Rural Cold Recycling

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Rural cold recycling in two eastern national parks is discussed and recent data are presented on a reevaluation of the existing pavement on one project. The first project discussed was built in the Cape Cod National Seashore Park in Massachusetts. This project consisted of recycling an existing pavement in place for use as a base material for a new bituminous concrete pavement. The roadway was closed to traffic during the construction except for emergency traffic. This project was successful and presented no problems. The second park project consisted of recycling an existing bituminous pavement after removal in Catoctin Mountain Park near Thurmont, Maryland. Part of this project used an emulsion as a compaction aid for the recycled material, which was used as a stabilized base under the new pavement. This project had a number of problems. The results of recent Dynaflect measurements and pavement core evaluations are discussed and compared with earlier measurements and the original mix design data.

The existing pavement structures on the two roads discussed were as follows:

1. Moor's Road
   a. 7.5 cm (3 in) bituminous concrete
   b. 7.5 cm sand-asphalt
   c. 15 cm (6 in) sand-clay mixture
   d. Sand subgrade
2. Province Lands Road
   a. 10 cm (4 in) bituminous concrete
   b. 5 cm (2 in) sand-asphalt
   c. 5 cm sand-asphalt
   d. 15 cm sand-clay mixture
   e. Sand subgrade

The 15.0 cm and 20.0 cm (8 in) of existing hot mix on these two roadways were cold recycled in place and covered with 6.25 cm (2.5 in) of hot bituminous concrete to complete the new pavement structure.

The recycling was accomplished by scarifying, windrowing, pulverizing, reshaping, and compacting. Figures 1-4 show the condition of the roadway before recycling, after construction in 1979, and in June 1982.

It was estimated that $38 000 or $10 810/km

Figure 1. Transverse cracks in existing pavement prior to construction, Cape Cod National Seashore Park, Oct. 1978.

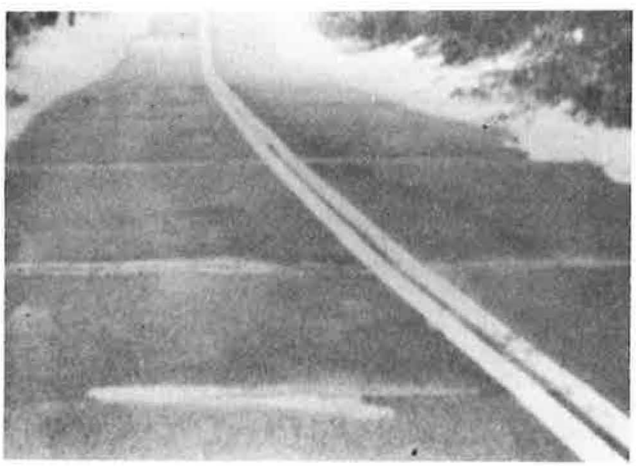

Figure 2. Completed pavement, Cape Cod National Seashore Park, June 1979.

Figure 3. Completed pavement on Province Lands Road in Cape Cod National Seashore Park, June 1982.

Figure 4. Completed pavement on Moor's Road in Cape Cod National Seashore Park, June 1982.

($10 378/0.6 mile) was saved by cold recycling in place. More details on this project have been presented elsewhere (1).

CATOCTIN MOUNTAIN PARK

Project Location

This project was located in Catoctin Mountain Park near Thurmont, Maryland. The location may be familiar to the reader because Camp 3, or Camp David, the President's retreat, is adjacent to the park grounds. In fact, the construction work on this project had to be discontinued when the Egyptian-Israeli summit conferences were held there in 1979.

Project Description

This project was 6.7 km (4 miles) long and included reconstruction of the existing pavement with some widening and some new alignment. The existing roadway that was recycled consisted of pavement 5.4 m (18 ft) wide of variable-depth bituminous concrete 7.5-20 cm thick; the latter thickness is at the pavement edge.

Project Construction

The existing pavement was removed with a CMI PR-750 Roto Mill, stockpiled at parking areas within the

Figure 5. Completed pavement in Catoctin Mountain Park, June 1979.

Figure 6. Completed pavement in Catoctin Mountain Park, June 1982.

Figure 7. Dynaflect in operation at Catoctin Mountain Park, July 1982.

Figure 8. Close-up of Dynaflect van and trailer.

Table 1. Pavement sections.

Pavement					Emulsion	
Section No.	Length (m)	Type	Thickness (cm)	Base Type	Type	Thickness (cm)
1	1120	HBCP	5.0	Recycled	SS1-H	10.0
2	2926	HBCP	8.9	Recycled	AEBM	10.0
3	76	HBCP	5.0	Crushed aggregate	None	15.0
4	373	HBCP	5.0	Recycled	None	15.0
5	137	HBCP	5.0	Crushed aggregate	None	15.0
6	1783	HBCP	5.0	Recycled	None	15.0
7	983	HBCP	5.0	Crushed aggregate	None	15.0

Notes: 1 cm = 0.39 in.
HBCP = hot bituminous concrete, AEBM = asphalt emulsion bituminous mix (= SS1).

park, mixed with crushed stone and an emulsion in a portable pugmill, placed on the prepared subgrade with a Barber-Greene paver, and compacted with a 10-ton Hyster roller. A wearing course of 5 cm of dense-graded bituminous concrete was placed over the recycled base material. Figures 5 and 6 show the completed pavement in June 1979 and June 1982 (1).

Construction Modifications

Work on this project started in December 1977. Sections of the roadway were closed in stages to through traffic. The pavement sections completed in 1978 indicated some lack of stability in certain locations in the spring of 1979. Due to this reported condition, the Design Division took Dynaflect (2) measurements to evaluate the pavement structure in relation to the original pavement design (3) and made corrective recommendations. Their report (4) recommended that an additional 3.8 cm (1.5 in) of hot mix be placed over a 198-km (6500-ft) section of the completed pavement to provide the required pavement structure equal to the original pavement design. This lack of adequate structure was attributed to a combination of factors. The emulsion added to the recycled base material did not cure out in the sections placed in the fall of the year due to the rainy weather, shady environment, and lift thickness of 10.0 cm. These elements, combined with the fact that some of the emulsion was washed from the base by rainfall, reduced the stability of the recycled base. Also, the trucks hauling hot mix over the recycled base may have damaged it (5,6).

The determination of the required overlay thickness was done by Symons (4). He used deflection measurements taken on the deficient section and the Asphalt Institute's approach as delineated by Kingham (7, p. 16). The deficient sections had 2.5 cm of the 5.0 cm of bituminous concrete in place when the measurements were taken. The results indicated that, as mentioned above, an additional 3.8 cm of hot mix was needed over the original 5.0 cm planned.

If the coefficients of the American Association of State Highway and Transportation Officials (AASHTO) (8, Table C.4.1, p. 77) had been used to estimate the required overlay thickness, assuming that the recycled base coefficients in the deficient section were not 0.14 (like crushed-stone base) in lieu of 0.25 as originally estimated, the result would have been that an additional 2.5 cm would have been required. [Change in structural number (SN) due to the change in the assumption for the base coefficient = (0.25 - 0.14) x 4 in = 0.44, which is equal to 2.5 cm of hot mix.]

From the above information, it was decided that for the remainder of the project the recycled base that contained emulsion would be eliminated and replaced with 15.2 cm of recycled base material without emulsion until this material was depleted. Then 15.2 cm of waterbound dense-graded base stone would be used.

As a result of these changes, the roadway base sections are of varied material types and thicknesses. Also, the project is one in which Dynaflect measurements were taken during construction and at two time intervals after construction and thus is one to continue monitoring.

Table 2. Dynaflect criteria.

Item	Criteria		
	Adequate	Marginal	Inadequate
DMD	<1.5	1.5-1.8	>1.8
SCI	<0.45	0.45-0.55	>0.55
BCI	<0.11	0.11-0.13	>0.13

REEXAMINATION OF CATOCTIN MOUNTAIN PARK PAVEMENT

In the summer of 1982, a reexamination of the pavement structure, recycled material, and hot-mix bituminous concrete was attempted. Pavement cores were obtained from the project and Dynaflect measurements were taken to evaluate the condition of the pavement structure.

Dynaflect Measurements

Dynaflect measurements were taken in July 1982 (Figures 7 and 8) and the Dynaflect maximum deflection (DMD), surface curvature index (SCI), and base curvature index (BCI) were determined for each section of the roadway. Table 1 gives information about the sections. Table 2 presents the criteria of the Federal Highway Administration's Eastern Direct Federal Division for DMD, SCI, and BCI, and Table 3 presents the values obtained.

The total number of tests for sections 3, 4, 5, and 6 are four, seven, six, and five, respectively. Also, these sections can be seen to be quite short. For these reasons, local spots that may be deficient have a greater influence on the overall rating for these sections. Further study is being planned to see if there may be future localized problems.

Overall, when the results from the 1982 data were compared with those obtained in 1979, there was a maximum increase of about 0.2 mil in the DMD values, which indicated no major changes in the pavement condition since construction had been completed. Further study of the data and analysis will be made when the next measurement cycle is completed.

Pavement Cores

Four cores 10.2 cm (4 in) in diameter were removed

Table 3. DMD, SCI, and BCI for left and right lanes and average values.

Section No.	DMD (mils)				SCI (mils)				BCI (mils)						No. of Tests		
	L	R	$\bar{X}$	C	L	R	$\bar{X}$	C	L	R	$\bar{X}$	C	Base	Top	L	R	Total
1	0.83	0.77	0.80	A	0.31	0.28	0.30	A	0.03	0.01	0.02	A	4RB	2HM	9	9	18
2	0.90	0.88	0.89	A	0.37	0.31	0.34	A	0.03	0.02	0.03	A	4RB	3.5HM	20	19	39
3	1.42	0.96	1.19	A	0.82	0.53	0.69	I	0.01	0.00	0.01	A	6CA	2HM	3	1	4
4	1.35	1.18	1.27	A	0.76	0.53	0.65	I	0.02	0.01	0.02	A	6RB	2HM	4	3	7
5	1.59	1.46	1.53	M	0.66	0.61	0.64	I	0.07	0.00	0.04	A	6CA	2HM	3	3	6
6	1.03	2.29	1.66	M	0.39	0.94	0.67	I	0.04	0.02	0.04	A	6RB	2HM	4	1	5
7	0.94	0.89	0.92	A	0.37	0.44	0.41	A	0.40	0.03	0.04	A	6CA	2HM	7	7	14
Total	1.15	1.20	1.18	A	0.53	0.52	0.53	M	0.03	0.01	0.03	A	-	-			

Notes: 1 mil = 25.4 microns.
L = left lane, R = right lane, $\bar{X}$ = mean, C = condition. A = acceptable, M = marginal, I = inadequate. 4RB = 10.0-cm recycled base, 6RB = 15.0-cm recycled base, 6CA = 15.0-cm crushed aggregate, 2HM = 5.0-cm hot mix, 3.5HM = 8.75-cm hot mix.

Figure 9. Cutting cores with portable electric core drill, Catoctin Mountain Park, June 1982.

Figure 12. Disintegrated recycled material showing curved faces of some aggregate particles caused by core bit.

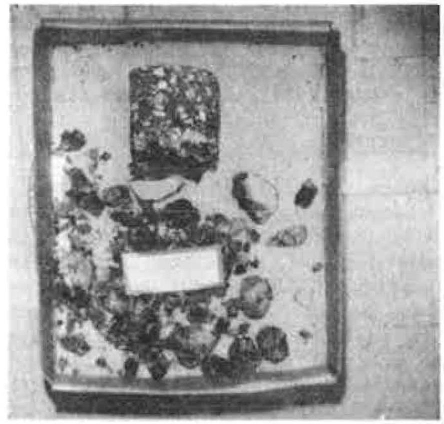

Figure 10. Typical pavement cores obtained from pavement in Catoctin Mountain Park, June 1982.

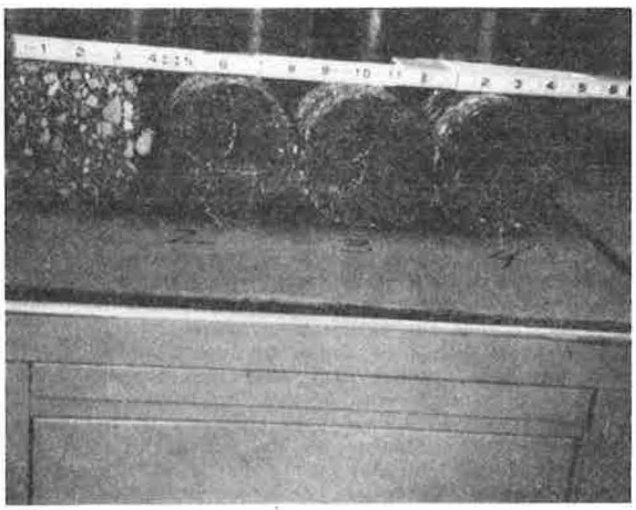

Figure 11. Disintegrated recycled base material and bituminous concrete after coring.

Table 4. Pavement core void analyses.

Item	$\bar{X}$	Range	N	SD
Bulk specific gravity	2.2649	0.185	10	0.050
Air voids (%)	10.3	7.8	10	2.1
Minimum aggregate voids (%)	22.1	5.9	10	1.6
Voids filled (%)	54.0	12.1	10	6.3
Maximum theoretical specific gravity	2.522	0.038	10	0.014
Effective specific gravity of aggregate	2.748	0.060	10	0.018
Asphalt content (%)				
Mix basis	5.437	0.53	10	0.19
Aggregate basis	5.743	0.60	10	0.21
Asphalt specific gravity	1.0396	0.022	10	0.010

Table 5. Gradations and asphalt content.

Item	Job Mix	$\bar{X}$	Range	N	SD
Percentage passing sieve size[a]					
19.0 mm	100	100	0	9	0
12.5 mm	98	97	11	9	3.4
9.5 mm	81	83	11	9	4.2
4.75 mm	61	63	7	9	2.1
2.36 mm	48	45	4	9	3.1
1.18 mm	36	34	9	9	3.4
0.600 mm	28	26	10	9	3.2
0.300 mm	15	15	5	9	1.5
0.150 mm	1	7	2	9	0.6
0.075 mm	6.6	6.6	1.4	9	0.6
Asphalt content (%)					
Mix basis	5.30	5.43	0.52	9	0.20
Aggregate basis	5.60	5.75	0.60	9	0.23

[a]Corresponding U.S. sieve series 0.75, 0.50, and 0.375 in and Nos. 4, 8, 16, 30, 50, 100, and 200.

from each of five locations in the roadway, one set from sections 1, 4, and 6 and two from section 2. The locations were selected so that samples of the different recycled base materials would be obtained. It was hoped that the recycled base material could be removed in whole pieces so that some laboratory strength measurements could be made on these materials. Figures 9, 10, 11, and 12 show the coring operation and representative cores removed from the pavement. It can be seen that the recycled material was not retrievable in core form. The use of a diamond core bit that required water as a coolant undoubtedly contributed to the disintegration of the recycled base material during the coring operation.

Table 6. Properties of original and recovered asphalts, 1982.

	Original AC[a]		Recovered AC (1982)			
Item	BTFO	ATFO[b]	$\overline{X}$	Range	N	SD
Penetration						
25°C	68	46	48	19	9	6.9
4°C	-	-	21	7	6	3.0
Ductility (cm)						
25°C	-	150+	150+	0	9	0
4°C	-	-	4.5	5.5	6	2.0
Viscosity (poises), 60°C	1939	3847	6086	8012	9	2838
Viscosity (cSt), 135°C	389	-	739	326	9	134
Softening point (°C)	-	-	58.1	8.8	9	2.9
Specific gravity, 25°C	1020	-	1.040	0.022	9	0.009

Note: t°C = (t°F − 32)/1.8.

[a]AC-20 = viscosity-grade asphalt cement (9, p. 539; 10, p. 148). BTFO = before thin-film oven test; ATFO = after thin-film oven test.

[b]Reference 11.

Since the material retrievable was only the bituminous concrete, this was the material toward which the primary laboratory testing was directed. The pavement layers were separated where indicated, and tests for voids analysis, asphalt content, and gradation of the extracted aggregate; tests on the recovered asphalt; and Marshall stability tests were performed. These were done to determine the existing pavement void contents and the degree of hardening that had occurred to date in the asphalt cement, to evaluate the existing aggregate gradations, and to obtain a measure of the pavement stability in place. Summaries of the average values and ranges are given in Tables 4, 5, and 6.

The results indicate the following:

1. Void contents: The existing void contents are higher than desired but within our requirements at the time this job was built, and with the low traffic levels that exist, no pavement problems related to void levels have developed.

2. Asphalt content and gradation: The asphalt content and gradations compare very well with the job-mix formula and indicate good construction control.

3. Recovered asphalt cement: The penetration of the recovered asphalts has now reached the level of the original asphalt after the thin-film oven test (TFOT) (10, p. 567). The viscosities at 60°C (140°F) are higher now than the original asphalt after the TFOT but less than the maximum allowable [(9, p. 539; 10, p. 148)] of 8000 poises in all but one case. The ductility values are all 150+ cm at 25°C (77°F).

All these results indicate that the asphalt was not overheated during construction and has adequate properties for long life without potential for thermal cracking or raveling.

4. Marshall stability and stiffness: Marshall stability values were determined on the core samples at 25° and 60°C. The results were adjusted by the factors given in the test method (11, p. 567) to correct them to 6.4 cm (2.5 in) in height. Stiffness values were calculated by using approaches given by McLeod (12, p. 18) and Gadallah, Wood, and Yoder (13, p. 11). The results appeared quite variable and low in some cases, so they are not reported here. Further analysis of these data is in progress.

CONCLUSIONS

Cape Cod

The recycle project in Cape Cod National Seashore Park was successful, presented no construction problems, and had a significant dollar savings.

Catoctin Park

The recycle project in Catoctin Park, Maryland, presented some problems that required modifications to the pavement structure and caused some overrun in costs. The experience gained to date from this project will improve future projects. It is hoped that further study and evaluation will provide a better insight into materials properties and pavement structure deflections.

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