COLD RECYCLE PAVEMENT USING UREA URETHANE DISPERSION AGENT AND RUBBER

FINAL REPORT

State Funded Project

By

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Prepared for
Oregon Department of Transportation
Salem Oregon 97310

December, 1994

Technical Report Documentation Page

1. Report No. OR-RD-95-12	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle "Cold Recycle Pavement Using Urea Urethane Dispersion Agent and Rubber" Final Report		5. Report Date December, 1994 6. Performing Organization Code
7. Author(s) Glenn E. Boyle, Elizabeth A. Hunt		8. Performing Organization Report No.
9. Performing Organization Name and Address Engineering Services Section Oregon Department of Transportation 2950 State Street Salem OR 97310-0785		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Engineering Services Section Oregon Department of Transportation 2950 State Street Salem OR 97310-0785		13. Type of Report and Period Covered Final Report August 1994 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This research study was a joint venture of the Oregon Department of Transportation (ODOT), Evans, Loosely, Inc., and Roseburg Paving Company, to evaluate the use of Urea Urethane Dispersion (UUD) agent, with finely ground tire rubber, high float emulsion, and recycled asphalt pavement (RAP). The combination of materials was reported to increase the pavement life of Cold Recycled Emulsified Asphalt Pavements (CREAP). A second benefit would be an additional opportunity to dispose of ground used tire rubber.

A conventional mix design procedure was not acceptable for the control and test mixes due to the variables associated with the fine, dense RAP gradation, and the compatibility of the high float emulsion with the UUD and rubber. The mixture blend that was used for a control section included: RAP with 2% HFE-150 plus 0.5% added mixing water. The test section included RAP with 1.5% HFE-150 plus 0.5% UUD, 1.8% fine ground tire rubber plus 1% added water.

Approximately 280 tons of control mix and 280 tons of test mix were placed as an overlay. Several hours after being layed, the mixtures could not be compacted without hairline cracking. The mixtures were blanket rolled, dusted with #10-0 material and opened to traffic. After two days under traffic, it was determined that the control section was only partially successful and the test section had not set up. Shortly thereafter, the entire pavement overlay was removed.

17. Key Words Pavement, cold recycle, admixtures, rubber		18. Distribution Statement Available through the Oregon Department of Transportation Research Unit	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72)Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

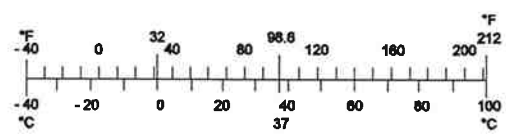
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

(4-7-94 jbp)

ACKNOWLEDGEMENTS

The authors wish to thank the following people for their cooperation and assistance on this project: Robb Paul, Project Manager; Steve Loosely, Roseburg Paving Company; and the Roseburg Paving Company Paving Crew. In addition, the authors thank Dale Allen, Dick Dominick, Wes Heidenreich, Keith Martin, Roger Miles, Scott Nodes, and Dan Sosnovske for their review of the report.

DISCLAIMER

COLD RECYCLE PAVEMENT USING UREA URETHANE DISPERSION AGENT AND RUBBER

FINAL REPORT

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1.0 INTRODUCTION

In 1994, the Oregon Department of Transportation (ODOT) was contacted by Evans, Loosley, Incorporated (ELI) to investigate the use of a new product. ELI proposed a joint venture with Roseburg Paving Company and ODOT to test a product called Urea Urethane Dispersion (UUD) agent. ELI claims that a mix of recycled asphalt pavement (RAP), emulsified asphalt (non-modified), UUD and ground rubber will provide a more fatigue resistant mix than a typical cold recycled emulsified asphalt pavement (CREAP) mix.

ODOT agreed to the joint venture with ELI and Roseburg Paving Company. To test the product, a 500 to 600-ton section (including a test and control section) would be constructed. The project would include paving both lanes of a two-lane section of roadway with the control and test sections placed end to end. The control section would be paved with a mixture of RAP and an emulsified asphalt. The test section would be paved with the UUD modified CREAP with the addition of finely ground tire rubber. A section of Oregon Route 99 between Winchester and Wilbur was selected as the evaluation site.

2.0 BACKGROUND

The Oregon Department of Transportation (ODOT) has been constructing cold recycled pavements since the early 1980s. To date, the cold mixes have been used on low volume roads as one alternative to conventional asphalt concrete pavement rehabilitation. Cold recycled pavements are cost effective on low volume roads, however, they are not strong enough to withstand loading conditions associated with higher volume roads. Technology that would provide a cold recycled pavement suitable for higher volume roads is currently not available. The addition of UUD with rubber may provide a more fatigue resistant pavement suitable for use on a higher volume road. In addition, as production costs decrease and knowledge of the product increases, the material may be cost competitive with hot-mix asphalt concrete (HMAC).

An additional benefit of using rubber in a cold mix modified with UUD, includes reducing the number of tires discarded in landfills. Tires in landfills take up a lot of space, are unsightly, are a fire hazard, and are a breeding area for pests. Using rubber may also assist ODOT in meeting the requirements of the Intermodal Surface Transportation Efficiency Act (ISTEA). ISTEA requires that set percentages of ground automobile tires be used in HMAC. ISTEA does not currently give credit for cold recycle projects with rubber, however, the Act is under revision and credit may be allowed in the future. A moratorium has been placed on the rubber use requirement through 1995.

No other work is currently being done by ODOT to evaluate cold mix additives to improve performance. A cursory review of literature on the use of crumb rubber in paving indicates that research on the addition of rubber to cold mixes has not been done.

In 1990, ODOT published the *In-Depth Study of Cold In-Place Recycled Pavement Performance* report written by Todd V. Scholz, R. Gary Hicks, and David F. Rogge (1). The study focused on the cold in-place recycled pavement projects constructed since 1984. The study included an estimation procedure for determining the emulsion content for a cold mix. This document was used as a guideline in preparing the mix designs.

3.0 MIX DESIGN

3.1 MIX DESIGN TESTING

Samples of the RAP, highfloat emulsion (HFE-150 and HFE-300), the UUD, and ground tire rubber were submitted to the ODOT Materials Laboratory for testing and mix design evaluation. The RAP had been crushed and stockpiled at the paving plant. A sieve analysis was performed on the RAP to determine the gradation. The "as received" gradation of the RAP, as shown in Table 3.1, is similar to a fine, ODOT Class "C" dense graded mix. The asphalt cement content was 5.0%. RAP material was batched into 1100 gram samples to match the "as-received" gradations and stored at room temperature.

Table 3.1 RAP Gradation

Sieve	% Passing
3/4	100
1/2	98
1/4	80
#10	46
#200	7.1

The estimated beginning emulsion content was determined in part, by the method described in the report *In-Depth Study of Cold In-Place Recycled Pavement Performance* by Todd Scholz, et al. This method was only partially usable since the RAP gradation was not produced by a pavement grinder but by crushing. In addition, the RAP material passing the 1/4" sieve exceeded the values on the nomograph and the RAP asphalt content was less than the lowest value on the nomograph. The tests on the recovered asphalt from the RAP indicated an absolute viscosity at 140°F of 24,500 poise, and a penetration at 77°F of 16 cm/100.

It was decided to mix three samples with 2% HFE-150, 0.5% UUD, 1.8% ground rubber and 0, 1.0, and 1.5% water. The samples were observed for amount of coating; type of coating, water or emulsion; and dispersion of the emulsion in the mixture.

The samples were placed in flat baking pans and heated for 20 minutes at 140°F. After heating, the coating was again evaluated. The samples were then compacted in a California kneading compactor with 20 blows at 225 psi followed by 150 blows at 500 psi. After compaction, the samples were static loaded to 1,000 psi, maintained for 90 seconds, and removed from the molds. The surface texture of the compacted samples was then rated.

Next, the samples were placed on flat glass plates and placed in a 140°F oven for 90 hours. It was discovered at this time that the samples were slightly bell shaped at the bottom and would not fit into the Hveem stabilometer. The samples were then inverted, pushed into the steel molds and recompacted. After the static load had been applied the samples were placed back in the oven and later tested for Hveem stability at 140°F.

The testing continued with other combinations of 1.5 and 2.5 percent emulsion as well as like combinations with HFE-300 grade emulsion. Samples were also fabricated using only the addition of emulsion or emulsion and water.

Conditioned resilient modulus testing was done on selected samples. The samples were tested for resilient modulus in the dry condition then vacuum saturated at 77°F for 30 minutes. The vacuum was released and the samples rested for 5 minutes. They were then double wrapped in plastic and placed in a freezer at 0°F for 15 hours, minimum. The wrapping was removed and the samples placed on glass plates in a 140°F water bath for 24 hours, cooled in a 77°F water bath for 3 - 6 hours, and tested for resilient modulus. The vacuum saturated/freeze thaw conditioning is considered to determine sensitivity to weathering. The results of the tests are shown in Table 3.2. The complete set of test results is presented in the Appendix.

Table 3.2: Results of Laboratory Testing

	HFE-150	HFE-150	HFE-150	HFE-300	HFE-300	HFE-300
HFE (%)	2.0	1.5	1.5	1.5	1.5	1.5
UUD (%)	---	0.5	1.0	---	0.5	1.0
Rubber (%)	---	1.8	1.8	---	1.8	1.8
Water Added (%)	1.0	1.0	1.0	---	1.0	1.0
Hveem Stability	24	23	24	39	19	22
Mr, psi, (Dry)	731,000	612,000	368,000	648,000	398,000	423,000
Mr, psi, (Freeze,Thaw)	797,000	(1)	(1)	642,000	(1)	(1)
Ratio:Freeze,Thaw/Dry	1.09	---	---	0.99	---	---

(1) Samples had not cured and were too soft to test after freeze, thaw conditioning.

The mix design laboratory test results did not support the product claims that UUD and ground rubber improve the performance of CREAP. Table 3.2 indicates that the stabilities for the unmodified mixes were the same or slightly better than the modified mixes. The resilient modulus test results were also higher for the unmodified mix samples.

The results of the resilient modulus testing may not be representative. There was little known about the combination of high float emulsion, UUD and finely ground tire rubber. Because of the unknowns, the curing temperatures of the mixtures did not exceed 140°F. With the relatively low mixing temperatures, some of the samples may not have completely cured before being subjected to the resilient modulus conditioning test.

In general, the testing program may not have included the most appropriate methods for evaluation since the tests were developed for conventional materials. Expanding the testing program was not possible with the limited amount of time and funding. Because of the number of variables, the laboratory test results were inconclusive. The decision was made to continue with the field testing to evaluate the in-place performance.

3.2 MIX DESIGN RECOMMENDATIONS

The recommendations for the control and test section mix designs were based on engineering judgment, and experience with cold mix designs using such test data as:

1. Compacted void percent
2. Hveem stability
3. Resilient modulus
4. Visual percent of mixture coated
5. Surface condition of compacted sample
6. Gradation of RAP in the pile as compared to the extracted aggregate gradation and asphalt content.
7. Absolute viscosity of the recovered asphalt
8. Penetration of the recovered asphalt.

The mix design recommended for the control section was 2% HFE-150 plus 0.5% added water. For the test section, the recommended combination included 1.5% HFE-150, 0.5% UUD, 1.8% fine ground tire rubber, and 1.0% added water.

4.0 CONSTRUCTION

RAP and anionic high float emulsion (HFE-150 also known as HFMS-2) were used for the construction of the control section. The test section included the same materials, the UUD dispersion agent, and finely ground recycled tire rubber. Approximately 280 tons of the unmodified cold mix and 280 tons of the modified cold mix were constructed.

The mixing plant was an ASTEC drum mix plant with some modifications. The tire rubber was added on a belt where it was sandwiched between two layers of crushed RAP. To accomplish this, one lime feeder bin was used as storage for the rubber and fed by the screw auger on to the belt between two aggregate cold feed bins. The HFE-150 emulsion was added to the mixture through the conventional asphalt spray bar in the mixing plant drum. The UUD and water were added at an in-line blending pipe inserted through the side of the chamber above the mixing paddles and was plumbed into the asphalt feeder line behind the spray bar. The quantity of UUD and water was controlled through adjustable flow meters.

The ground tire rubber was packaged in 50-pound bags on pallets of 20 bags each. The pallets were lifted by fork lift to the storage bin opening where three or four laborers loosened the rubber in the bags, opened the bags and worked the chunks of rubber through a one inch screen that had been welded into a 30- gallon barrel cut lengthwise to make a funnel. Adding the rubber was very labor intensive and required more time to accomplish than was anticipated. This delayed the start up time by about two hours.

The control section material included 2% HFE-150 with 0.5% water added to help disperse the HFE-150 in the RAP. At the discharge chute, the mixture appeared to be about 75 percent coated and had a "damp" appearance.

The mixture traveled up the slat conveyer and into the short term storage silo. When the mixture was held more than about 5 minutes in the silo, the mixture would bridge over and not flow freely when the discharge gate was opened. To overcome the problem, laborers poked the mixture with long sticks to start the flow into the trucks.

The truck beds were treated with a foaming water soluble liquid called "Zeb Truck Bed Release Agent" which worked very well. At the Blaw-Knox PF510 paver, the mixture was dumped into the hopper that had just been used to place a hot mix wedge to feather in the existing pavement. Since the screed was hot, the emulsion in the cold mix would "break" on the screed. Asphalt would build up on the leading edge, then drag until the screed would "dive" into the mat. After a couple of attempts to clean the screed, it was finally cooled with water.

The mat behind the paver appeared moist and grey and had a very fine, dense texture. Approximately 800 feet of a two lane pavement was constructed for the control section.

The control mixture was not compacted until the emulsion had "broken" throughout the mat. After 5 1/2 hours, compaction was attempted with a steel wheeled static roller. The attempted compaction resulted in transverse hairline cracking on about 1" to 1 1/2" centers. The rolling was discontinued until 7:00 pm, providing an additional 4 hours of curing time. At that time, the roller made a pass up and back over the mat. In addition, the mat was dusted with a light choke of #10 - 0 material to allow traffic to proceed without picking up coated aggregate particles with their tires.

The mixture for the test section contained the crushed RAP with the addition of 1.5% HFE-150 emulsion, 0.5% UUD, 1.8% finely ground tire rubber, and 1% water added. This combination appeared to coat the RAP more uniformly than the control mixture. The test section mixture handled the same as the control, except it supported the paver screed better than the control mixture. About 800 feet of the pavement was constructed for the test section.

Compaction was done after the mix had been down about three hours. The compaction was provided by a steel wheel static roller making only a blanket coverage to reduce the hairline checking of the mat. A light choke of #10 - 0 material was used to reduce tire pickup and the road, posted with "Slow" signs, was opened to traffic.

5.0 POST CONSTRUCTION

Post construction performance was evaluated for both the control and test sections. After two days under traffic, the control section showed some surface raveling but was intact in the wheel tracks. The mixture was consolidated only about 3/4 inches down from the surface. The material below 3/4-inch was keyed with the pneumatic action of the traffic tires. Also after two days under traffic, the test section had completely disintegrated with the traffic action and had no cohesion to support the loadings. The pavement resembled a gravel road. Both sections were later removed.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The use of UUD and rubber in a cold mix was primarily investigated due to the reported performance of similar mixes tested in other laboratories. The laboratory testing done by ODOT did not indicate enhanced performance, however, due to the variables involved and the unknown mix field performance, test and control sections were constructed. Unfortunately, the sections failed. Several factors may have contributed to the failure of the test and control sections. They are in part:

1) The fine, dense gradation of the RAP did not allow the emulsion to break and cure properly.

2) The UUD seemed to either coat or react with the HFE-150 and did not allow the emulsion to break, even on the surface of the constructed mat.

3) The HFE-150 emulsion that was used may not be as compatible with the UUD and finely ground tire rubber as the emulsion used during the preliminary work done by ELI.

4) The addition of rubber to the cold mix may have compounded the other problems.

6.2 RECOMMENDATIONS FOR IMPLEMENTATION

1) ODOT should not use UUD as a cold mix modifier.

2) ODOT should not participate in additional laboratory testing or pilot tests until independent laboratory and field test results are provided to substantiate the claims of enhanced pavement performance associated with the use of UUD and rubber.

6.3 RECOMMENDATIONS FOR FUTURE STUDY

Future evaluations should include, but not be limited to, blending the UUD and rubber with various emulsions or recycle agents and a variety of RAP gradations. Several curing combinations should also be evaluated. This testing should be performed using standard testing procedures to allow for verification and comparison with conventional processes.

7.0 REFERENCES

1. Todd V. Scholz, R. Gary Hicks, and David F. Rogge, *In-Depth Study of Cold In-Place Recycled Pavement Performance*, Volume I, Final Report (Salem, Oregon: Oregon Department of Transportation, December 1990).

APPENDIX

MIX DESIGN TEST RESULTS

TABLE A.1: Samples Prepared with HFE-150

Sample #	1	2	3	8	9	11	12	13	14	15
HFE (%)	2	2	2	2	2	1.5	2.5	1.5	1.5	1.5
UUD(%)	0.5	0.5	0.5	0	0	0.5	0.5	0	1	1
Rubber (%)	1.8	1.8	1.8	0	0	1.8	1.8	0	1.8	1.8
H_2O (%)	0	1	1.5	0	1	1	1	1	1	0
BSG	2.341	2.301	2.318	2.393	2.401	2.294	2.318	2.359	2.248	2.269
Rice Gravity	2.399	2.420	2.410	2.443	2.447	2.411	2.406	2.457	2.408	2.422
Voids (%)	2.4	4.9	3.8	2.0	1.9	4.9	3.7	4.0	6.6	6.3
Stability	11	19	18	25	24	23	18	35	24	17
Mr: Dry (psi)					731,000	612,000			368,000	
Mr: Freeze, Thaw (psi)					797,000	Fell Apart*			Fell Apart*	
IRMr (Freeze Thaw/Dry)					1.09					

* Samples had not cured and were too soft to test after freeze, thaw conditioning

TABLE A.2: Samples Prepared with HFE-300

Sample #	4	5	6	7	10	16	17	18	19	20
HFE (%)	2	2	2	2	1.5	1.5	2.5	1.5	1.5	0
UUD(%)	0	0	0.5	0.5	0	0.5	0.5	1	1	0
Rubber (%)	0	0	1.8	1.8	0	1.8	1.8	1.8	1.8	0
H_2O (%)	0	1	0	1	0	1	1	0	1	0
BSG	2.413	2.421	2.316	2.299	2.394	2.279	2.311	2.260	2.283	2.316
Rice Gravity	2.454	2.434	2.421	2.400	2.463	2.420	2.408	2.428	2.424	2.486
Voids (%)	1.7	0.5	4.3	4.2	2.8	5.8	4.0	6.9	5.8	6.8
Stability	24	3	16	15	39	19	15	16	22	39
Mr: Dry (psi)					648,000	398,000			421,000	
Mr: Freeze, Thaw (psi)					642,000	Fell Apart*			Fell Apart*	
IRMr (Freeze Thaw/Dry)					0.99					

* Samples had not cured and were too soft to test after freeze, thaw conditioning