Cost Evaluation of Alternatives To Rehabilitate Asphaltic Rural Roads

ROBERT S. KORBA

The debilitating effects of frost and the steady increase in the number and weight of trucks using asphaltic rural roads have contributed to the loss of desirable cross-slopes by creating potholes, rutting, shoving, corrugations, and double crowns. Two general methods are available for local governments to correct this deteriorated condition. The traditional method is to level the road by adding either hot-mix or cold-mix asphalt to re-establish the proper cross-slope and add structural depth. Another method is to recycle the existing asphaltic materials and base in place. This practice has resumed because of the dramatic increases in asphalt products that resulted from the worldwide petroleum crisis that started in the 1970s. The cost-effectiveness of both methods combined with the use of different top courses for the wearing surface are analyzed in this paper. Examples of this work that were completed by county personnel will also be analyzed.

INTRODUCTION

Tioga County, New York, is located adjacent to the Pennsylvania state border in the central part of the state. Tioga County has a population of 50,000 and primarily consists of rural farms. The county could be considered a bedroom community that serves the larger industrial centers in the three adjacent counties. In addition to the farming industry, a good logging business encompasses the entire county. The terrain consists of rolling hills and valleys. The soil types of the valley areas are mostly characterized by well-drained gravelly type soils; the hills consist of poorly drained fine clays known in New York State as "hardpan" or "rock flour."

The jurisdictional highway systems in the state consist of state, county, town, and city and village roads. The State system obviously occupies the better valley areas and the county and town systems are located in the hills.

Winter temperatures are as low as -20°F. The county road system consists of 145 mi of two-lane, paved roads that vary from 18 in to 24 in wide with 4-in-wide shoulders. Traffic volumes range from 100 to 4,700 vehicles per day (vpd). Truck volume is unknown but from observations it is known to be significant. Most of these roads were built over the original ground and very little select base material was brought in at the time of construction. Over the years the county roads have increased in depth with a layering of a variety of road building materials. These materials consisted of gravelly soils, cold-mix stone aggregates, road oils, and hot-mix asphaltic concrete.

The problem with the county roads is that the structural condition weakens in the spring when the hardpan soil is saturated with water that thawed from winter frost. The period of saturation can last as long as 3 months (March, April, and May). When the milk tankers, logging trucks, and municipal dump trucks use the county roads during this period, the roads are distorted by the unstable clay soil, or hardpan, beneath the road. This distortion takes the form of rutting, shoving, creation of a double crowned road, alligator cracking, and poor road surface drainage, which further worsens all of the other conditions.

Tioga County Department of Public Works, P.O. Box 291, Owego, N.Y. 13827.

The ideal solution would be to rebuild the problem roads in the following manner:

- Scarify the existing roadway;
- Lay down engineering fabric the full width and length of the roadway;
- Haul in 12 to 18 in of select gravel material (Table 1); and
- Lay down a 4-in-deep layer of bituminous concrete base course followed by 1-1/2 in layer of bituminous concrete binder course and top it with 1-1/2 in layer of bituminous concrete Type 7F (Table 2).

TABLE 1 SUBBASE COURSE SPECIFICATIONS

Graduation Type	Sieve Size Designation	Percent Passing By Weight
1	3 in.	100
	2 in.	90-100
	1/4 in.	30-65
	No. 40	5-40
	No. 200	0-10
2	2 in.	100
	1/4 in.	25-60
	No. 40	5-40
	No. 200	0-10
3	4 in.	100
	1/4 in.	30-75
	No. 40	5-40
	No. 200	0-10
4	2 in.	100
	1/4 in.	30-65
	No. 40	5-40
	No. 200	0-10

Source: *Standard Specifications of Construction and Materials*, New York State Department of Transportation, Jan. 2, 1985.

This method would produce a road that should last 15 to 20 years in this area with little road maintenance. At 1986 prices, construction would cost $13/yd^2$ for materials only. It should be noted that when company costs are addressed, they apply to materials only.

Of the 145 mi of roads in the county, 30 mi are in good condition, which means that little maintenance would be required over the next 10 years. The remaining 115 mi of road

TABLE 2 COMPOSITION OF BITUMINOUS PLANT MIXTURES

MIXTURE REQUIREMENTS	BASE TYPE 2		BINDER TYPE 3		TOP TYPE 7	
Screen Sizes	General Limits % Passing	Job Mix Tol. %	General Limits % Passing	Job Mix Tol. %	General Limits % Passing	Job Mix Tol %
2"	100	-				
1-1/2"	75-100	± 7	100	-		
1"	55-80	± 8	95-100			
1/2"	23-42	± 7	70-90	± 6	100	-
1/4"	5-20	± 6	48-74	± 7	90-100	-
1/8"	2-15	± 4	32-62	± 7	45-70	± 6
No. 20			15-39	± 7	15-40	± 7
No. 40			8-27	± 7	8-27	± 7
No. 80			4-16	± 4	4-16	± 4
No. 200			4-8	± 2	2-6	± 2
Asphalt Content %	2.5-4.5	± 0.4	4.5-6.5	± 0.4	6.0-8.0	± 0.4
Asphalt Cement Upstate Grade & No.	AC-10 702-02		AC-10 702-02		AC-10 702-02	
Asphalt Cement Downstate Grade & No.	AC-20 702-03		AC-20 702-03		AC-20 702-03	
Mixing and Placing Temperature Range °F	225-300		250-325		250-325	
Description and Typical Uses	Open base course with relatively high permeability		dense intermediate course with relatively low permeability		dense, gritty texture for single course resurfacing of rural, suburban and urban arterial	

Note: (-) Dash means data not applicable

Source: *Standard Specifications of Construction and Materials,* New York State Department of Transportation, Jan. 2, 1985.

require some type of pavement rehabilitation. The ideal solution described earlier would cost $17.5 million, or $1.75 million each year, for the next 10 years.

Because the road capital construction budget is currently being funded at $0.6 million a year, a compromise must be made on what costs are acceptable against the effective life of the pavement. A variety of good solutions for road rehabilitation were found based on the variable given conditions of the road and traffic, and they are described in the following recent case histories in road rehabilitation.

CASE 1 (1981)

Sulphur Springs Road is a cold-mix bituminous road that is 18 ft wide and carries 600 vpd. It is a farm-to-market road that experiences severe rutting and cracking. Budgetary constraints forced the development of a process that would reshape this roadway at a very reasonable cost. A solution was found that involved an in-place recycling process and double surface treatment and cost a total of $1.60/yd^2$.

Double surface treatment is a process in which a layer of #1 aggregates (Table 3) are spread over a CRS 2 cationic asphalt emulsion (Table 4). The first layer of cationic asphalt emulsion was spread the full width of the road at a rate of .5 gal/yd^2. This rate is variable and depends on how dry the existing asphalt is. After the first layer of asphalt was cured, the process was repeated again, usually with less asphalt, which in this case was .4 gal/yd^2.

The recycling was accomplished by using a combination of county personnel and equipment and special rental equipment and operators from a contractor in the area that specialized in this type of work. The contractor furnished a water truck, a grader, scarifier (Figure 1), and a self-propelled mixing machine (Figure 2). The county furnished a grader and operator for final grading and compaction equipment. The mixing machine or rotomill was able to produce material that ranged in size from 1/8 to 1/2 in (Figure 3). It was determined through the use of core samples that enough residual asphalt (5 to 6 percent) was present. No additives or rejuvenators were used because it was believed that the residual asphalt was adequate and the goal was to be as cost-effective as possible.

The existing roadway had varying depths of cold-mix and hot-mix overlays as a result of patching operations. The pavement thickness of a cross-section of asphaltic material varied from 3 to 6 in. It was believed that this variable pavement depth contributed to further distortion of the cross-slope of the road. The intent was to recycle the road to blend all the different kinds and depths of asphalt products into a homogenous 6-in-deep product that would serve as an asphaltic foundation for the riding surface, which was still to be determined. This process created an opportunity to correct subsurface drainage problems.

TABLE 3 SIZES OF STONE, GRAVEL, AND SLAG AGGREGATES

Size Designation	Screen Sizes[a] 4 in.	3 in.	2-1/2 in.	2 in.	1-1/2 in.	1 in.	1/2 in.	1/4 in.	1/8 in.	No. 80 Sieve
Screenings[b]	-[c]	-	-	-	-	-	100	90-100	-	-
1B	-	-	-	-	-	-	-	100	90-100	0-15
1A	-	-	-	-	-	-	100	90-100	0-15	-
1ST	-	-	-	-	-	-	100	0-15	-	-
1	-	-	-	-	-	100	90-100	0-15	-	-
2	-	-	-	-	100	90-100	0-15	-	-	-
3A	-	-	-	100	90-100	0-15	-	-	-	-
3	-	-	100	90-100	35-70	0-15	-	-	-	-
4A	-	100	90-100	-	0-20	-	-	-	-	-
4	100	90-100	-	0-15	-	-	-	-	-	-
5	90-100	0-15	-	-	-	-	-	-	-	-

Source: *Standard Specifications of Construction and Materials,* New York State Department of Transportation, Jan. 2, 1985.
Note: Dash means data not applicable.
[a]Percentage by weight passing the following square openings.
[b]Screenings include all of the fine material that passed through a 1/4 in. screen. All crushing plants will be fitted with tailing chutes so that no aggregate will reach the bins other than that which passes through the proper screens.

TABLE 4 CATIONIC ASPHALT EMULSION SPECIFICATIONS

TYPE	RAPID SETTING		MEDIUM SETTING	
MATERIAL DESIGNATION	702-4101		702-4201	
GRADE	CRS-2		CMS-2	
	MIN	MAX	MIN	MAX
Tests on Emulsion:				
Viscosity, Saybolt Furol, 77F (25C) Sec	-	-	-	-
Viscosity, Saybolt Furol, 122F (50C) Sec	100	400	50	450
Storage Stability Test, 1 Day (Difference in percent Residue)	-	1	-	1
Classification Test	Passes		-	-
Stone Coating Test	-	-	Satisfactory	
Particle Charge Test	Positive		Positive	
Sieve Test, percent		0.10	-	0.10
Cement Mixing	-	-	-	-
Residue by Distillation percent	65	-	65	-
Oil Distilate, Volume Total Emulsion percent	-	3	-	12
Tests on Residue from Distillation Test:				
Penetration 77F (25C), 100g, 5 sec	100	200	100	250
Tests on Asphalt Base for Emulsion:				
Penetration 77F (25C), 100g, 5 sec	100	200	100	200
Solubility in trichloroethylene, percent	99.0	-	99.0	-
Ductility, 77F (25C), 5 cm/min, cm	100	-	100	-
Flash Point, F	350	-	350	-
(C)	(177)	-	(177)	-
Typical Application:				
Note (a)	Surface Treatment Penetration Macadam		Cold Mixes Penetration Macadam	
Suggested Temperature Range				
Mixing F	-	-	100-170	
(C)	-	-	(38-77)	
Spraying F	130-170		130-170	
(C)	(54-77)		(54-77)	

Note:
(a) These typical applications are intended only as a guide for selecting the proper emulsion grade
(b) (-) Dash means data not applicable

Source: Standard Specifications of Construction and Materials, New York State Department of Transportation, Jan. 2, 1985.

FIGURE 1 Grader scarifying roadway.

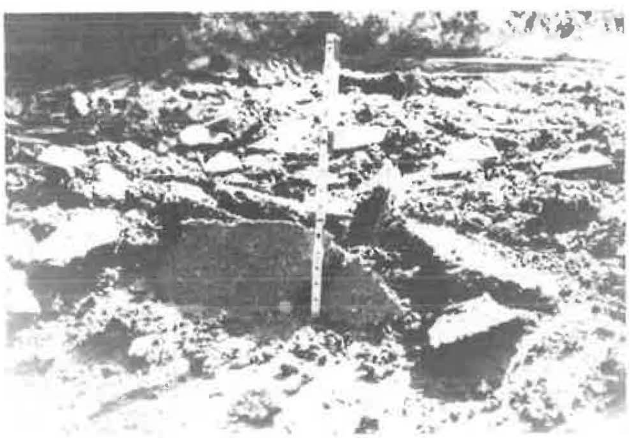

FIGURE 2 Asphalt chunks of pavement after scarifying.

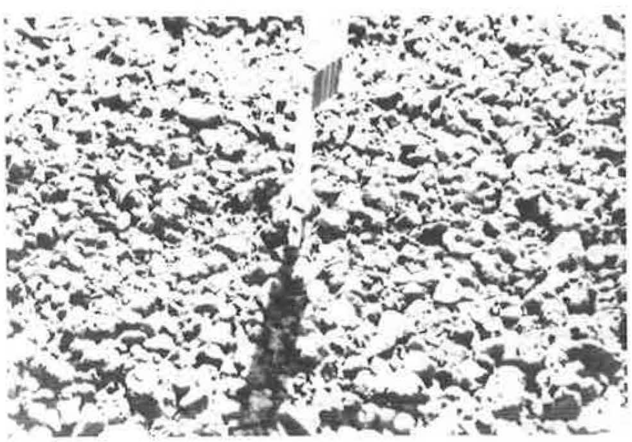

FIGURE 3 Scarified asphaltic material after rotomill work.

Throughout any extended wet period, portions of this road would totally fail because of the number of springs in the area.

After the roadway was scarified (Figure 4) and the rotomill performed its job (Figure 3), the grader operator bladed this material aside in the known trouble spots so that the crew could install underdrain or engineering fabric, or both. In cases in which the roadway elevation was at the same height as an adjacent wetlands, the scarified roadway material was picked up, engineering fabric was installed, 12 in of Type 3 subbase material was brought in (Table 1), and the original roadway was reinstalled (Figure 5). The engineering fabric was applied to prevent pumping of the original ground (clay) material into the gravel, which would reduce the effective drainage characteristics of the gravel and result in a loss of load bearing strength. No failures have resulted since use of the engineering fabric was begun in 1978.

Five years have passed since this project was completed and the roadway is doing very well structurally. It still has a uniform cross slope, and there are no signs of rutting, shoving, or any type of pavement failure. The road rides comfortably, although the double surface treatment creates a tire noise that is louder than normal. Because the roadway is now structurally sound, a higher quality riding surface could be installed when budget priorities allow it.

One major obstacle to recycling a road in place is the time-consuming problem of breaking down pavement that is greater than 6 in deep. Pavement depths greater than 6 in require the use of another piece of equipment called a hammer mill. The hammer mill breaks down the larger chunks of pavement before the rotomill can proceed. This process can prolong construction by as much as three times, and cannot be tolerated because of the construction schedule and the inconvenience to the traveling

FIGURE 4 Underside of rotomill showing cutting teeth.

FIGURE 5 Darker material is the result of in-place recycling of existing asphalt.

public. Pavement that was greater than 6 in deep received a two-course mix of trueing and leveling, and top. Most of the time this is of a cold-mix design.

This recycling project was unique in that it required the interaction of county personnel and the contractor's personnel to form a combined crew that worked well together and kept the project on the planned fiscal schedule. In 1986, 19 mi of road were reconstructed through the use of this recycling method.

CASE 2 (1982 AND 1984)

Wilson Creek Road is a cold-mix bituminous, farm-to-market roadway that is 22 ft wide and carries 530 vpd. The overlay method was used to rehabilitate this road. The trueing and leveling course consisted of a 50-50 blend of millings from a hot-mix pavement and virgin #1 aggregates. These aggregates were processed through a pugmill that added bituminous material emulsion CMS-2 (Table 4) to the millings to create the product. The average thickness was 2 in.

The top course consisted of a 50-50 blend of #1 aggregates (Table 3) and #1 aggregates that were premixed by the supplier. These aggregates were dumped into a traveling mix paver, blended with the emulsion CMS-2, and laid down at a depth of 2 in. A month later this overlay was sealed with CRS-2 emulsion and #1 aggregates.

The construction of 3.5 mi of road was completed in 1982 at a cost of \$2.87/yd^2. In 1984 the remaining 2.5 mi of road were completed at a cost of \$3.20/yd^2.

There are currently some minor cracks in the road surface. However, the roadway has a good cross shape that shows no signs of rutting.

TABLE 5 ANIONIC ASPHALT EMULSION SPECIFICATIONS

TYPE	RAPID SETTING		MEDIUM SETTING			
MATERIAL DESIGNATION	702-3101		702-3301		702-3401	
GRADE	RS-2		HFMS-2		HFMS-2h	
	Min	Max	Min.	Max	Min	Max
Tests on Emulsion:						
Viscosity, Saybolt Furol 77F (25C). Sec.	-	-	100	-	100	-
Viscosity, Saybolt Furol, 122F (50C). Sec.	100	400	100	400	-	-
Storage Stability Test, 1 Day (Difference in percent Residue)	-	1	-	1	-	1
Demulsibility, 35ml. 0.02N $CaCl_2$.percent	60	-	-	-	-	-
Stone Coating Test	-	-	Satisfactory		Satisfactory	
Cement Mixing Test, percent	-	-	-	-	-	-
Sieve Test, percent	-	0.10	-	0.10	0	0.10
Residue by distillation, percent	63	-	65	-	65	-
Oil Distillate, volume Total Emulsion percent	-	3	-	10	-	3
Tests on Residue from Distillation Test						
Penetration 77F (25C), 100g, 5 Sec.	100	200	100	250	40	90
Float Test, 140F (60C) Note (a) Sec.	-	-	1200	-	1200	-
Tests on Asphalt Base for Emulsion:						
Penetration 77F (25C), 100g, 5 Sec.	100	200	100	200	60	100
Solubility in trichloroethylene, percent	99.0	-	99.9	-	99.9	-
Ductility, 77F (25C, 5cm/min cm	100	-	100	-	50	-
Flash Point F	350	-	350	-	435	-
(C)	(177)	-	(177)	-	(225)	
Typical Applications:						
Note b	Surface Treatment, Penetration Macadam		Base and Shoulder Stabilization, Cold Mixes, Shoulder Seal		Penetration Macadam, Hot and Cold Mixes	
Suggested Temperature Range						
Mixing F	-	-	100-170		75-170	
(C)	-	-	(38-77)		(24-77)	
Spraying F	130-170		130-170		130-170	
(C)	(54-77)		(54-77)		(24-77)	

Notes:

a - Float Test AASHTO T-50, except that the residue from distillation shall be poured immediately into the float collar at 500F (260C).

b - These typical applications are intended only as a guide for selecting the proper emulsion grade.

c - (-) Dash means data not applicable

Source: Standard Specifications of Construction and Materials, New York State Department of Transportation, Jan. 2, 1985.

CASE 3 (1984 TO 1985)

Oak Hill Road is a cold-mix bituminous, farm-to-market roadway that is 20 ft wide and carries 400 vpd. The road was rehabilitated by overlaying the road surface with a two-course, cold-mix application. The trueing and leveling course consisted of a 50-50 blend of #1 and #2 aggregates (Table 3) that was put through a traveling mix paver using a CMS-2 emulsion. The overlay was an average of 3 in deep. The top course consisted of a 50-50 blend of #1 and #1A aggregates that were also put through the traveling mix paver using a CMS-2 emulsion. The top course had a uniform depth of 2 in. It was sealed a month later with a CRS-2 emulsion and #1A aggregates. The cost of this process was $\$3.76/yd^2$. No problems have been experienced with this roadway to date.

CASE 4 (1986)

Montrose Turnpike and Ellis Creek Road were constructed by applying several layers of cold-mix bituminous materials over the original hardpan subsurface. The original width of the roads was 18 ft and the total length of both roads is 18.7 miles. Traffic on both roads is approximately 300 vpd.

The roads were rehabilitated by recycling existing materials to create a homogenous asphaltic base course. The recycling process was the same as that described in Case 1. Both roads were widened to 22 ft during this recycling process, and underdrain and engineering fabric were installed at predetermined locations. The cost of the recycling process in 1986 was $\$.50/yd^2$.

A dense, graded asphaltic cold-mix blend that consisted of 60 percent screened and washed sand and 40 percent #1 aggregates was installed over the 6-in recycled asphaltic base. A type HFMS-^{2h} anionic emulsion at the rate of 18 gal/ton of sand and aggregates was used to bind the mix together (See Table 5).

This mix was laid at a depth of 3 in and compacted with a double-drum vibratory roller. This mix created a high-quality roadway and did not require a seal coat because of its tightness.

This mix was produced in a pugmill at the aggregate source, trucked to the job site, and laid through a conventional paving machine. The cost of the mix was $\$2.06/yd^2$. The total cost of recycling the roads with the contractor's rental equipment, including the cost of materials for the new cold-mix wearing surface, was $\$2.56/yd^2$.

It should be noted that in the study area the emulsions were best adhered to the aggregates by the use of cationic emulsions. Cationic emulsions are positively charged, as opposed to anionic emulsions, which are negatively charged. The local aggregates were negatively charged, and the attraction of negative and positive particles acted to bind the emulsion to the aggregates.

To summarize, the cost of rehabilitating the roads ranged from $\$1.60/yd^2$ to $\$3.76/yd^2$. The method of rehabilitation was determined by assessing the following variables:

- Traffic volume,
- Available funds,
- Type and depth of existing material,
- Road drainage problems, and
- Subbase analysis.

A wide variety of road rehabilitation methods were used that produced more than satisfactory results. However, it appeared that in-place recycling and a new, densely graded cold-mix overlay provided the best results for the dollars spent.