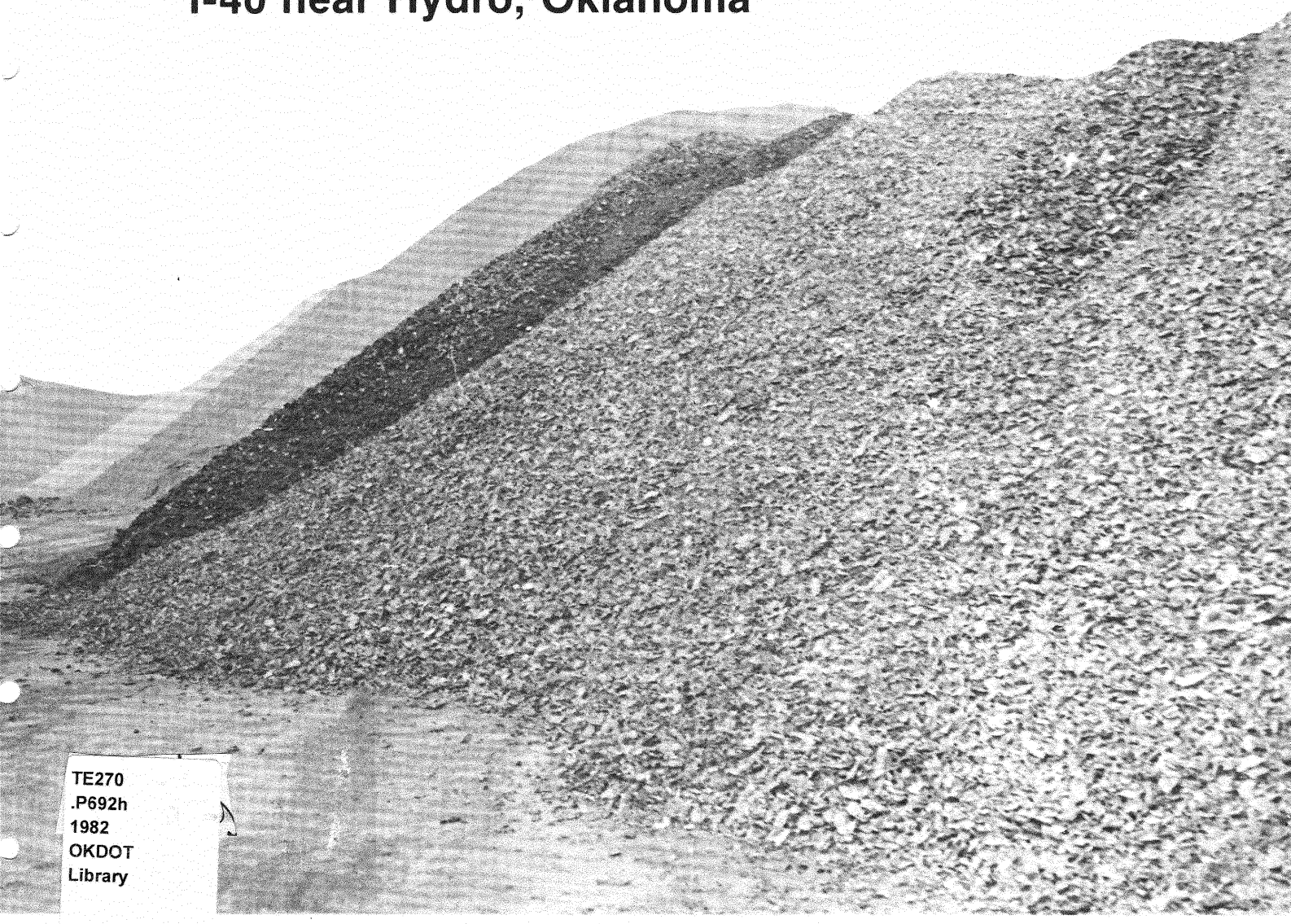
(Revised October, 1982)

HOT RECYCLING of ASPHALT PAVEMENT

I-40 near Hydro, Oklahoma



Research & Development Division
Oklahoma Department of Transportation

H

HOT RECYCLING OF ASPHALT PAVEMENT

by

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Under the Supervision

of

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16. ABSTRACT

The objective of this report is to evaluate the feasibility and benefit of utilizing asphalt pavement hot recycling in Oklahoma. The work began in April, 1980 and lasted through June 1980. The 8 1/2 mile (13.6 km) project was located on I-40 in Caddo County. The project involved cold milling the top one inch (25 mm) of roadway. A non-woven polypropylene fabric, Petromat, was placed on the cold milled surface. This material was overlaid with 1 1/2 inches (38 mm) of the hot recycled mixture containing recycled asphalt concrete, virgin aggregate, and asphalt cement.

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INTRODUCTION

Background

The increasing cost of construction materials along with decreasing highway revenues, has generated the need to recycle asphalt concrete (AC) pavement.

There are three methods of recycling AC pavement; hot mix recycling, cold mix recycling, and surface recycling.

The Oklahoma Department of Transportation (ODOT) believed that hot recycling would provide at least three significant advantages over a conventional overlay. Recycling can conserve energy, materials, and retain the original grade.

At the time of this report, seven projects have been completed in Oklahoma. Approximately 50 miles (80 km) of four lane Interstate highways; namely I-40 and I-35, have been hot recycled. These projects are located in Caddo, Love, Custer, Sequoyah, Payne/Noble, and Beckham Counties.

The project described herein was the second hot recycling job conducted by ODOT. The project was a contract job and done by Brooks and McConnell Construction Corporation. The first project was on I-40 near Weatherford in Custer County and this project was finished in July, 1980.

ODOT Engineers estimate the savings for 50 miles (80 km) of four lane highway to be about $1,250,000. Efforts are currently being made to make greater use of hot asphalt recycling.

Purpose

The purpose of this project is to evaluate the feasibility and benefits of utilizing asphalt pavement hot recycling in Oklahoma.

Scope

The work began on the hot recycling project in April, 1980, and lasted through June, 1980. The project was in two sections located on I-40 in Caddo County. The first section began 1.5 miles (2.4 km) east of the Caddo-Custer County line and extended east six miles (9.6 km). The other began at the US 281 junction and extended east 2.5 miles (4.0 km) ending at the Canadian County line.

The project involved cold-milling the top one inch (25 mm) of roadwa . A non-woven polypropylene fabric, Petromat, was then placed on the cold-milled surface. This material was then overlaid with one and one-half inches (38 mm) of hot recycled mixture containing recycled asphalt concrete, virgin aggregate, and asphalt cement.

A specification relating to the feasibility of hot recycling will be developed and evaluated. (See Appendix A.)

Site Description

Caddo County has a warm continental climate. Winters are mostly moderate and sunny. Temperature ranges from 25° to 45°F (-4° to 7°C) in the winter, and $75^{\circ}$to 95°F (24° to 35°C) in the summer. The lowest recorded temperature since 1936 was -17°F (-27°C) and the highest was 117°F (47°C).

Summers generally are long and hot. The driest month is August. The average annual rainfall is about 32 inches (813 mm) and snowfall is 7.5 inches (91 mm) annually. The maximum frost penetration is about 20 inches (508 mm). The average number of annual freeze-thaw cycles in this area is 40. The average freeze-thaw season for northwest Caddo County lasts 210 days.

About 80 percent of the soils on the project site include the Pond Creek and the Minco soil series with slopes of 0 to 5 percent. The remaining 20 percent are Minco or Lucien soil series with slopes of 0 to 30 percent.

The Pond Creek soil consists of deep, nearly level, or very gently sloping soils on uplands. It is well drained and has moderately slow permeability. The Pond Creek is rated poor to fair as road fill, good for subgrade material, and has low shrink-swell potential.

The Minco soil consists of deep, gently sloping to steep soils on uplands. The Minco soils are well drained and moderately permeable. The Minco soil is rated good for topsoil, good to fair for road fill, and has low shrink-swell potential.

The Lucien soil consists of fine sandy loam developed from sandstone. Lucien is rated good for topsoil, fair as road fill, and has low shrink-swell potential. All three soils, Pond Creek, Minco, and Lucien, are classed as A-4 in the AASHTO Soil Classification System.

PRELIMINARY INVESTIGATION

Description of Pre-Existing Pavement

The roadway section evaluated is located on eastbound and westbound I-40 near the city of Hydro (see Figure 1). Each section includes two lanes, 24 feet (7.3 m) wide, with a 10 foot (3.0 m) outside shoulder and 4 foot (1.2 m) inside shoulder. The road was built in 1961. The design included 8 inches (203) mm) of stabilized aggregate base course; 8 inches (203 mm) of fine aggregate bituminous base; 3 inches (76 mm) of (AC) Type A; and a top layer of 1.5 inches (38 mm) of AC Type C (see Fi ure 2).(2)

Traffic

The average daily traffic (ADT) count was 13,000 vehicles in 1980. The projected ADT for the year 2000 is 29,000 vehicles. The equivalent truck factor (T) is 20 percent.

Crack Survey

The pre-construction crack observations were made approximately two weeks before rehabilitation.

The outside lanes were extensively cracked, east and westbound. The crack types were transverse, longitudinal, random (large block), and alligator. A condition rating for a 2.8 mile (4.5 km) extent of the westbound lane appears in Appendix B.

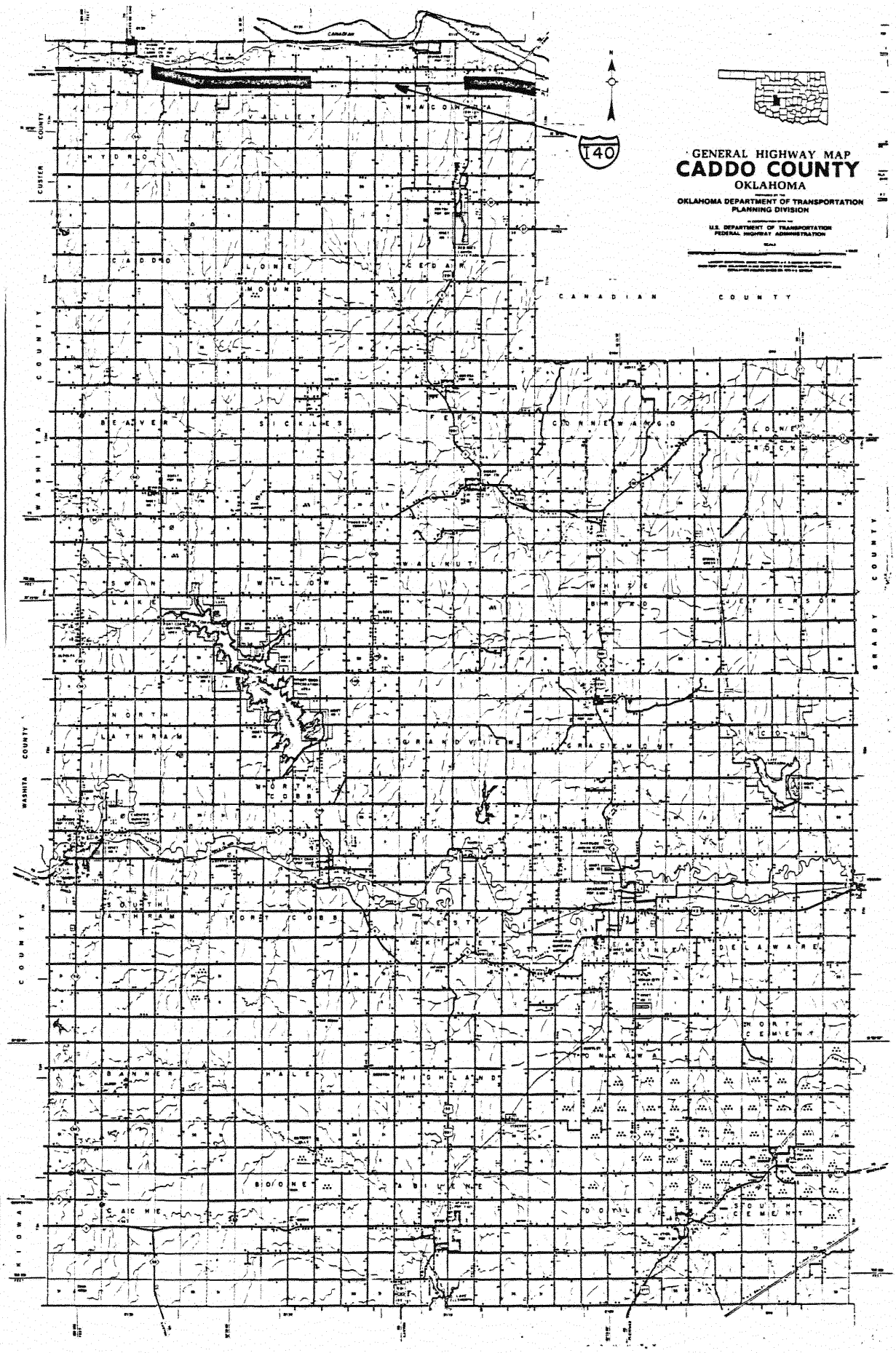

Figure 1. Location of Existing Roadway

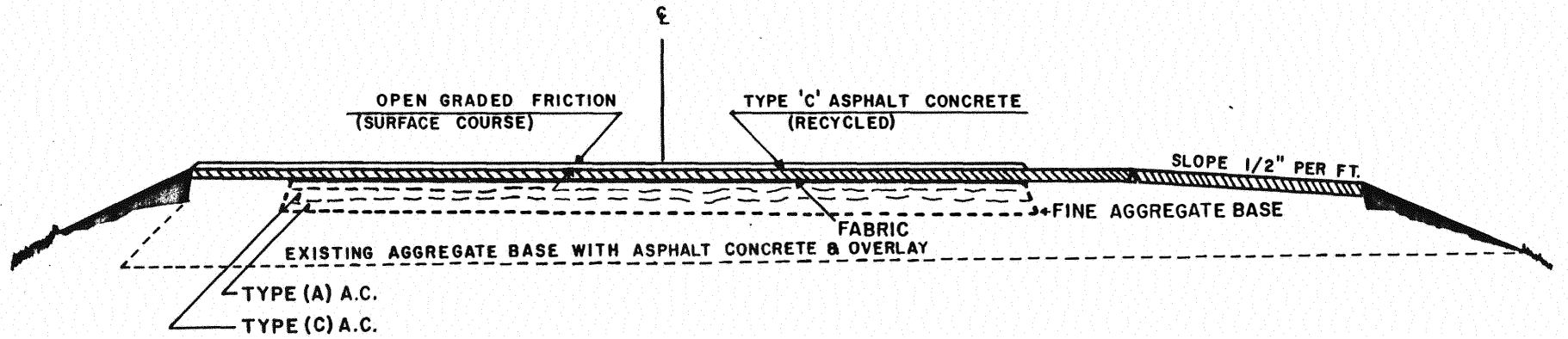

Figure 2. An Illustration showing Pre-Existing Pavement and Recycled Overlay

POST-CONSTRUCTION EVALUATION

The post-construction evaluation was conducted approximately one month after the completion of the project.

Rut Depth Measurement

Rut depth measurements were conducted on July 23, 1980 at 0.25 mile (0.4 km) intervals throughout the project (See Appendix B). The rut depth readings ranged from 0.0 inches to 0.3 inches (0.0 mm to 7.6 mm).

Benkelman Beam Deflection

Benkelman beam deflection measurements were made at 0.25 mile (0.40 km) intervals throughout the project (see Appendix B). The beam deflections ranged from 0.003 inches to 0.025 inches (0.07 mm to 0.6 mm).

Crack Survey

A visual inspection was made approximately one month after the road had been opened to traffic. There were no visible cracks on the road at that time.

FIRST YEAR EVALUATION

Rut Depth Measurement

- Rut depth measurements were conducted on October 29, 1981, at 0.25 mile (0.4 km) intervals throughout the project (see Appendix B). The rut depths ranged from 0.0 inches to 0.4 inches (0.0 mm to 10 mm).

Benkelman Beam Measurement

Benkelman Beam tests were made on October 29, 1981, at 0.25 mile (0.4 km) intervals throughout the project. The Benkelman Beam deflection measurements ranged from 0.006 to 0.025 inch (0.15 to 0.63 mm).

Crack Survey

A crack survey was made on August 19, 1981. There were no cracks observed on the six mile section. The 2.5 mile (4 km) section had only transverse cracks. About 80 percent of the transverse cracks were full width, crossing the road from the edge of the outside shoulder to the edge of the inside shoulder. The transverse crack widths range from light to medium, 1/8 to 3/8 inch (3 to 9 mm). However, the road was in excellent condition. The eastbound lane had a total of 64 transverse cracks and the westbound lane had a total of 107 transverse cracks.

COST ANALYSIS

Economics

In theory, utilizing the old pavement at the project site as a source of material should prove economically feasible. However, the method of recovering the old material generates a significant cost. This cost must be somewhat less than the cost of virgin material in order for the recycling process to be feasible.

The cost analysis for Oklahoma's second hot recycling project is listed below. The total amount of bituminous material used was 30,905 tons, including 14,732 tons of recycled material. See Table 2.

DESIGN AND CONSTRUCTION

Design

The asphalt design mixture for Oklahoma's Type C asphalt concrete (2) used on the project is given in Appendix B. The aggregate consisted of 50 percent crushed limestone, 30 percent limestone screenings, and 20 percent coarse sand. The AC content was 4.8 percent by weight of total mixture. The old asphalt materials analysis is given in Appendix B.

Construction Procedure

The work on the project began on April 30, 1980 and ended on June 3, 1980. A rotomill CMI Model 375 was used to cold mill the old road to a depth of approximately one inch (25 mm). (See Appendix C.) The cold milled material was transferred, by a conveyor belt on the rotomill, to five-axle trucks, brought to the plant site, and stockpiled. It then was screened to separate any material greater than 2 inches (51 mm).

A Boeing drum with CMI mid-point feeder modification was used to recycle the material. The material less than 2 inch (51 mm) in size was brought in half way down the drum mixer. The virgin aggregate was superheated at 450^{o}F (232^{o}C) in the drum and transferred to the end of the drum. There it was mixed with recycled material and then AC was added. The AC content for the mix was 4.8 percent (See Appendix B).

The tack coat (120-150 penetration) was applied to the cold milled surface at the rate of 0.25 gal/yd^2 (1.13 l/m^2). It was used to bind Petromat.

An average 1 and 1/2 inch (38 mm) overlay was laid using a blend of 48 percent reclaimed pavement and 52 percent virgin material. The asphalt cement temperature was 320^{o}F (160^{o}C). The laydown temperature of the hot mix was

about 285°F (141°C). The hot mix material was placed on the road using standard laydown equipment. Compaction was done with a steel wheeled Bomag vibratory roller and a standard pneumatic roller.

Table 1

COSTS FOR CONVENTIONAL OVERLAY

Quantity(Tons)	Material	Cost/Ton($)	Total($)
29,421	Virgin Aggregate	18.75	551,644
1,483	Asphalt Cement	150	222,450
Total cost, conventional mixture:			774,094
Cost per ton, conventional mixture:			25.05

COSTS FOR RECYCLED OVERLAY

Quantity(Tons)	Material	Cost/Ton($)	Total($)
15,448	Virgin Material	18.75	289,650
724	Asphalt Cement	150	108,600
17,393	Cold Mill/Stockpiling	15.74	273,772
14,732	Processing Recycled Material	13.75	202,565
Subtotal			874,587

VALUE OF RECYCLED MATERIAL

Quantity(Tons)	Material	Cost/Ton($)	Total($)
14,010	Cold Mill. Aggregate	18.75	262,688
722	Cold Mill. Asp. Cmt.	150	108,300
Subtotal			370,988
Total Cost: $874,587- $370,988 =			503,599
Cost per ton, recycled overlay:			16.30

Savings

Savings per ton by recycling ($): 8.75

Savings per sq. yd., per inch ($): 0.47

Or

35 percent savings.

Conservation

The amount of materials used in the recycling project and the estimated amount of materials required for an equivalent conventional method are listed in Table 2.

Table 2

QUANTITY COMPARISONS

Quantities Used on Recycled Project	
Recycled materials	14,732 tons
Virgin aggregate	15,448 tons
Asphalt cement 4.8% (avg)	724 tons

Quantities Required for Conventional Method	
Virgin aggregate	29,421 tons
Asphalt cement at 4.8% (avg)	1,483 tons

Quantities Saved by Recycling	
Virgin aggregate	13,973 tons
Asphalt cement	759 tons

ENERGY CONSUMPTION

The energy consumption calculations were made similarly to those in the Asphalt Institute's "Energy Requirements for Roadway Pavements."(1) All fuels are converted to BTU's (British Thermal Units) and then to equivalent gallons of gasoline.

When comparing the results in Table 3 and 4, the energy equivalent of 0.54 gallons (2.04 l) more of gasoline per ton was required to produce asphalt concrete by the conventional method. Therefore, there was a saving of energy equivalent to 0.54 gallon (2.04 l) per ton. Since the project utilized 14,732 tons of recycled material, 7,995 gallons (30.113 l) of gasoline were saved.

Table 3

Energy to Produce One Ton of Recycled Asphalt

1.	Remove, screen, and stockpile recycled material. 0.15 gal.gas/t x 152,000* BTU/gal. x 0.480 t	= 10,944 BTU	= 0.09 gal.gas
2.	Crushing of virgin aggregate. 42,500* BTU/t x 0.497 t	= 21,123 BTU	= 0.17 gal.gas.
3.	Hauling of virgin aggregate. 1,960* BTU/t - mi x 72 mi x 0.497 t	= 70,137 BTU	= 0.56 gal.gas.
4.	Burner fuel. 28,000* BTU/t @ 1% moist. + 470* BTU/F/t x 250° F (0.977 t)	= 142,153 BTU	= 1.14 gal.gas.
5.	Process and delivery of liquid asphalt. [587,500* BTU/t + (1,960* BTU/t - mi x 21 mi x 2)] (0.023 t)	= 15,406 BTU	= 0.12 gal.gas.
6.	Haul of old pavement. 1,960* BTU/t mi x 13 mi x 2 x 0.48 t	= 24,461 BTU	= 0.20 gal.gas.
	Total to produce 1 ton of recycled asphalt concrete		= 2.23 gal.gas.

*Estimate from Reference (1)

Diesel Fuel #5	152,000 BTU/gal
Gasoline	125,000 BTU/gal

1 BTU = 1,055 J
1 gal = 3.78 l
1 ton (English unit) = 0.45 ton (metric unit)
1 mi = 1.6 km

Table 4

Energy to Produce One Ton of Conventional Asphalt Concrete

1.	Crushing of virgin aggregate. 42,500 BTU/t x 0.952 t	= 40,460 BTU	=0.32 gal.gas.
2.	Hauling of virgin aggregate. 1,960 BTU/t mi x 72 mi x 0.952 t	= 134,346 BTU	= 1.07 gal.gas.
3.	Burner fuel. [28,000 BTU/t@1% moist. + (470 BTU/F/t x 250°F)] x 0.952 t	= 139,860 BTU	= 1.12 gal.gas.
4.	Process and delivery of liquid asphalt. [587,500 BTU/t + (1,960 BTU/t mi x 21 mi x 2)] x 0.048 t	= 32,151 BTU	= 0.26 gal.gas.
	Total to produce one ton of conventional asphalt concrete		= 2.77 gal.gas.

CONCLUSIONS AND RECOMMENDATIONS

While the durability performance is yet to be determined, the first year evaluation of the recycled asphalt project shows that it is comparable to conventional asphalt concrete in strength and stability.

The 8.5 mile (13.6 km) recycled overlay project cost about $270,495 less than an equivalent conventional overlay. The savings per yd^2 (0.84 m^2) per inch (25.4 mm) was $0.47.

The energy saving was 0.54 gallon (2.04 l) gasoline per ton of recycled material. Also, 13,973 tons of virgin aggregates and 759 tons of asphalt cement were saved in an 8.5 mile (13.6 km) extent of recycled interstate highway maintenance overlay.

The use of reclaimed AC pavement in new AC pavement is feasible. It is recommended that blending reclaimed pavement and virgin material can be used if proper mix designs and construction quality controls are provided.

REFERENCES

1. "Energy Requirements for Roadway Pavements" (MISC-75-3), the Asphalt Institute, College Park, Maryland, April, 1975.

2. Oklahoma Department of Transportation Specifications, 1976.

APPENDIX A

SPECIFICATIONS

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS
FOR
RECYCLED PLANT MIX ASPHALT CONCRETE PAVEMENT
(TYPE C MIXTURE)

These Special Provisions revise, amend and where in conflict, supersede applicable Sections of Standard Specifications for Highway Construction, Edition of 1976.

411.01. DESCRIPTION. (Add the following). This work shall consist of Recycling Salvaged Bituminous Pavement Materials combined with Virgin Aggregates, Asphalt and/or Softening Agents as specified or directed by the Engineer.

411.02. MATERIALS. (Add the following). Materials shall meet the requirements of Section 708, except as herein specified. Salvaged materials stockpiled at the mixing plant site in accordance with Special Provision 416 (Cold Milling and Stockpiling Existing Bituminous Pavement) shall be utilized in the production of the specified Plant Mixed Bituminous Pavement Mixture. The recycling process shall consist of reprocessing Salvaged Bituminous Pavement Materials combined with Virgin Aggregates, Asphalt and/or Softening Agents as required (Estimated 40% Virgin Aggregate and two (2) percent new Asphalt Cement of total mix) to produce a blend of materials meeting the requirements of Subsection 708.04 Type C mixture.

Any Softening or Rejuvenating Agent required to restore the Salvaged Asphalt Material shall be submitted for tests and approval by the Materials Engineer prior to use.

411.03. EQUIPMENT. (a) General. (Add the following). The plant as specified shall be modified to process Reclaimed Materials. Plant modifications shall be in accordance with the manufacturers recommendations or as approved by the Engineer. The Mixing Plant used shall be designed, equipped and operated in such a manner that the heating and proportioning will yield a uniform blended mix.

The plant shall be provided means of independent calibration and measurement of Virgin Aggregates, Reclaimed Bituminous Mixture, Asphalt and/or Softening Agents.

411.05. METHOD OF MEASUREMENT. (Amend as follows). (a) Virgin Aggregate and Reclaimed Bituminous Mixture will be measured seperately by the ton.

(b) (Revise the second sentence to read) Measurement of Virgin Aggregate, Asphalt, and Reclaimed Bituminous Mixture shall be determined by weighing the composite mixture as provided in Section 109.01(a). The weight of Virgin Aggregate, Asphalt, and Reclaimed Bituminous Mixture will be based on proportions established by the job-mix formula.

Softening or Rejuvenating Agents will not be measured for payment.

411.06. BASIS OF PAYMENT. (Add the following). Accepted quantities for Recycled Plant Mix Asphalt Concrete Pavement, measured as provided above, will be paid for at the contract unit price for:

(A) Sp.	VIRGIN AGGREGATE	TON
(B) Sp.	ASPHALT	TON
(D) Sp.	PROCESSING RECLAIMED BITUMINOUS MIXTURE	TON

which shall be full compensation for furnishing all materials, equipment, labor and incidentals to complete the work as specified.

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS
FOR
COLD MILLING AND STOCKPILING EXISTING BITUMINOUS PAVEMENT

These Special Provisions revise, amend, and where in conflict, supersede applicable Sections of Standard Specifications for Highway Construction, Edition of 1976.

416.01. DESCRIPTION. This work shall consist of cold milling and removing the existing bituminous pavement surface to a depth shown on the plans below the present finished grade, removing ridges, ruts and other imperfections and stockpiling the resulting material at the site of the central mixing plant or at locations shown on the plans or determined by the engineer. The milling work shall furnish a plane surface providing traffic a smooth riding surface. The surface aggregate shall be sheared and textured by the milling machine in a manner approved by the Engineer.

416.03. EQUIPMENT. The contractor shall provide a power operated milling machine capable of planing a depth of one and one-half inches in a single pass. The equipment shall be self-propelled with sufficient power, traction and stability to maintain accurate depth of cut and slope. The equipment shall be capable of accurately and automatically establishing profile grades along each edge of the machine by referencing from the existing pavement by means of a ski or matching shoe or from an independent grade control and shall have an automatic system for controlling cross slope at a given rate. The machine shall be equipped with an integral loading means to remove the material being cut from the surface of the roadway and discharge the cuttings into a truck, all in one operation.

416.04. CONSTRUCTION METHODS. The existing pavement shall be uniformly milled providing a uniform texture, true to line, grade and cross section, it shall have no deviations in excess of 3/16 inch (4.8 mm) in ten feet. Any portion of the planed surface not meeting this requirement shall be corrected in a manner approved by the Engineer.

The machine shall make as many passes as necessary to remove irregularities and to profile the surface to the depth and cross slope shown on the plans.

The cold milling shall be done in a manner that will not create undue traffic hazards with one traffic lane open at all times.

The milling operation shall be performed in each lane in such a manner that the milled lanes will be evened up as near as practical at the end of each days operation so as to eliminate the hazard of an exposed vertical edge when traffic is carried through construction.

It is expected that this method of removal will provide salvaged material such that 100% of the material sizes will have at least one dimension of 2 inches (50 mm) or less. Hauling and stockpiling of the salvaged material will be done in accordance with Section 106.07.

All aggregate removed and stockpiled and not used in the recycled bituminous mix shall become the property of the contractor and shall be disposed of by him in accordance with Section 104.06 unless otherwise specified on the plans.

416.05. METHOD OF MEASUREMENT. Cold milling will be measured by the square yard of surface area. Hauling and stockpiling operations will not be measured as a separate item.

416.06. BASIS OF PAYMENT. Accepted quantities of cold milling, measured as provided above, will be paid for at the contract unit price for:

COLD MILLING SQ. YD.

Which shall be full compensation for furnishing all materials, equipment, labor and incidentals to complete the work as specified.

APPENDIX B

TEST RESULTS

CONDITION RATING
FOR
FLEXIBLE PAVEMENTS

DATE: May 7, 1980

LOCATION: I-40 Westbound

LENGTH: _____ MILES SURVEYED BY: Jack Stewart

Condition Rating	I Cracking	II Surface Roughness	III Distortion	IV Ravelling	V Base Failure
1					
2	1	1			
3	2	2	1	1	
4	3	3	2	2	1
5	4	4	3	3	2-3
6	4	4	4	4	4

1 = less than 5%
2 = 5% to 15%
3 = 15% to 30%
4 = more than 30%

Mileage Location	Condition Rating	I	II	III	IV	V	% Condition Rating	Beam Deflection	S.W.L.	Rut Depth	S. F. Patching
0.0	-							Immediately over box			
0.2	6	4	4	4	1	4		Rt. lane is extensively cracked			
0.4	5	2	2	3	1	2					
0.6	5	4	4	2	1	3					
0.8	5	4	4	2	1	3					
1.0	5	4	3	2	1	2					
1.2	5	4	3	2	1	2					
1.4	5	3	3	2	1	3					
1.6	6	3	3	2	1	4					
1.8	6	4	3	2	1	4		Rt. Lane extensively cracked Lt. Lane same			
2.0	5	4	3	2	1	3					
2.2	5	4	3	2	1	3					
2.4	6	4	3	2	1	4					
2.6	6	4	4	3	1	3		Rt. Lane is by far the worse			
2.8	5	4	3	3	1	3					

Rut Depth Measurements
Seven Months after Construction

Caddo Co. (6 mile long project) IR-40-4(288)090

			in.
1.	Milemarker 90 (west end of project)	A. 0.0 in all wheelpaths	
2.	Station 4885+15	A. Rt. wheelpath-Rt. Lane	0.3
		B. Lt. wheelpath-Rt. Lane	0.0
		C. Rt. wheelpath-Lt. Lane	0.1
		D. Lt. wheelpath-Lt. Lane	0.1
3.	Milemarker 93	A. Rt. wheelpath-Rt. Lane	0.0
		B. Lt. wheelpath-Rt. Lane	0.1
		C. Rt. wheelpath-Lt. Lane	-0.1
		D. Lt. wheelpath-Lt. Lane	0.0
4.	1/4 mile W of the E end of project (Approx. 1/4 mile E of Bethel Rd.)	A. Rt. wheelpath-Rt. Lane	0.0
		B. Lt. wheelpath-Rt. Lane	-0.1
		C. Rt. wheelpath-Lt. Lane	-0.1
		D. Lt. wheelpath-Lt. Lane	0.0

Caddo Co. (2.5 mile long project) IR-40-4(293)102

1.	Milemarker 102	A. Rt. wheelpath-Rt. Lane	0.1
		B. Lt. wheelpath-Rt. Lane	0.05
		C. Rt. wheelpath-Lt. Lane	-0.1
		D. Lt. wheelpath-Lt. Lane	-0.05
2.	Milemarker 104 (1/4 mile W of the E end at Canadian County line)	A. Rt. wheelpath-Rt. Lane	0.0
		B. Lt. wheelpath-Rt. Lane	-0.1
		C. Rt. wheelpath-Lt. Lane	-0.1
		D. Lt. wheelpath-Lt. Lane	0.0

D H-FORM 352-63

Calculations Checked By

Proof Read By

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STATE OF OKLAHOMA

DEPARTMENT OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

ASPHALTIC MIXTURES DESIGN

3013-39366
1130-39366
3050-39366
3050-39367
Report No. 3050-39368
3050-39369
C. S. No. ~~1130~~-39369
0113-

Project No. IR-40-4(288)090 03045(04) County Caddo Hwy I-40 Division 5

Contractor Brooks & McConnell Const.Corp Specification Item 708 Type C Design No. 3013-39366
Plant at Weatherford

MATERIAL	SOURCE	% USED
Old Asph. Mixture	McConnells Plant site at Weatherford	52%
New Asph. Mixture	(95% New Agg. + 5.0% New AC)	48%
3/8" Chips	The Dolese Co. at Cooperton	50%
Screenings	" " " "	30%
Sand	Sec. 23, T13N, R17W, Custer Co.	20%

Laboratory No.	39369	39366	39367	39368	Combined	Job	Required
Percent Passing	old asph	chips	Screenings	Sand	Aggregate	Formula	Spec's.
3/4"				100	100	100	100
1/2"	100	100		97	100	100	95-100
3/8"	99	93	100	96	97	93	80-100
No. 4	82	20	98	90	70	68	55-75
No. 10	57	4	61	81	47	47	40-55
No. 40	35	2	24	44	26	26	18-33
No. 80	23	2	16	26	17	18	10-22
No. 200	12.1	1.3	11.3	13.3	9.4	8	4-10
% Asph. Cement						4.8	4.4-7.5
Asph. Content 4.9							

Sand Equivalent---------- 63----- 45 Min.
Los Angeles Abrasion, % Wear (500 Rev.)----------26.3--- 40 Max.
Durability, Dc Factor----------78----- 40 Min.
Bulk Impregnated Specific Gravity----------2.695

TESTS ON COMPRESSED MIXTURES

Percent Asphalt	Specific Gravity Specimen	Max. Theo. Specific Gravity	V.M.A. (%)	V.F./AC. (%)	Vv (%)	Density % of Max. Theo.	Stability Value
4.4	2.378	2.511	15.6	66.0	5.3	94.7	56
4.9	2.388	2.491	15.7	73.9	4.1	95.9	54
5.4	2.400	2.472	15.8	81.6	2.9	97.1	47

Recommended 2.4% Asph. Cement (180-200 Pen.)
Compacted Wt. 112 lbs/sq.yd./1" thickness

Absorption	old mix	new mix
Penetration	38	66
Ductility	25	150+

cc:Materials
2-Asph. Design
1-W.J. Heerwald
1-Div. 5
1-Brooks & McConnell
1- Liaison

MEETS SPECIFICATION REQUIREMENTS

Transmitted 4-22-80 19

J.D. Telford, P.E.
Materials Engineer

AC OVERLAY PROGRAM

from

BENKELMAN BEAM TESTS

DIVISION 5 COUNTY CADDO TEST DATE September 23, 1980

DESCRIPTION: I-40 Westbound lanes from US 281 East 2.5 miles

Rut Depth** (inches)	Mileage Extents (miles)	Beam Deflection (inches)	Load Supporting Ability (lbs.)	Required Overlay for 15,000 lbs wheel load (inches)
**	2.50	0.000	*	0
**	2.25	0.011	*	0
**	2.00	0.002	*	0
**	1.75	0.017	19915	0
**	1.50	0.007	*	0
**	1.25	0.014	*	0
**	1.00	0.015	*	0
**	0.75	0.011	*	0
**	0.50	0.021	15504	0
**	0.25	0.013	*	0
**	0.00	0.019	17456	0

*Wheel load greater than 20,000 lbs.
**Not available

AC OVERLAY PROGRAM

from

BENKELMAN BEAM TESTS

DIVISION 5 COUNTY CADDO TEST DATE September 23, 1980

DESCRIPTION: I-40 Eastbound lanes from US 281 East 2.5 miles

Rut Depth** (inches)	Mileage Extents (miles)	Beam Deflection (inches)	Load Supporting Ability (lbs.)	Required Overlay for 15,000 lbs wheel load (inches)
**	0.00	0.000	*	0
**	0.25	0.015	*	0
**	0.50	0.005	*	0
**	0.75	0.016	*	0
**	1.00	0.010	*	0
**	1.25	0.016	*	0
**	1.50	0.008	*	0
**	1.75	0.012	*	0
**	2.00	0.016	*	0
**	2.25	0.015	*	0
**	2.50	0.018	*	0

*Wheel load greater than 20,000 lbs.
**Not available.

AC OVERLAY PROGRAM

from

BENKELMAN BEAM TESTS

DIVISION 5 COUNTY CADDO TEST DATE September 23, 1980

DESCRIPTION: I-40 Westbound lanes from Hydro extending East 6.0 miles

Rut Depth** (inches)	Mileage Extents (miles)	Beam Deflection (inches)	Load Supporting Ability (lbs.)	Required Overlay for 15,000 lbs wheel load (inches)
**	5.75	0.001	*	0
**	5.50	0.020	16427	0
**	5.25	0.015	*	0
**	5.00	0.015	*	0
**	4.75	0.020	16427	0
**	4.50	0.016	*	0
**	4.25	0.012	*	0
**	4.00	0.020	16427	0
**	3.75	0.018	18611	0
**	3.50	0.001	*	0
**	3.25	0.006	*	0
**	3.00	0.004	*	0
**	2.75	0.023	13919	1.2
**	2.50	0.022	14672	0
**	2.25	0.015	*	0
**	2.00	0.010	*	0
**	1.75	0.018	18611	0
**	1.50	0.012	*	0
**	1.25	0.013	*	0
**	1.00	0.011	*	0
**	0.75	0.015	*	0
**	0.50	0.007	*	0
**	0.25	0.015	*	0

* Wheel load greater than 20,000 lbs.
** Not available.

AC OVERLAY PROGRAM

from

BENKELMAN BEAM TESTS

DIVISION 5 COUNTY CADDO TEST DATE September 23, 1980

DESCRIPTION: I40 Eastbound lanes from Hydro extending East 6.0 miles

Rut Depth** (inches)	Mileage Extents (miles)	Beam Deflection (inches)	Load Supporting Ability (lbs.)	Required Overlay for 15,000 lbs wheel load (inches)
**	0.0	0.0	159	0
**	0.25	0.008	*	0
**	0.50	0.016	*	0
**	0.75	0.021	15504	0
**	1.00	0.015	*	0
**	1.25	0.007	*	0
**	1.50	0.018	18611	0
**	1.75	0.018	18611	0
**	2.00	0.016	*	0
**	2.25	0.023	13919	1.2
**	2.50	0.017	19915	0
**	2.75	0.015	*	0
**	3.00	0.018	18611	0
**	3.25	0.020	16427	0
**	3.50	0.015	*	0
**	3.75	0.022	14672	0
**	4.00	0.013	*	0
**	4.25	0.014	*	0
**	4.50	0.023	13919	1.2
**	4.75	0.006	*	0
**	5.00	0.015	*	0
**	5.25	0.018	18611	0
**	5.50	0.014	*	0
**	5.75	0.015	*	0
**	6.00	0.028	11025	4.4

* Wheel load greater than 20,000 lbs.
** Not available.

AC OVERLAY PROGRAM

from

BENKELMAN BEAM TESTS

DIVISION 5 COUNTY CADDO TEST DATE October 29, 1981

DESCRIPTION: I-40 West bound lanes from US 281 extending East 2.5 miles

Rut Depth (inches)	Mileage Extents (miles)	Beam Deflection (inches)	Load Supporting Ability (lbs.)	Required Overlay for 15,000 lbs wheel load (inches)
0.0	2.50	0.011	*	0
0.1	2.25	0.011	*	0
0.2	2.00	0.009	*	0
0.2	1.75	0.008	*	0
0.3	1.50	0.008	*	0
0.3	1.25	0.009	*	0
0.3	1.00	0.011	*	0
0.2	0.75	0.008	*	0
0.0	0.50	0.009	*	0
0.3	0.25	0.009	*	0
0.2	0.0	0.010	*	0

* Wheel load greater than 20,000 lbs.

AC OVERLAY PROGRAM

from

BENKELMAN BEAM TESTS

DIVISION 5 COUNTY CADDO TEST DATE October 29, 1981

DESCRIPTION: I-40 East bound lanes from US 281 extending East 2.5 miles

Rut Depth (inches)	Mileage Extents (miles)	Beam Deflection (inches)	Load Supporting Ability (lbs.)	Required Overlay for 15,000 lbs wheel load (inches)
0.0	0.0	0.012	*	0
0.2	0.25	0.011	*	0
0.2	0.50	0.010	*	0
0.0	0.75	0.009	*	0
0.1	1.00	0.008	*	0
0.2	1.25	0.009	*	0
0.1	1.50	0.007	*	0
0.1	1.75	0.007	*	0
0.0	2.00	0.008	*	0
0.0	2.25	0.009	*	0
0.0	2.50	0.011	*	0

* Wheel load greater than 20,000 lbs.

AC OVERLAY PROGRAM

from

BENKELMAN BEAM TESTS

DIVISION 5 COUNTY CADDO TEST DATE Ocotber 29, 1981

DESCRIPTION: I-40 Westbound lanes from Hydro extending East 6.0 miles

Rut Depth (inches)	Mileage Extents (miles)	Beam Deflection (inches)	Load Supporting Ability (lbs.)	Required Overlay for 15,000 lbs wheel load (inches)
0.2	6.00	0.014	*	0
0.1	5.75	0.011	*	0
0.2	5.50	0.020	16427	0
0.1	5.25	0.015	*	0
0.2	5.00	0.021	15504	0
0.1	4.75	0.008	*	0
0.0	4.50	0.025	12610	2.7
0.2	4.25	0.020	16427	0
0.1	4.00	0.020	16427	0
0.1	3.75	0.021	15504	0
0.1	3.50	0.015	*	0
0.1	3.25	0.006	*	0
0.1	3.00	0.017	19915	0
0.0	2.75	0.024	13235	2.0
0.2	2.50	0.008	*	0
0.0	2.25	0.015	*	0
0.1	2.00	0.012	*	0
0.0	1.75	0.014	*	0
0.2	1.50	0.011	*	0
0.1	1.25	0.015	*	0
0.2	1.00	0.010	*	0
0.1	0.75	0.014	*	0
0.1	0.50	0.014	*	0
0.4	0.25	0.015	*	0
0.1	0.0	0.016	*	0

* Wheel load greater than 20,000 lbs.

AC OVERLAY PROGRAM

from

BENKELMAN BEAM TESTS

DIVISION 5 COUNTY CADDO TEST DATE October 29, 1981

DESCRIPTION: I-40 Eastbound lanes from Hydro East extending 6.0 miles

Rut Depth (inches)	Mileage Extents (miles)	Beam Deflection (inches)	Load Supporting Ability (lbs.)	Required Overlay for 15,000 lbs wheel load (inches)
0.0	0.0	0.018	18611	0
0.1	0.25	0.010	*	0
0.1	0.50	0.015	*	0
0.0	0.75	0.012	*	0
0.0	1.00	0.008	*	0
0.1	1.25	0.016	*	0
0.0	1.50	0.016	*	0
0.1	1.75	0.012	*	0
0.2	2.00	0.007	*	0
0.1	2.25	0.011	*	0
0.2	2.50	0.018	18611	0
0.1	2.75	0.012	*	0
0.2	3.00	0.018	18611	0
0.1	3.25	0.011	*	0
0.1	3.50	0.018	18611	0
0.1	3.75	0.012	*	0
0.1	4.00	0.014	*	0
0.1	4.25	0.016	*	0
0.0	4.50	0.022	14672	0
0.0	4.75	0.012	*	0
0.0	5.00	0.012	*	0
0.0	5.25	0.016	*	0
0.1	5.50	0.018	18611	0
0.0	5.75	0.016	*	0
0.1	6.00	0.024	13235	2.0

*Wheel load greater than 20,000 lbs.

APPENDIX C

PHOTOGRAPHS

Figure 1. The old pavement was cold milled approximately one inch deep. The material was then transported to the plant site.

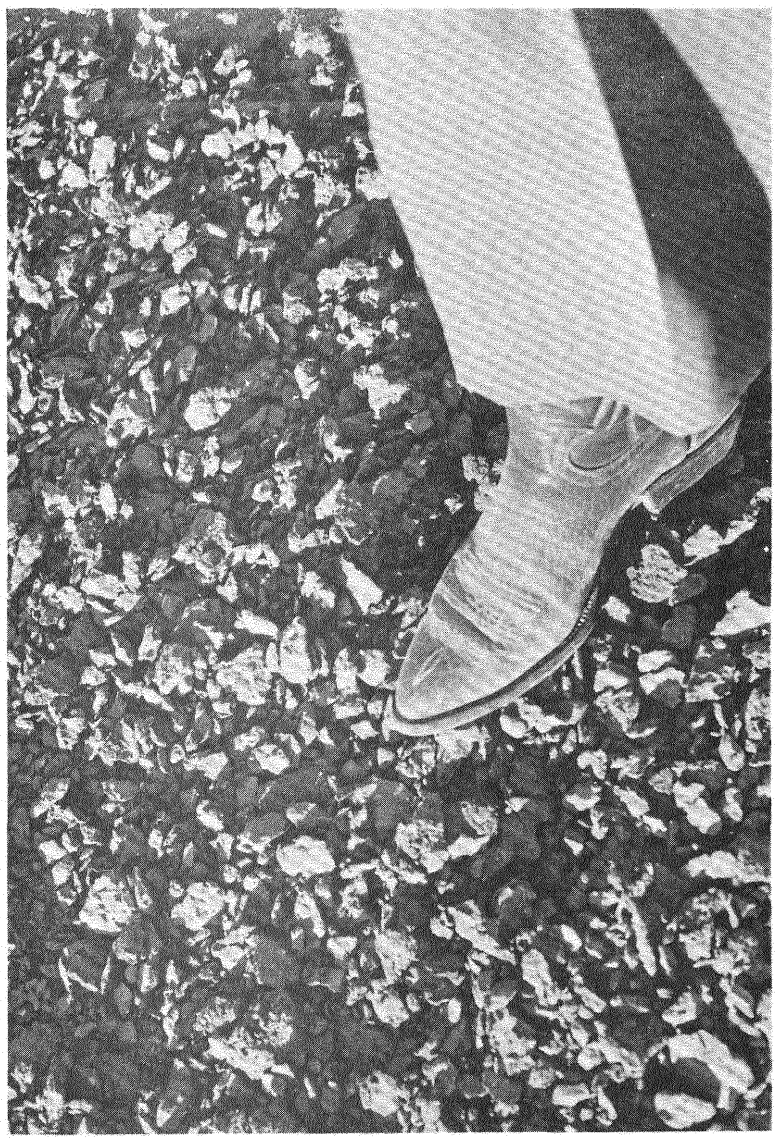

Figure 2. Typical recyclable material after cold milling. It was a nominal 2 inch size.

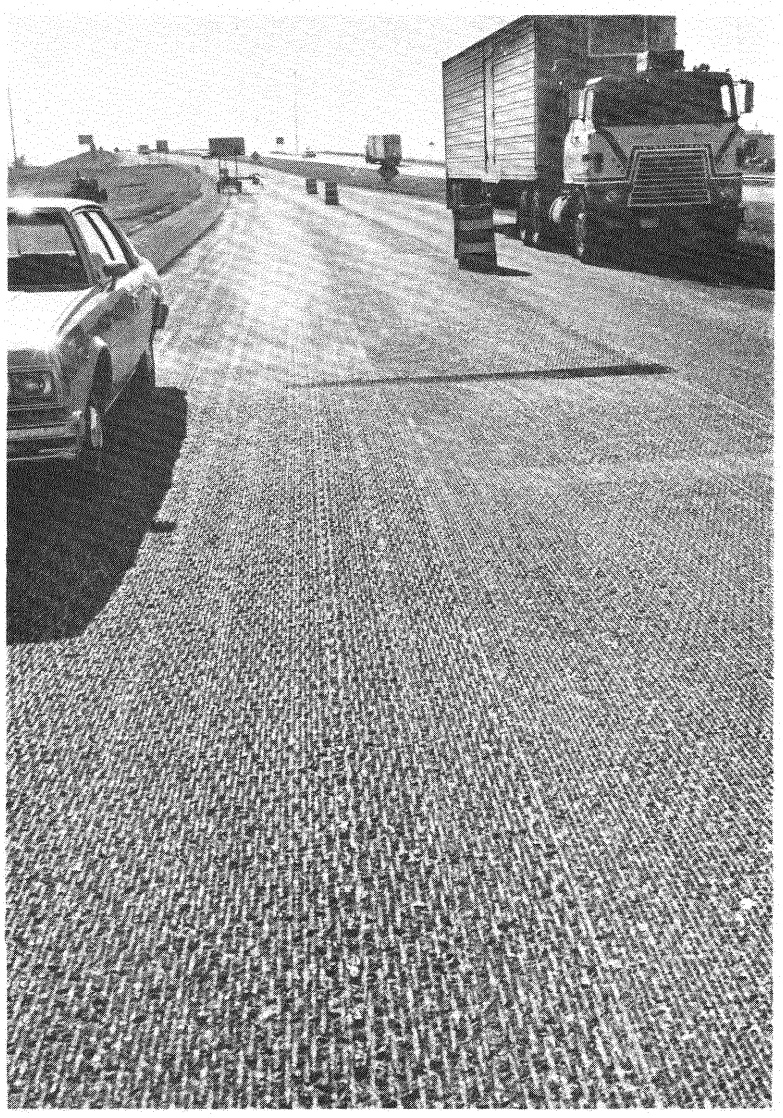

Figure 3. The rotomill used to cold mill the surface left a uniform texture.

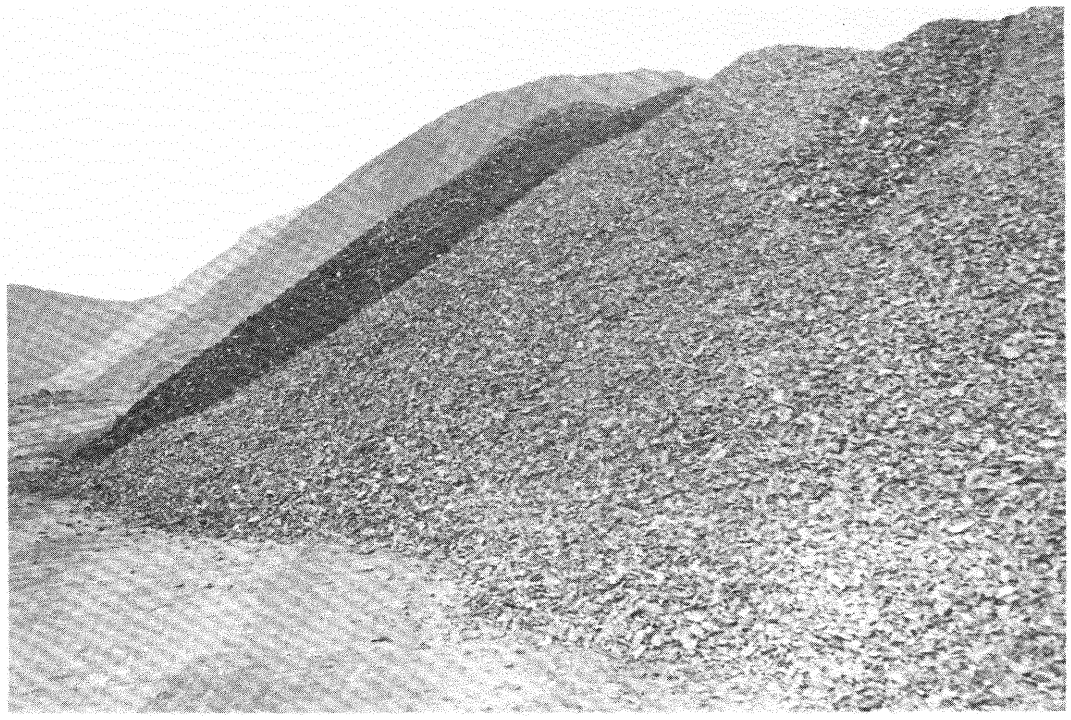

Figure 4. Recyclable material stockpiled in the foreground. Three stockpiles of virgin aggregate are in the background.

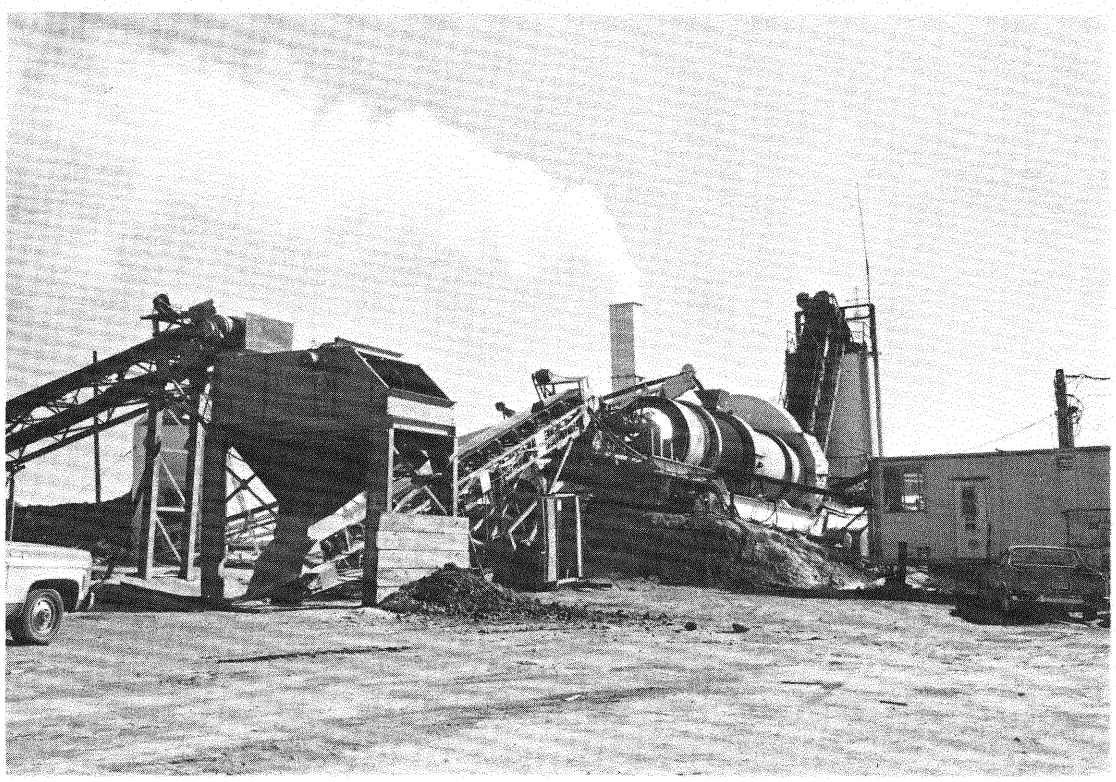

Figure 5. The recycling plant was an old boeing drum with a C.M.I. modification. This allowed the recycled material to be introduced mid-way down the drum - away from the flame.

Figure 6. Petromat was placed on the cold-milled surface prior to the overlay. It would carry traffic for approximately ten days.

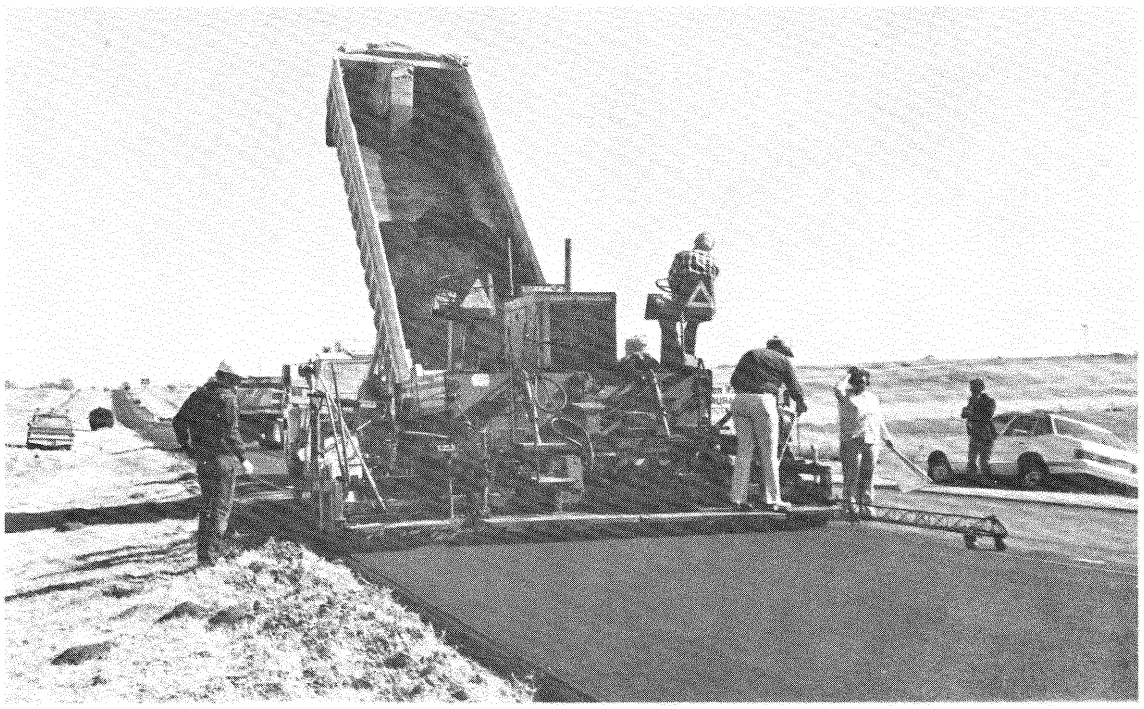

Figure 7 and 8. The recycled overlay was placed in a conventional manner. No special equipment was required.