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Cold-Mix Recycling of Asphalt Materials: An Application to Low-Volume Roads

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For several years now, rising asphalt prices and diminishing revenues have led many highway departments, especially local agencies, to experiment with alternative methods of rehabilitating their old asphalt pavements. One such method, which has received particular attention in Illinois, is the process of cold, in-place recycling. It has been found to be an economical alternative to other more conventional patching and overlay treatments. Cold, in-place recycling makes it possible to remove surface deficiencies and improve levels of safety and serviceability while minimizing the addition of new asphalt and aggregate materials. Furthermore, it has been found that this type of rehabilitation can be accomplished by using available equipment and basic road mix procedures. Recycling work performed by the Vermilion County, Illinois, Highway Department during the summer of 1982 is described, and details of the overall work sequence are discussed.

In July 1982, the Vermilion County Highway Department began to recycle a 4.25-mile segment of IL-1 north of Henning, Illinois. The existing road was 18 ft wide and consisted of repeated A-3 seal coat treatments applied over about 3 to 4 in. of gravel base. An on-site pavement condition rating indicated that the road was in an advanced stage of deterioration with such deficiencies as potholes, alligator cracks, raveling, bleeding, and shoving (see Figure 1) (1). Average daily traffic totaled 350 vehicles/day, of which a large portion consisted of heavy farm machinery and tandem-axle trucks.

SAMPLING AND TESTING

A consultant was hired to perform the necessary sampling and testing work. Field sampling involved the use of a Koehring (Bomag) rotary speed mixer that cut full-depth cross sections of the pavement at 500-ft intervals. Test material was then collected from these cuts at left, right, and centerline locations along the project, and a visual inspection was made of the thickness and composition of the existing pavement cross section. This cross section was later used to determine the tilling depth.

All field samples were laboratory tested as a means of evaluating both the quality and reusability of the existing in-place materials. Specific asphalt properties tested showed an average recovery penetration at 75°F of 17.2 and a residual asphalt content of 3.7 percent. These values were used as a basis for selecting new asphalts that could be added to replenish the old asphalt properties. Subsequent sieving of the extracted aggregate provided the in-place gradation given below:

Sieve Size	Percentage Passing
1.5 in.	100.0
1 in.	100.0
0.75 in.	98.7
0.5 in.	89.7
0.375 in.	82.2
No. 4	55.6
No. 8	33.5
No. 16	23.3
No. 30	17.4
No. 50	13.2
No. 100	9.8
No. 200	7.7

Several trial mixes, consisting of assorted combinations of old (reusable) and new materials, were then designed and tested to determine the optimum mix design. Low traffic volumes and economics led to mix designs within the following parameters: residual asphalt contents of 4 to 5 percent and aggregate gradations of CA-6 (No. 200 to 1 in. in size) or equivalent (2, p. 596). None of the mixes tested involved the use of a rejuvenator because of limited amounts of asphalt found in the test samples.

Test results indicated that the optimum mix design should provide a modified Marshall stability (Illinois method) (3) of 4,000 lb at 75°F. To reproduce this mix design in the field, an additional 3 in. of modified CA-7 aggregate (0.375 to 1 in. in size) and 2.5 gal/yd² of HFE-150 (high-float) emulsion were needed.

Actual quantities and specifications of virgin materials added to reproduce the optimum mix design are given in the following tables (the CA-6 gradation represents the design parameter, which was not used in the added materials):

Material	Use	Quantity
CA-7	Base	6,780 tons
HFE-150	Base	113,390 gal
CSS-1h	Prime	4,860 gal
CRS-2	Seal coat	17,000 gal
CA-16	Seal coat	610 tons

	Percentage Passing		
Sieve Size	CA-6	CA-7 (modified)	CA-16
1.5 in.	100	-	-
1 in.	90-100	100	-
0.75 in.	-	65-100	-
0.5 in.	60-90	15-45	100
0.375 in.	-	0-10	94-100
No. 4	30-56	-	15-45
No. 16	10-40	-	0-2
No. 50	-	-	-
No. 200	4-12	-	-

EQUIPMENT SELECTION

The types of equipment used for the recycling process were similar to those used for normal road-mix projects. Collectively, the equipment included a spreader box, a road grader, an asphalt distributor, and a vibratory roller. The only specialized machine used during the recycling was the Koehring (Bomag) rotary speed mixer, which was essential to perform the initial tilling and successive mixing operations.

MIX SEQUENCE

The overall operation for in-place recycling of the existing pavement consisted of tilling, furnishing, and spreading new aggregate, adding emulsified asphalt, and shaping and compacting the mixture. All work was completed in segments of 1.5 miles or less, excluding seal coat, before progressing to the next segment. The actual recycling involved a repetitive sequence of operations completed, as follows, to ensure proper thickness and width (see Figure 2):

1. Initial tilling: The existing surface on Henning Road was tilled to a depth of approximately 1.5 in. and a width of 18 ft with the Bomag. This depth was determined from individual cross-section sketches made during the initial sampling stage.
2. Adding new aggregate: A Jersey spreader box mounted on a D-7 dozer was used to apply 3 in. of new aggregate to the tilled materials. The aggregate was a modified CA-7 gravel (0.375 to 1 in. in size) selected to minimize the amount of fines in the final mix.
3. Applying emulsion: A pressure distributor applied the HFE-150 (high-float) emulsion at a maximum rate per pass of 1 gal/yd². This limit on the application rate provided for easier workability and more uniform mixing than if all 2.5 gal of emulsion/yd² had been applied in a single pass.
4. Mixing materials: The emulsion and aggregate materials were given a preliminary mixing with the Bomag between each successive distributor pass. Periodically, a road grader would follow the Bomag to aid in additional mixing as needed. After the final amount of emulsion was applied and mixed, the road grader completed the windrowing and aeration operation.
5. Spreading and shaping: The aerated mixture was then spread and shaped with the road grader into a smooth, finished surface of uniform consistency. This operation was performed to approximate the proposed pavement cross section (see Figure 3).
6. Compaction: When the mixture had attained sufficient rigidity to bear the weight of the roller without shoving, a vibratory roller was used to compact the mixture. Rolling started along the edges and progressed toward the center, overlapping on successive trips by at least one-half the roller width. The entire surface was rolled twice in this manner.
7. Curing and analysis: The pavement was cured for a minimum of 3 weeks to allow for additional traffic compaction and aeration. This provided a tighter surface on which to apply prime and seal coat materials. During this curing period, core samples were obtained at random locations along the project. Analysis of these cores provided a comparison between the (laboratory-formulated) optimum design mix and the actual field mix. The results of this comparison indicated that the field-mix modified Marshall stability was 90 percent of the optimum design, i.e., 3,600 of 4,000 lb. Field-mix residual asphalt content was found to be 4.1 percent and well within the laboratory design range of 4.0 to 4.5 percent. The final, overall gradation was also within the design limits of a CA-6 aggregate (see Figure 4).
8. Priming and sealing: After the curing period, the surface was primed and sealed to fill in the open-graded texture and prevent the intrusion of water. A CSS-1h (slow-set) emulsion was applied as a prime coat at a rate of 0.10 gal/yd²; this was followed by 0.35 gal/yd² of CRS-2 (rapid-set) emulsion and 25 lb/yd² of CA-16 aggregate (0.25 to 0.5 in. in size).

ECONOMICS

The Henning Road work was awarded in conjunction with two other roads at a total cost of $296,300;

Figure 1. Asphalt pavement rating form.

STREET OR ROUTE Henning Road (CH 1) CITY OR COUNTY Vermilion

LENGTH OF PROJECT 4.25 mi. WIDTH 18 ft.

PAVEMENT TYPE Bituminous (oil/chip) DATE June 24, 1982

(Note: A rating of "0" indicates defect does not occur)

DEFECTS		RATING
Transverse Cracks	0-5	2
Longitudinal Cracks	0-5	0
Alligator Cracks	0-10	10
Shrinkage Cracks	0-5	0
Rutting	0-10	6
Corrugations	0-5	3
Raveling	0-5	5
Shoving or Pushing	0-10	4
Pot Holes	0-10	8
Excess Asphalt	0-10	10
Polished Aggregate	0-5	0
Deficient Drainage	0-10	6
Overall Riding Quality (0 is excellent; 10 is very poor)	0-10	6
	Sum of Defects	60

Condition Rating = 100 - Sum of Defects
= 100 - 60

Condition Rating = 40

Figure 2. Cold-mix recycling flowchart.

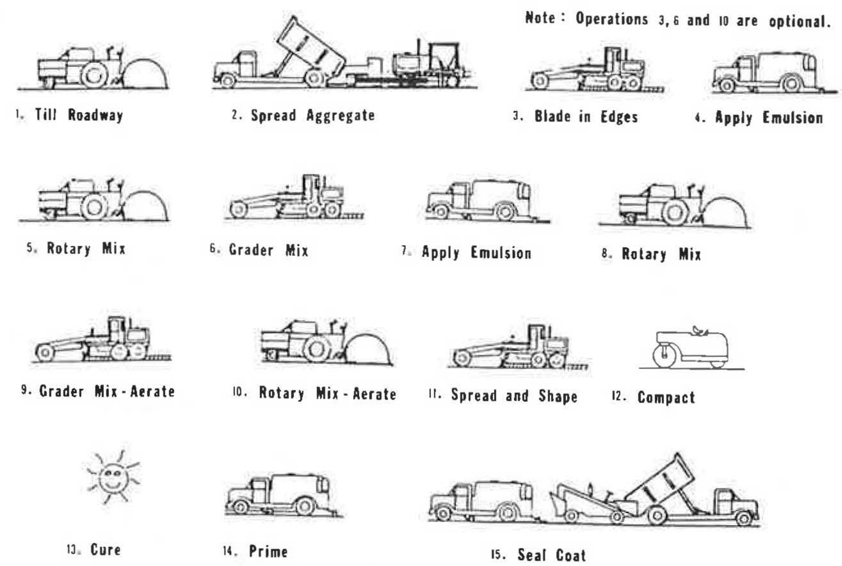


Figure 3. Proposed cross section of Henning Road.

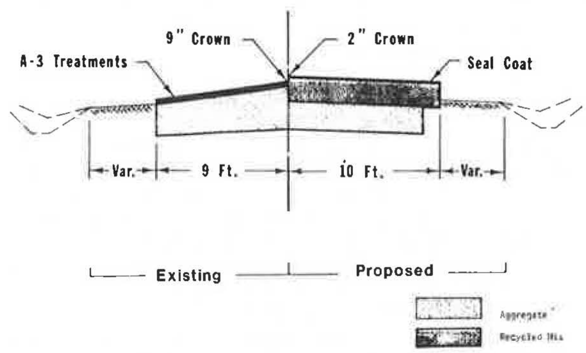
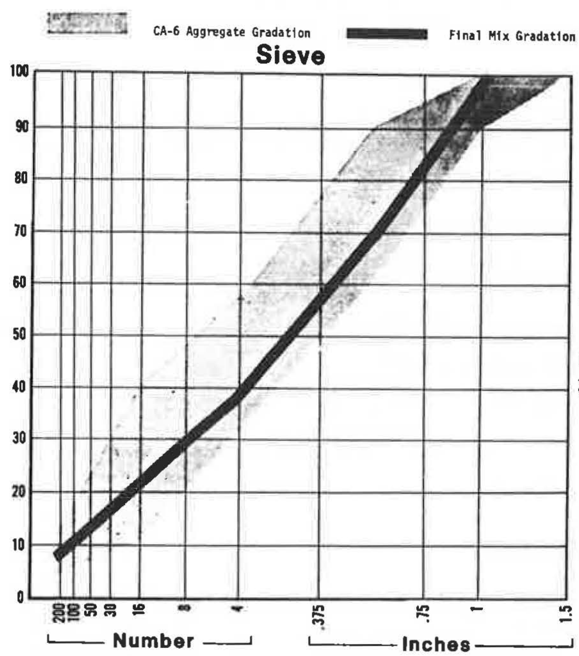


Table 1. Project recycling costs.

Item	Quantity	Unit Price ($)	Cost ($)
Tilling, shaping, and compacting 4 in.	48,600 yd^2	0.20	9,720
Aggregate materials			
Base (CA-7 modified)	6,780 tons	9.50	64,410
Seal coat (CA-16)	610 tons	10.50	6,405
Bituminous materials			
Base (HFE-150)	113,390 gal	0.79	89,580
Prime (PEP)	4,860 gal	1.25	6,075
Seal coat (CRS-2)	17,000 gal	0.78	13,260
Total			189,450

Note: Project area = 49,865 yd^2; average cost = \$3.80/yd^2.

Figure 4. Gradation of existing and proposed materials.



consequently, the recycling costs listed for Henning Road are proportionate costs based on material use and project area (see Table 1). As shown, the average recycling cost amounted to \$3.80/yd^2.

The recycling alternatives considered included such treatments as

1. Applying bituminous aggregate mix or leveling binder along the edges to reduce the pavement crown,
2. Blading and scarifying along the center to remove the pavement crown, and
3. Patching potholes and applying a seal coat to the surface.

Each of these alternatives was discounted either because of the cost required to perform the work or because the treatment would merely cover up surface deficiencies and not correct underlying base failures.

OBSERVATIONS

Because cold-mix recycling is a new process, it involves many factors that may require consideration or selection of a specific method. The following field observations identify some of these factors.

Testing

The most important factor in recycling is the laboratory analysis. Two sampling methods were observed:

1. Coring at 500-ft intervals at left, right, and centerline locations and

2. Transverse cutting at 500-ft intervals with a Bomag and collection of test samples from the cut.

Weather

Cold-mix recycling should be scheduled for a time of the year when weather conditions are hot and dry because this helps to (a) soften the existing surface during the initial tilling, which provides a more uniform particle size; (b) dry materials during the mixing and aeration processes; (c) soften materials before final shaping and rolling; and (d) keep moisture content low for better compaction. In the event of impending rain, the tilled material should be windrowed to facilitate water shedding and moisture control.

Tilling

On roads with excessive crown, depth of penetration can best be controlled by first tilling the center of the roadway. The tilling depth should not exceed that necessary to provide the material quantities required by the mix design. The tiller operator should watch for any mix discoloration that would indicate penetration into underlying soil and the intrusion of undesirable fines. Maximum efficiency was observed at a tiller speed of 45 to 60 ft/min.

Aggregate Spreading

Virgin aggregate should be evenly spread over the total width of the roadway to promote mix uniformity. Tailgate spreading and the use of a spreader box were two of the methods observed. Of the two, the spreader box appeared to be the better because it provided more equal thickness and distribution as well as faster application of the aggregate and it did not require additional grader spreading of the aggregate.

Distributing Emulsion

The best results were observed when the emulsion was applied at a maximum rate per pass of 1 gal/yd^2 and mixed with the Bomag between successive passes.

Road Mixing of Materials

Aggregate that migrated to the shoulder during mixing was pulled back into the windrow and remixed to prevent material loss. The mixing of materials in windrows should continue until all aggregate particles are coated and saturated, surface-dry. If necessary, additional mixing or aeration can be done by mixing the windrows with the tiller. Materials in shaded areas usually required additional aeration.

Sealing

Before sealing, the road should be reopened to traffic and allowed to cure 3 to 4 weeks. This promotes additional compaction and aeration of the mix.

Traffic

Work should be planned to avoid inconvenience to traffic. However, to avoid interruption of the construction by traffic, it would be a good practice to close the road during the construction day and reopen it to traffic at night. At such times, the mix can be either spread or windrowed to one side.

SUMMARY

This paper has focused on the operations involved in recycling one rural project and has identified the factors involved in proper design and control of the quality of work performed. However, these same basic principles also apply to urban cold recycling work, as recently discovered in Illinois cities such as Clinton, Decatur, and Danville. The applications for this type of work are limited only by the imagination. Over the past year, we have observed the recycling of existing in-place materials with such additives as millings, rejuvenators, and numerous virgin aggregates to restore base stabilization.

In conclusion, the use of cold-mix recycling to upgrade local roads and streets in Illinois has been found to be both an economical and mechanically workable alternative to more conventional patching and overlay practices. It can be a method of restoration that, when properly controlled, will greatly extend maintenance capabilities and provide sufficient base stabilization for future surface courses.

The information gained through field observation is being reviewed for possible incorporation into recommended guidelines for cold in-place recycling work. When the guidelines are completed, they will be issued to interested local highway agencies. Any additional factors observed to be beneficial in the performance of such work will be included as needed.

ACKNOWLEDGMENT

We would like to extend our grateful appreciation to Jesse Irvin and Phil Weaver of the Vermilion County Highway Department for their assistance. They provided the data necessary for this paper and were most cooperative throughout the project.

For other highway agencies that are planning to use the cold, in-place recycling process, individual quality-control measures and specifications used to complete the project are available from the Illinois Department of Transportation.

The contents of this paper reflect our views, and we are responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the Illinois Department of Transportation. This paper does not constitute a standard, specification, or regulation.

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