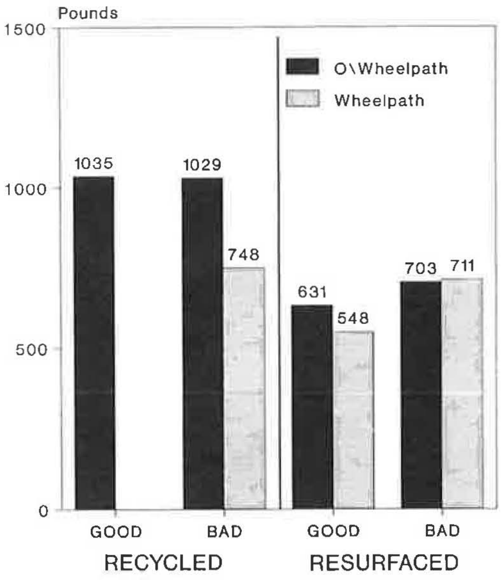

FIGURE 10 Marshall stability of surface.

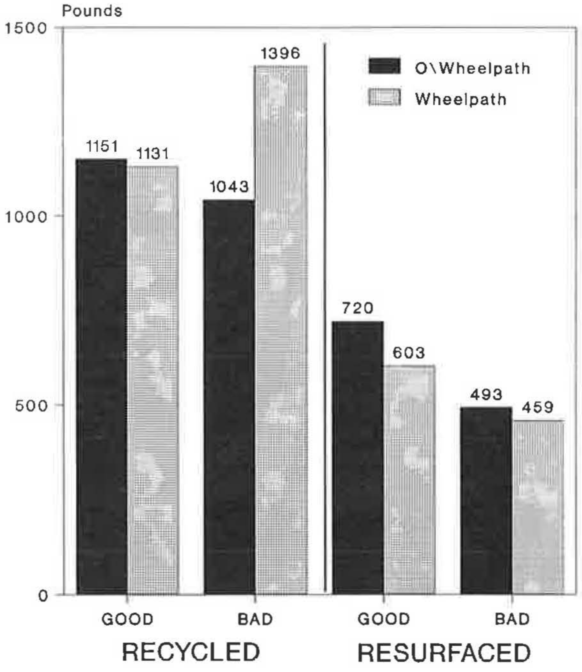

FIGURE 11 Marshall stability of binder.

The tests indicate that after 5 years in service since cold in-place recycling, the pavement is in very good condition and is performing better than the pavement that received the standard conventional resurface treatment. The laboratory and field observations indicate that the pavement will last at least another 5 years before major rehabilitation work is required. The western half of the project, which received the standard treatment, is showing greater distress and will need treatment much sooner.

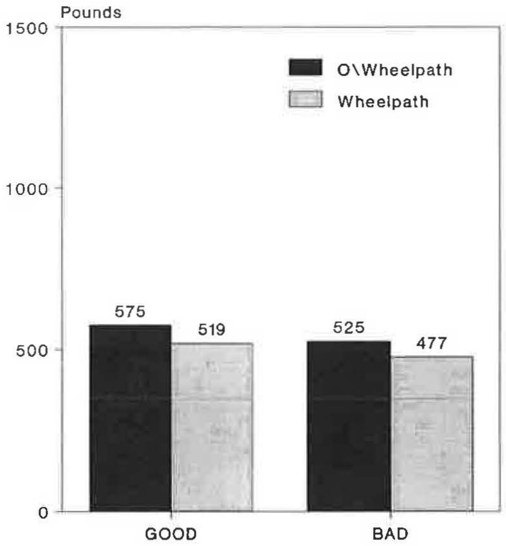

FIGURE 12 Marshall stability of base.

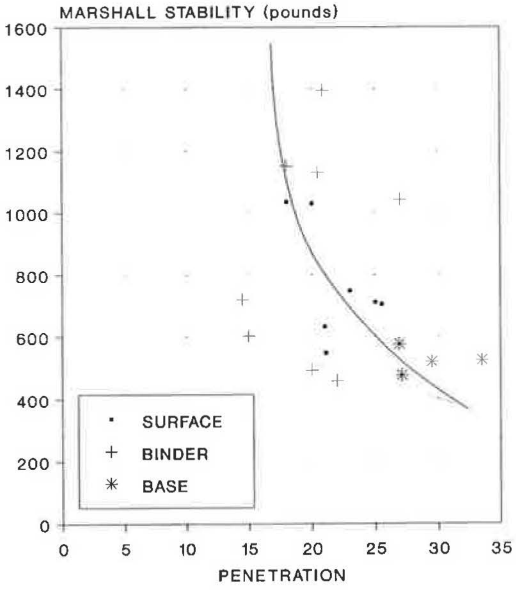

FIGURE 13 Relationship between Marshall stability and penetration values.

CONCLUSION

The cold in-place recycling project constructed on a trial basis in 1986 on SR-38 in Indiana can be called a success, because after 5 years in service it has been shown to perform better than a stretch of initially identical pavement that was rehabilitated conventionally. The recycled pavement shows less distress and has a better PCI and greater support values from the Dynaflect tests than the other. It has needed very little maintenance work since construction ended and still performs well. Test results confirm findings by other researchers about similar projects and indicate that this technique is indeed an alternative for rehabilitating medium- to low-volume asphalt pavements.

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