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EVALUATION OF A RECYCLED ASPHALTIC CONCRETE PAVEMENT DEMONSTRATION PROJECT NO. 39 U.S. ROUTE 65, DALLAS COUNTY, MISSOURI INITIAL REPORT

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ABSTRACT

The concept of recycling asphaltic concrete is certainly not new. Attempts to use old asphalt pavements in new construction were qualified successes many years ago. However, the economics of the times usually made new mixes more practical.

In the recent past, many agencies have tested the recycling concept as the cost of new material and the technology of cold milling and drum mixing made it increasingly attractive. This experience has shown recycling to be a workable and economical method of asphaltic concrete pavement construction.

This asphaltic concrete recycling project was developed through the experience of other agencies as well as preliminary design and testing completed by the MHTD Laboratory in the past few years on numerous pavements proposed for recycling.

The report includes field observations of the existing surface and the construction and initial performance of both the recycled and control mixtures. Summaries of tests performed in the course of the work are shown.

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INTRODUCTION

The traditional method of resurfacing a deteriorated asphalt pavement has been to add appropriate layers of new mix to restore the cross section and repair structural deficiencies. In most cases, this also dictated additional shoulder work, guardrail, curb or manhole adjustment and the use of all new materials in the overlay. By removing a portion of the existing asphalt surface, and restoring the mix to current design criteria, it is possible to restore the surface cross section at the same grade while using a fraction of the usual new material quantities.

This study was undertaken to evaluate the feasibility of recycling the riding surface of existing pavements. Should the method prove satisfactory it could result in significant cost savings and conservation of materials and energy.

PURPOSE AND SCOPE

This study was developed to field evaluate a recycled asphaltic concrete pavement. Specific questions to be answered were:

a. Can a specification mixture be produced using recycling methods?

b. Can a recycled pavement conserve material economically?

c. Will a recycled pavement be durable enough to be economical?

A complete evaluation of recycled asphalt pavement will not be possible during the term of this study unless early failure occurs, however, visual observations and Laboratory tests on cores from the surface will be made periodically until a projected service life can be established.

The asphalt plant used to prepare the recycled mixture was the first drum mix asphalt plant used to produce high-type mixtures on Missouri highway projects. Although the mixture and the plant were closely observed, this report is not intended to be an evaluation of this relatively new mixing process.

PROJECT DESCRIPTION

The work included cold milling and resurfacing, with recycled asphaltic concrete, U.S. Route 65 in Dallas County, Missouri from the town of Buffalo, south to near the Green County line, a total length of approximately 15.7 miles. A control section, approximately 2 miles long, extended from Route O, south to the end of the project, 0.3 mile north of Route AA (Figure 1). The control section was to receive standard Type C asphaltic concrete composed of all virgin aggregate with the remainder to receive recycled asphaltic concrete containing 30-50% reclaimed surface mixture.

The original pavement consisted of a twenty foot wide portland cement concrete pavement with a monolithic gutter or "lip" edge (Figure 2). Originally resurfaced in 1955, another resurfacing and widening took place in 1967 producing a total surface thickness of approximately 3 inches of existing Type C asphaltic concrete available for recycling.

EXISTING CONDITION OF OLD ROADWAY SURFACE

The existing surface had good stability and there was no serious rutting (Figure 3). The deepest ruts, ranging from 1/2" to 5/8", occurred along the edge widening joint. The traffic volume was 3,910 vehicles per day, according to the 1981 traffic count. Reflective cracks from the old faulted and deteriorated concrete slab joints and the edge widening had received extensive, periodic sealing (Figure 4). There were occasional, random patches across the full width of one or both lanes (Figure 5).

After cold milling, ravelling was noted at reflected slab joints and along the edge widening joint (Figure 6). These loosely bedded areas extended deeper than the 1 1/4" cold milling and could be a source of early distress in the recycled mix. It was also noted during cold milling that, especially where moisture was present, the existing overlay was disbonded from the previous overlay. Since limited funds prevented the additional cold milling needed to remove the full depth of the mix placed in 1967, some thin, disbonded layers of this mix were present in many areas (Figure 7).

The surface mix being reclaimed, C67-291 (hereafter referred to as reclaim), was approved with 5.0% 70-85 penetration grade asphalt (Table 1). Tests on recovered asphalt indicated an existing penetration in the high teens to low twenties. Extractions on preliminary cores drilled from the roadway (Figure 8) showed the mix to be well graded, closely complying with the original job mix (Table II).

MIX DESIGN CRITERIA

The basic design criteria for a normal Type C Asphaltic Concrete mix were used for the recycled mix. Requirements for gradation, stability and voids were not changed. Quality and gradation requirements on the virgin aggregates also remained unaltered from those used in a normal mix.

Preliminary cores had been taken in June, 1980. Extracted gradations and asphalt content were relatively close to the original job mix values. A check on the Theoretical Maximum Specific Gravity by the "Rice Method", AASHTO T 209, was close enough to the value shown on the original job mix formula that the job mix value was used for the reclaim in the recycled mix designs.

Gradation tests were also performed on the milled reclaim (Table III). The contractor chose to process this material through a hammer mill to insure compliance with the contract requirement that 100% of the reclaim pass a 1 1/2" sieve. Some degradation was apparent when comparing the trial mix and preliminary core gradations, most notably in the 3/8-4 and -200 sieve fractions (Table II).

When the extracted gradation of the reclaim and the gradation of the virgin aggregates were combined, it was not necessary to add any mineral filler to comply with normal Type C mix requirements.

Asphalt from the preliminary cores was extracted in the Laboratory and blended with several different penetration grades of new asphalt. A range of blends was tested indicating an accelerated trend toward rejuvenation as the percentage of new asphalt increased (Figures 9 and 10). The use of special chemical rejuvenators was not considered necessary since the contract specified a maximum of 50% reclaim and the 200-300 penetration grade material appeared to be satisfactory at that percentage. The tests on recovered asphalt shown in Table IV indicate that the asphalt in the recycled mix exhibited properties close to those predicted by the laboratory blends.

The actual percentage of new asphalt added depended to a great extent on the gradation of the reclaim. The gradation determined the amount and type of virgin aggregate needed to produce a specification mix. Once a suitable combined grading was obtained, additional new asphalt was added to produce a well coated mix satisfying stability and void requirements.

The contractor requested mixes using 40% (Table V), 45% (Table VI), and 50% (Table VII) reclaim. Initial production began with the 50% mix and when no problems were encountered it was decided to use it throughout the test section.

The control section was surfaced with a similar, all virgin mix, C82-57 (Table VIII). This mix, approved with 4.4% 60-70 penetration grade asphalt, represents a typical Type C surface mix. It is composed of all new aggregates identical to the new aggregates combined with the reclaim in the recycle mix. There was no intent to design the control mix so that both mixes would have identical design characteristics. Rather, the control mix was typical of any Type C surface mix approved by MHTD with the materials encountered in this area.

CONSTRUCTION PROCEDURE

Cold milling of the existing pavement began on March 16, 1982 on the north end of the project. A CMI PR750 Roto-Mill was used to remove the mix to the design depth of cut in one pass (Figure 11). The depth of the cold milling was specified to be 1 1/4". When the project was widened and resurfaced in 1967, a 1/2" minimum leveling course was placed prior to the 1 1/4" Type C surface course. Figure 13 shows the layers of various mixtures. When the full 1 1/4" was cold milled to produce the desired cross section, a thin layer of the 1967 level course, some of which was loosely bonded to the underlying (1955) mix (Figures 7 and 12), was left in irregular shaped areas throughout the project. Much of the loosely bonded thin layer slabbed off during the milling operation and was removed by normal traffic activity. Because of limited funds, it was felt the extensive work needed to remove more of the old mix and repair ravelled out edge widening and reflected slab joints could not be done at this time.

The milled reclaim was loaded into trucks directly from the Roto-Mill (Figure 14). After a sufficient quantity had been hauled to the contractor's asphalt plant for processing to obtain a representative trial mix sample, reclaim was stockpiled on an abandoned section of pavement at the south end of the project. This remaining reclaim for recycling was then hauled to the asphalt plant as trucks which hauled recycled mixture to the project returned to the asphalt plant. Reclaim not needed in the recycled mix was taken to Maintenance lots at several locations where it became the property of MHTD (Figure 15).

The construction of the recycled pavement was performed with conventional equipment and procedures. A hammer mill (Figure 16) reduced the chunks of reclaim to 100% passing a 1 1/2" sieve as it passed from its cold feed bin to a surge bin, then onto the recycle belt scale conveyor (Figure 17). The hammer mill was run as slow as possible to minimize fracture of the aggregate in the reclaim. The crushed reclaim was added to the drum mix plant, a CMI Model UDM 700, through a recycle collar located midway down the length of the drum (Figure 18).

The mix left the plant at 310°F and arrived on the project approximately 35 miles north of the plant at 300°F. Daily ambient temperatures ranged from the low 50's to highs in the upper 60's to upper 80's. Besides being somewhat cool for this time of year, rain caused frequent delays and early shutdowns.

Compaction was performed with a steel wheel initial roller, a pneumatic intermediate roller, and a steel wheel final roller (Figure 19). Vibratory rollers were not used. Test cores showed compaction above the 98% minimum in all but two instances. In both cases retests showed specification compliance.

Gradation control at the plant was accomplished by sampling the combined cold feed aggregate flow with a manually operated sampling device that could be passed through the full flow of material at any time during production. No significant gradation problems occurred. This may have been due somewhat to the use of 50% reclaim which provided a constant gradation from the job mix to decrease the effect of the virgin aggregate gradation fluctuations. Plant gradations for mixture C82-63 (Recycled) are shown in Table IX.

Construction of the control section was performed with the same equipment and procedures as the recycled section. Some gradation problems were encountered at the plant due to the heavier flow of combined cold feed aggregates when running the 100% virgin aggregate mix. These problems were later determined to be due to the method of sampling. Several different sampling techniques were tried but when a large sample, consisting of at least two full pans of aggregate, was split down, specification compliance was obtained. Plant gradations for mixture C82-57, the control mix, are shown in Table IX.

The use of mineral filler in a drum mix plant was a new process for both MHTD and the contractor. All of the surface mix in the control section was produced and laid in two days, hardly a long enough run to fully evaluate the plant and the mineral filler system. However, calibration and verification data and regular checks of the plant material totalizers (Figures 20 and 21) showed the mix was uniformly and accurately proportioned. Loose mix samples of both the control and the recycled mix were taken at random intervals and the results are shown in Table IX.

The mix left the plant at 305°F and arrived on the project at 300°F. Compaction tests were all above the 98% minimum required. Ambient temperatures ranged from the mid 50's to the upper 60's with occasional light rain on both days.

The surface texture of the control mix appeared more open than the recycle mix (Figures 22-24). Both mixes were visually uniform throughout the length of each section.

COST COMPARISON

The analysis of actual cost for any first-time process, such as recycling, will be influenced by the many unknowns facing the contractor. This was further complicated by the use of drum mix plants, another relatively new process on MHTD projects. The cost of handling the reclaim was undoubtedly a major factor since MHTD was to receive any not used in the mix. The location designated in the contract required a relatively short haul, however, load limits on a small bridge along the route necessitated construction of a low water crossing to permit fully loaded trucks to make the trip. Whether or not these factors entered into the bid prices for cold milling or recycled asphalt and aggregate is not known. For these reasons, the following analysis should be considered approximate and may not reflect the full value of recycling.

On the basis of bid prices, the cost of the virgin mix was $30.12 per ton. The recycled mix, including the cost of cold milling, was $28.31 per ton for a savings of $1.81 per ton or $29,040 total. In addition, assuming 4.9% asphalt in the reclaim, the approximately 7,200 tons delivered to MHTD represents $71,400 in asphalt value alone. Other substantial savings resulted from the fact that shoulder work was not necessitated by the additional thickness produced by a conventional overlay.

ENERGY CONSIDERATIONS

There is a close relationship between energy requirements and costs. The recent, large increases in the costs for highway construction are closely related to the increases in the cost of petroleum based fuels and asphalt. The fact that recycling resulted in a considerable cost reduction on this project is a general indication that energy was saved.

Several situations unique to this project lead to some initial assumptions. It is estimated that the energy expended in cold milling the old pavement was more than compensated for by the omission of shoulder work that would have been needed if new mix had been added to the old pavement. The cost of transporting the reclaim to the plant site was minimized by using the same trucks hauling the hot mix to haul reclaim back to the plant.

Actual energy savings were therefore computed from estimated BTU's required to manufacture the quantities of materials actually recycled as follows:

Reclaimed Asphalt in Recycled Mix	385 tons	483 million BTU's
Reclaimed Aggregate in Recycled Mix	7,653 tons	313 million BTU's
		796 million BTU's

In addition, the stockpiles of reclaim available for use in future maintenance work represent a substantial reserve as follows:

Salvaged Asphalt in Reclaim Stockpiles	353 tons	443 million BTU's
Salvaged Aggregate in Reclaim Stockpiles	6,851 tons	280 million BTU's
		723 million BTU's

The total energy value of the recycled reclaim and that available for future use would be 1,519,000,000 BTU's or the equivalent of 12,150 gallons of gasoline.

Note: The energy contained in the asphalt cement itself was not included in calculating the savings for the project. This was due to the fact that this inherent energy was not available for consumption when the asphalt cement was used as a construction material.

CONSERVATION OF RESOURCES

The recycled mix contained 50% reclaim which provided 2.4% of the asphalt in the total mix. This represented 51% of the total asphalt in the mix for a savings of 385 tons of asphalt. Approximately 7,600 tons of asphalt quality aggregates were recycled.

SUMMARY

The recycling of the 15.7 mile section of Route 65 in Dallas County was followed immediately by the recycling of another surface mix on Route 65 BR (Glenstone) in Springfield by the same contractor. The experience gained on the Dallas County work proved invaluable. The contractor had gained earlier experience on other recycled jobs in the area and had made modifications to his plant for recycling.

The appearance and performance of the recycled mix on this project was only slightly different from a standard Type C surface mix. The recycled mix did appear finer and somewhat stiffer than standard mixes, however, neither characteristic was objectionable (Figures 25 and 26).

Tests on recovered asphalt, summarized in Table IV, show the asphalt in the reclaim was substantially rejuvenated. Compaction tests and gradations at the plant and from extracted loose mix samples have shown that a specification mixture can be produced using recycling methods. Cost analysis are quite favorable and have shown that recycled pavement can conserve material economically. Further testing will include tests on recovered asphalt from cores taken from the surface, visual observations, rut depth measurements, and friction tests. Initial friction tests performed on September 21, 1982, are shown in Table X. The results of these tests and observations will show whether or not recycled pavement is durable and economical.

TABLE I
TYPE C ASPHALTIC CONCRETE
MIXTURE NUMBER C67-291
JOB MIX FORMULA

	Aggregate Gradations			Mixture Composition			
Sieve Size Passing/Retained	Crushed Stone	Blended Sand	Mineral Filler	Crushed Stone (61.0%)	Blended Sand (30.0%)	Mineral Filler (4.0%)	Combined Gradation
1" - 3/4"							
3/4" - 1/2"	2.6			1.6			1.6
1/2" - 3/8"	23.5			14.3			14.3
3/8" - #4	45.3	0.3		27.6	0.1		27.7
#4 - #10	20.9	4.1		12.7	1.2		13.9
#10 - #40	5.2	33.9		3.2	10.2		13.4
#40 - #80	1.0	31.0		0.6	9.3		9.9
#80 - #200	0.6	28.4	8.1	0.4	8.5	0.3	9.2
- #200	0.9	2.3	91.9	0.6	0.8	3.7	5.0
TOTAL	100.0	100.0	100.0	61.0	30.0	4.0	95.0
						% Asphalt	5.0
						TOTAL	100.0

MIX CHARACTERISTICS

Specific Gravity	Air Void Content (%)	Voids in Mineral Aggregate Filled (%)	Stability (psi)
2.350	3.33	77.4	382

TABLE II

EXTRACTED RECLAIM
GRADATIONS AND TESTS ON RECOVERED ASPHALT

(Test results from the centrifuge extraction of Mix C67-291).

Location	Stkpl. @ Charity	Stkpl. @ Buffalo	Stkpl. @ Buffalo	Stkpl. @ S. End	Stkpl. @ Journagan Plt.	Trial Mix (Hammer Milled)	Preliminary Cores	Job Mix
Lab. No.	82-1403	82-1219	82-1220	82-1877	82-1879	82-1714	80-4932	C67-291
3/4	100	100	100	100	100	100	100	
3/4 - 1/2	3.2	0.4	0	0	1.5	0.5	0.8	1.6
1/2 - 3/8	6.5	3.9	3.8	7.8	5.0	3.3	9.3	14.3
3/8 - 4	29.9	22.3	24.2	28.9	23.2	20.1	31.4	27.7
4 - 10	14.8	17.1	17.7	16.1	17.1	18.5	13.6	13.9
10 - 40	14.3	17.6	18.1	15.6	17.8	20.0	14.1	13.4
40 - 80	8.8	10.0	10.1	9.5	10.9	10.9	9.5	9.9
80 - 200	9.9	12.0	10.9	10.3	11.0	11.8	11.0	9.2
-200	7.8	11.3	10.4	6.9	8.4	10.0	5.6	5.0
% AC	4.8	5.4	4.8	4.9	5.1	4.9	4.7	5.0
Pen.	17	18	25	16	14	15	22	70-85
V. @ 275	1,091	1,546	724	1,090	1,089	1,325	870	
V. @ 140	29,462	21,365	10,689	30,431	30,462	47,827	16,800	
Ductility	--	--	--	--	22	13	--	

TABLE III

COLD MILLING GRADATION SUMMARY

(Dry, loose gradations of cold-milled, reclaimed mix C67-291).

Location	Stkpl. @ Charity	Stkpl. @ Buffalo	Stkpl. @ Buffalo	Stkpl. @ S. End	Stkpl. @ Journagan Plt.
Lab. No.	82-1404	82-222	82-1223	82-1876	82-1878
3"	100				
3 - 2 1/2	6.0				0
2 1/2 - 2	5.9				3.6
2 - 1 1/2	1.6	0	0	2.0	5.8
1 1/2 - 1	7.8	2.8	1.6	5.2	4.0
1 - 3/4	11.3	3.9	8.5	9.3	5.3
3/4 - 1/2	11.8	9.0	13.4	15.3	8.8
1/2 - 3/8	12.3	10.7	12.1	15.2	11.1
3/8 - 4	21.5	32.0	30.6	26.8	28.3
4 - 10	8.5	18.1	16.1	11.0	14.0
10 - 40	7.5	14.5	11.6	9.1	11.8
40 - 80	3.5	6.0	3.8	4.1	4.9
80 - 200	1.5	2.1	1.5	1.6	2.1
-200	0.8	0.9	0.8	0.4	0.3

TABLE IV

TESTS ON RECOVERED ASPHALT

Source Lab. No.	Preliminary Cores 80-4932	C67-291 Reclaim 5 Tests, Avg.	Trial Mix Reclaim 82-1714	C82-63 (Recycled) 3 Tests, Avg.	50/50 Lab. Blend 82-1714	C82-57 Control 82-4376
Pen. @ 77	22	18	15	36	45	51
Visc. @ 275	870	1,108	1,325	612	496	519
Visc. @ 140	16,800	24,482	47,827	7,383	4,962	3,617
Ductility	--	--	13	84	--	150+

TABLE V

TYPE C ASPHALTIC CONCRETE, RECYCLED
MIXTURE NUMBER C82-83 (RECYCLED)
Job Mix Formula

	Aggregate Gradations			Mixture Composition			
Sieve Sizes Passing/Retained	Reclaimed Asphalt Pavement (RAP)	Crushed Stone	Blended Sand	RAP (40.0%)	Crushed Stone (43.3%)	Blended Sand (14.0%)	Combined Gradation
1" - 3/4"							
3/4" - 1/2"	0.5	1.1		0.2	0.5		0.7
1/2" - 3/8"	3.3	24.0		1.3	10.4		11.7
3/8" - #4	20.1	50.3	0.6	8.0	21.8	0.1	29.9
#4 - #10	18.5	21.2	3.4	7.4	9.2	0.5	17.1
#10 - #40	20.0	1.0	29.1	8.0	0.4	4.1	12.5
#40 - #80	10.9	0.5	43.9	4.4	0.2	6.1	10.7
#80 - #200	11.8	0.4	20.2	4.7	0.2	2.8	7.7
- #200	10.0	1.5	2.8	4.0	0.6	0.4	5.0
% ASPHALT	4.9			2.0			2.0
TOTAL	100.0	100.0	100.0	40.0	43.3	14.0	97.3
						% New Asphalt	2.7
						TOTAL	100.0

MIX CHARACTERISTICS

Specific Gravity	Air Void Content (%)	Voids in Mineral Aggregate Filled (%)	Stability (psi)
2.360	3.67	74.9	616

TABLE VI

TYPE C ASPHALTIC CONCRETE, RECYCLED
MIXTURE NUMBER C82-86 (RECYCLED)
Job Mix Formula

	Aggregate Gradations			Mixture Composition			
Sieve Sizes Passing/Retained	Reclaimed Asphalt Pavement (RAP)	Crushed Stone	Blended Sand	RAP (45.0%)	Crushed Stone (40.0%)	Blended Sand (12.5%)	Combined Gradation
1" - 3/4"							
3/4" - 1/2"	0.5	1.1		0.2	0.4		0.6
1/2" - 3/8"	3.3	24.0		1.5	9.6		11.1
3/8" - #4	20.1	50.3	0.6	9.1	20.1	0.1	29.3
#4 - #10	18.5	21.2	3.4	8.3	8.5	0.4	17.2
#10 - #40	20.0	1.0	29.1	9.0	0.4	3.6	13.0
#40 - #80	10.9	0.5	43.9	4.9	0.2	5.5	10.6
#80 - #200	11.8	0.4	20.2	5.3	0.2	2.5	8.0
- #200	10.0	1.5	2.8	4.5	0.6	0.4	5.5
% ASPHALT	4.9			2.2			2.2
TOTAL	100.0	100.0	100.0	45.0	40.0	12.5	97.5
						% New Asphalt	2.5
						TOTAL	100.0

MIX CHARACTERISTICS

Specific Gravity	Air Void Content (%)	Voids in Mineral Aggregate Filled (%)	Stability (psi)
2.357	3.72	74.7	674

TABLE VII

TYPE C ASPHALTIC CONCRETE, RECYCLED
MIXTURE NUMBER C82-63 (RECYCLED)
Job Mix Formula

	Aggregate Gradations			Mixture Composition			
Sieve Size Passing/Retained	Reclaimed Asphalt Pavement (RAP)	Crushed Stone	Blended Sand	RAP (50.0%)	Crushed Stone (36.7%)	Blended Sand (11.0%)	Combined Gradation
1" - 3/4"							
3/4" - 1/2"	0.5	1.1		0.2	0.4		0.6
1/2" - 3/8"	3.3	24.0		1.6	8.8		10.4
3/8" - #4	20.1	50.3	0.6	10.1	18.4	0.1	28.6
#4 - #10	18.5	21.2	3.4	9.3	7.8	0.4	17.5
#10 - #40	20.0	1.0	29.1	10.1	0.4	3.2	13.7
#40 - #80	10.9	0.5	43.9	5.4	0.2	4.8	10.4
#80 - #200	11.8	0.4	20.2	5.9	0.1	2.2	8.2
- #200	10.0	1.5	2.8	5.0	0.6	0.3	5.9
% ASPHALT	4.9			2.4			2.4
TOTAL	100.0	100.0	100.0	50.0	36.7	11.0	97.7
						% New Asphalt	2.3
						TOTAL	100.0

MIX CHARACTERISTICS

Specific Gravity	Air Void Content (%)	Voids in Mineral Aggregate Filled (%)	Stability (psi)
2.358	3.60	75.4	735

TABLE VIII

TYPE C ASPHALTIC CONCRETE
MIXTURE NUMBER C82-57, CONTROL MIX
Job Mix Formula

	Aggregate Gradations			Mix Composition			
Sieve Size Passing/Retained	Crushed Stone	Blended Sand	Mineral Filler	Crushed Stone (64.0%)	Blended Sand (26.9%)	Mineral Filler (4.7%)	Combined Gradation
1" - 3/4"							
3/4" - 1/2"	1.1			0.7			0.7
1/2" - 3/8"	24.0			15.4			15.4
3/8" - #4	50.3	0.6		32.2	0.2		32.4
#4 - #10	21.2	3.4		13.6	0.9		14.5
#10 - #40	1.0	29.1		0.6	7.8		8.4
#40 - #80	0.5	43.9	0.5	0.3	11.8		12.1
#80 - #200	0.4	20.2	16.6	0.2	5.4	0.8	6.4
- #200	1.5	2.8	82.9	1.0	0.8	3.9	5.7
TOTAL	100.0	100.0	100.0	64.0	26.9	4.7	95.6
						% Asphalt	4.4
						TOTAL	100.0

MIX CHARACTERISTICS

Specific Gravity	Air Void Content (%)	Voids in Mineral Aggregate Filled (%)	Stability (psi)
2.365	4.48	69.5	529

TABLE IX

JOB MIX GRADATION SUMMARY

C82-63 (Recycled)

SIEVES	PLANT GRADATIONS RANGE	PLANT GRADATIONS AVERAGE	LOOSE MIX EXTRACTIONS RANGE	LOOSE MIX EXTRACTIONS AVERAGE	JOB MIX
1 - 3/4	0.0	0.0	0.0	0.0	0.0
3/4 - 1/2	0.4-2.0	1.0	0-1.6	0.6	0.6
1/2 - 3/8	9.4-14.4	11.5	7.1-13.4	9.8	10.4
3/8 - 4	25.1-29.3	27.4	27.6-35.2	31.5	28.6
4 - 10	16.0-20.1	18.5	16.8-21.4	18.9	17.5
10 - 40	12.6-13.5	13.6	11.0-13.9	12.4	13.7
40 - 80	8.4-10.3	9.2	8.2-9.4	8.8	10.4
80 - 200	7.6-8.5	8.1	7.2-8.6	7.9	8.2
-200	5.4-6.3	6.0	4.9-6.1	5.5	5.9
% AC	4.7	4.7	4.5-5.1	4.6	4.7

C82-57, Control

SIEVES	PLANT GRADATIONS RANGE	PLANT GRADATIONS AVERAGE	LOOSE MIX EXTRACTIONS RANGE	LOOSE MIX EXTRACTIONS AVERAGE	JOB MIX
1 - 3/4	0.0	0.0	0.0	0.0	0.0
3/4 - 1/2	0.5-1.5	0.9	0.6-0.9	0.5	0.7
1/2 - 3/8	14.4-19.4	17.3	9.7-14.0	12.5	15.4
3/8 - 4	25.9-35.0	30.6	34.1-36.2	34.9	32.4
4 - 10	13.3-17.0	15.3	15.5-19.8	17.6	14.5
10 - 40	6.7-12.1	9.4	8.2-12.5	9.3	8.4
40 - 80	7.0-12.8	9.5	8.5-9.8	9.0	12.1
80 - 200	5.5-7.4	6.5	6.0-6.6	6.2	6.4
-200	5.8-6.4	6.1	5.5-6.0	5.7	5.7
% AC	4.4	4.4	3.9-4.5	4.3	4.4

TABLE X

Special Friction Tests at 40 MPH (FN_{40}) and 55 MPH (FN_{55})
Recycled Asphaltic Concrete, Project FR-PMS-65-2(25)
Route 65, Dallas County

Tests Performed September 21, 1982

Log Mile	Northbound (N2) 40 MPH	Northbound (N2) 55 MPH	Southbound (S2) 40 MPH	Southbound (S2) 55 MPH
		Conventional AC		
33.64	47.4		43.2	
33.46	43.8		43.8	
33.27	48.2		42.9	
33.09	47.6		43.8	
32.91	45.8		47.2	
32.73	46.2		42.6	
32.55	49.0		44.9	
32.37	48.4		42.3	
32.18	43.8		41.7	
32.00	47.1		42.5	
31.77		Route O and Recycled AC		
31.53	51.6	42.9	42.4	37.4
31.25	50.6	42.7	39.5	34.3 34.3
30.96	38.7	35.3	40.9	32.8
30.67	46.3	40.4	48.3	39.4
30.39	49.7	41.2	46.6	40.3
30.10	46.2	37.5	48.6	41.6
29.81	46.5	40.4	44.8	37.1
29.53	48.3	37.3	43.4	39.3
29.24	50.6	39.7	47.5	38.8
28.95	49.1	40.1	46.3	36.5
28.67	47.7	40.2	46.6	39.8
28.38	48.7	39.4	48.1	39.4
28.09	49.4	42.4	45.7	38.6
27.81	37.1	34.1	46.3	39.0
27.78		Route 38		
27.52	44.8	35.6	40.8	35.4
27.23	43.7	37.4	45.1	37.6
26.95	47.0	38.3	44.7	36.4
26.66	47.7	38.6	47.1	38.6
26.37	49.2	39.4	47.5	37.7
26.09	46.0	38.6	43.8	34.2
25.80	47.0	41.7	31.2	32.2
25.51	50.0	42.3	48.3	40.3
25.23	49.5	43.5	45.2	38.5
24.94	50.1	39.9	46.2	39.3
24.76		Route EE		
24.65	47.3	37.6	49.7	41.1
24.37	43.3	35.7	46.4	39.6
24.08	47.2	39.6	48.9	41.1
23.79	49.5	40.3	49.8	39.9
23.51	44.9	36.9	43.6	36.5

TABLE X (CONTINUED)

Special Friction Tests at 40 MPH (FN_{40}) and 55 MPH (FN_{55})
Recycled Asphaltic Concrete, Project FR-PMS-65-2(25)
Route 65, Dallas County

Tests Performed September 21, 1982

Log Mile	Northbound (N2) 40 MPH	Northbound (N2) 55 MPH	Southbound (S2) 40 MPH	Southbound (S2) 55 MPH
23.22	47.5	35.1	45.0	38.5
22.93	49.2	37.1	47.5	39.3
22.65	46.8	39.8	46.3	39.1
22.36	48.2	40.4	45.4	38.3
22.07	46.3	38.5	45.2	39.6
21.79	48.3	39.1	46.7	37.5
21.41		Route F		
21.30	48.8	38.6	40.1	34.0
21.11	51.2	38.6	44.1	39.6
20.91	49.5	38.3	43.4	37.0
20.71	48.0	39.9	43.8	37.6
20.52	50.5	41.4	41.8	36.5
20.32	48.0	38.9	45.8	37.3
20.12	50.9	38.8	42.0	33.9
19.93	49.3	41.6	35.5	31.0
19.73	49.5	40.3	40.7	34.2
19.53	42.2	35.9	38.5	32.0
18.79		Route 32		

TABLE X (CONTINUED)

Summary of Friction Tests at 40 MPH and 55 MPH
Project FR-PMS-65-2(25)
Route 65, Dallas County

	Recycled AC				Conventional AC			
	N2		S2		N2		S2	
	40 MPH	55 MPH	40 MPH	55 MPH	40 MPH	55 MPH	40 MPH	55 MPH
	Tests Performed September, 1982							
Average	47.6	39.1	44.6	37.5	46.7		43.5	
Number	45	45	45	45	10		10	
High	51.6	43.5	49.8	41.6	49.0		47.2	
Low	37.1	34.1	31.2	31.0	43.8		41.7	

FIGURE 1

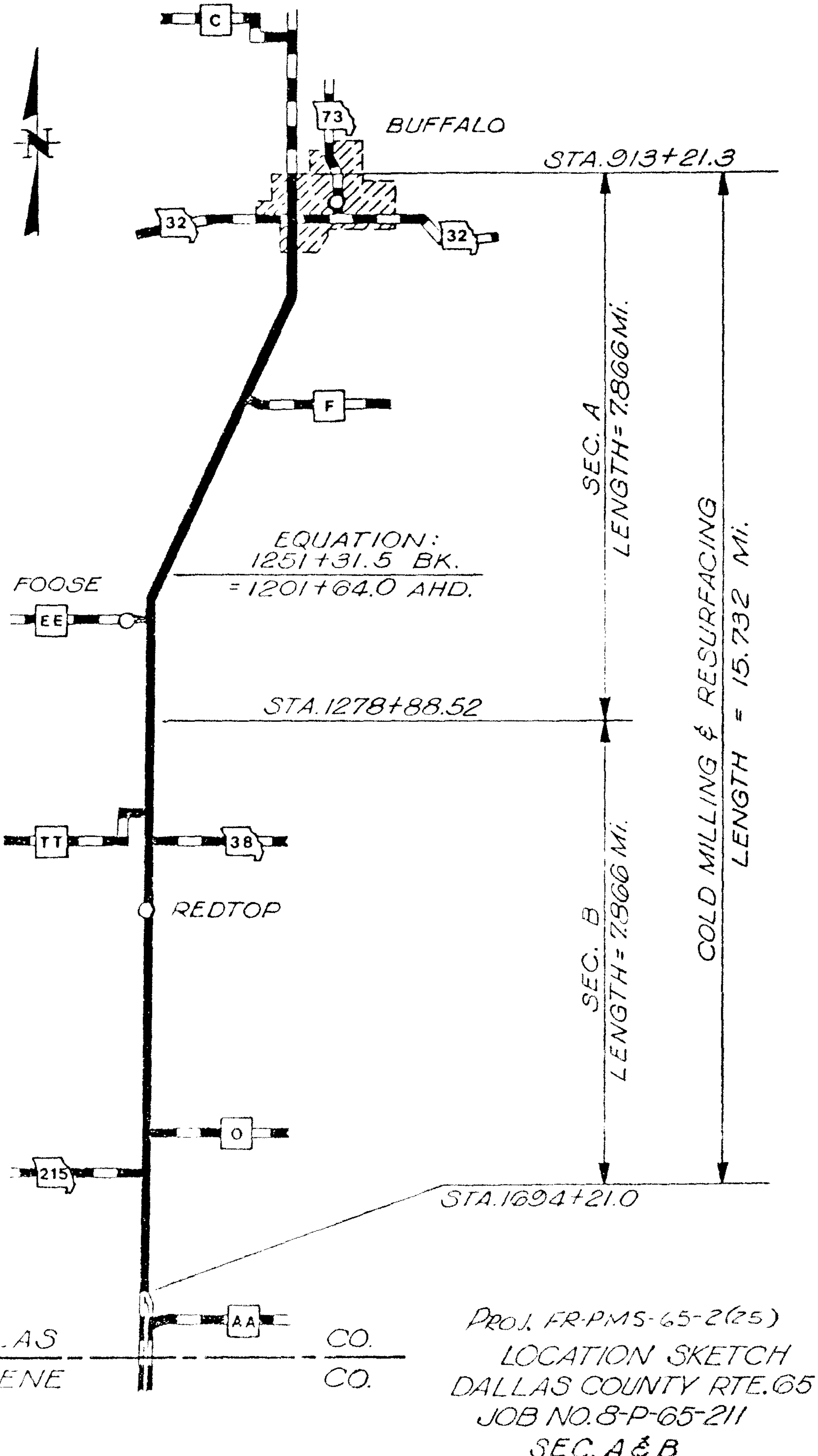
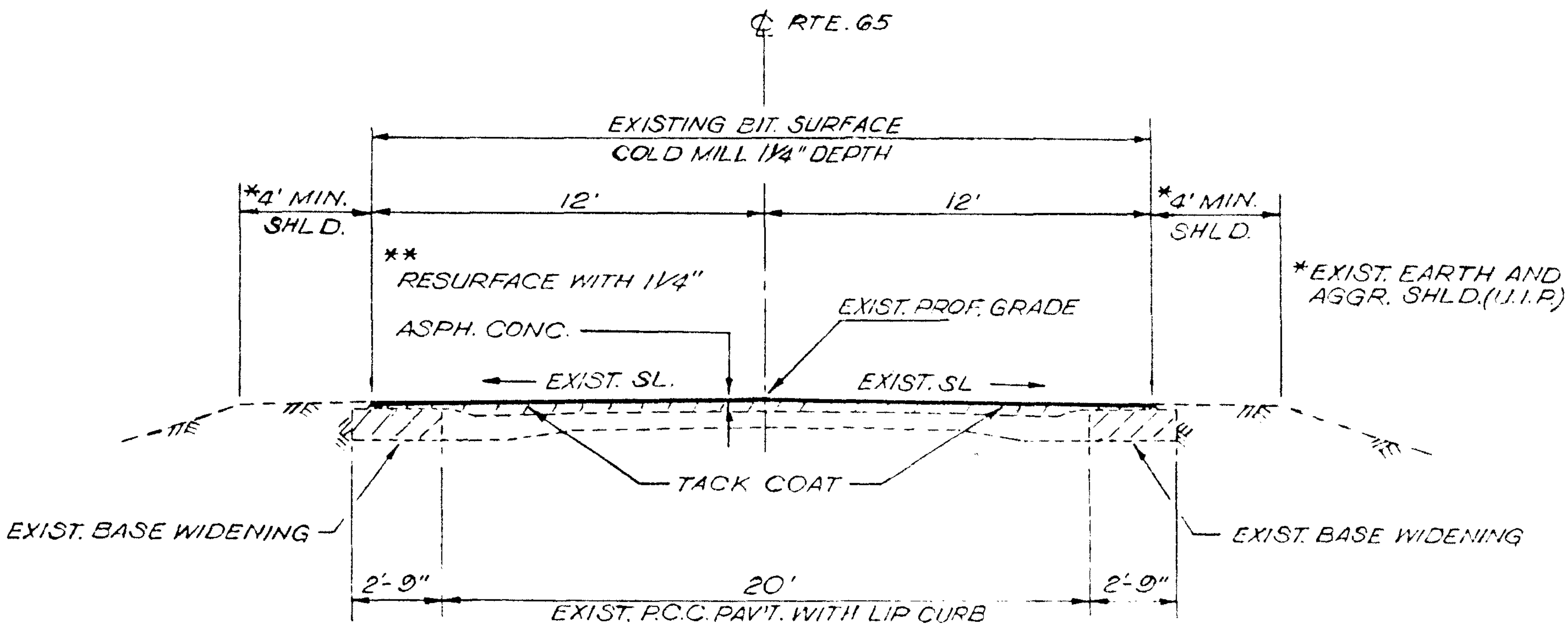

C
73
BUFFALO
STA. 913+21.3
32
32
F
SEC. A
LENGTH = 7.866 Mi.
COLD MILLING & RESURFACING
LENGTH = 15.732 Mi.
EQUATION:
1251+31.5 BK.
= 1201+64.0 AHD.
FOOSE
EE
STA. 1278+88.52
TT
38
REDTOP
SEC. B
LENGTH = 7.866 Mi.
O
215
STA. 1694+21.0
AA
DALLAS CO.
GREENE CO.
PROJ. FR-PMS-65-2(25)
LOCATION SKETCH
DALLAS COUNTY RTE. 65
JOB NO. 8-P-65-211
SEC. A & B

FIGURE 2



TYPICAL SECTION
(RESURFACING)

** STA. 913+21.3 TO STA. 1278+88.52 (1¼" RECYCLED A.C.)
STA. 1278+88.52 TO STA. 1588+61 (1¼" RECYCLED A.C.)
STA. 1588+61 TO STA. 1694+21 (NEW 1¼" TYPE "C" A.C.)

PROJ. FR-PMS-65-2(25)
ROUTE 65
DALLAS COUNTY
JOB NO. 8-P-65-211
SEC. A & B

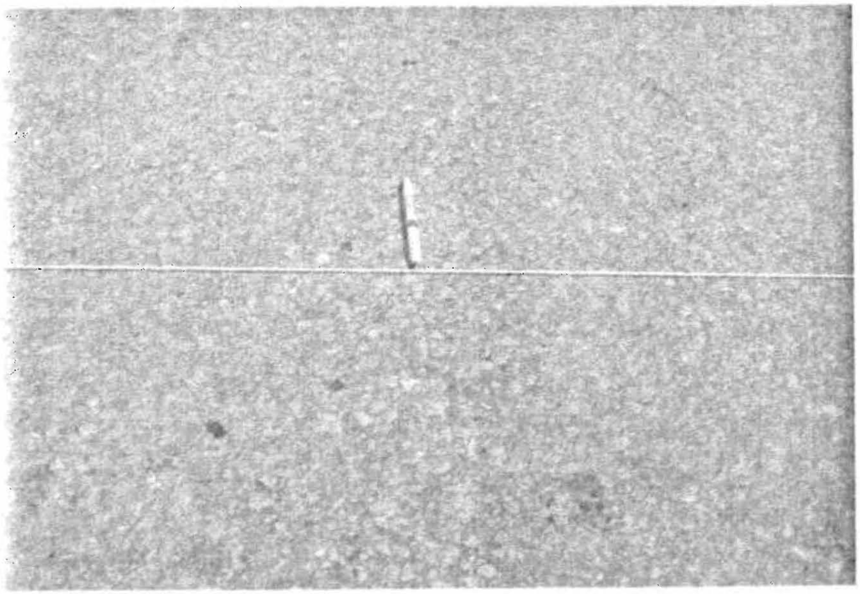


Figure 3
Surface condition of Mix C67-291.

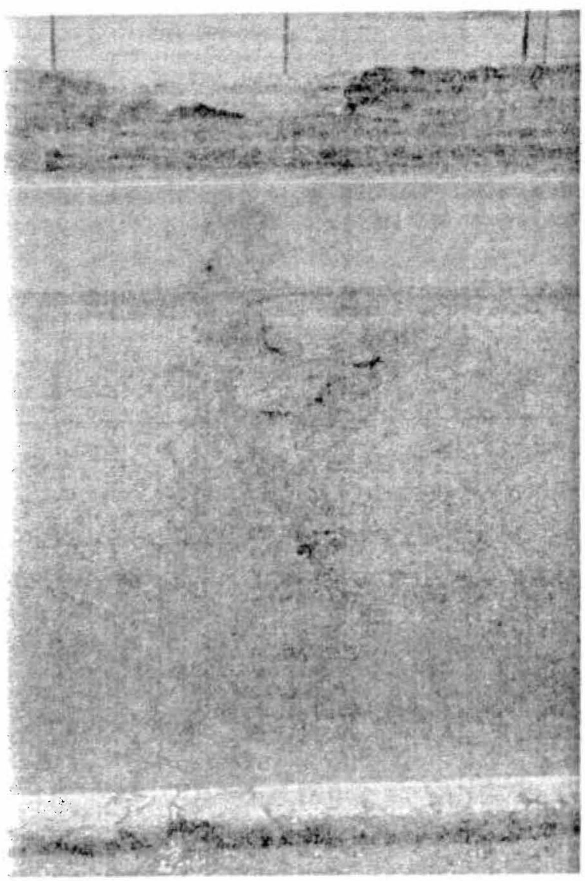


Figure 4
Extensive joint sealing.

Figure 5
Patch across both lanes.

Figure 6
Ravelling at joints.

Figure 7
Disbonded slabs of 1967 mix. Surface in foreground is mix placed in 1955.

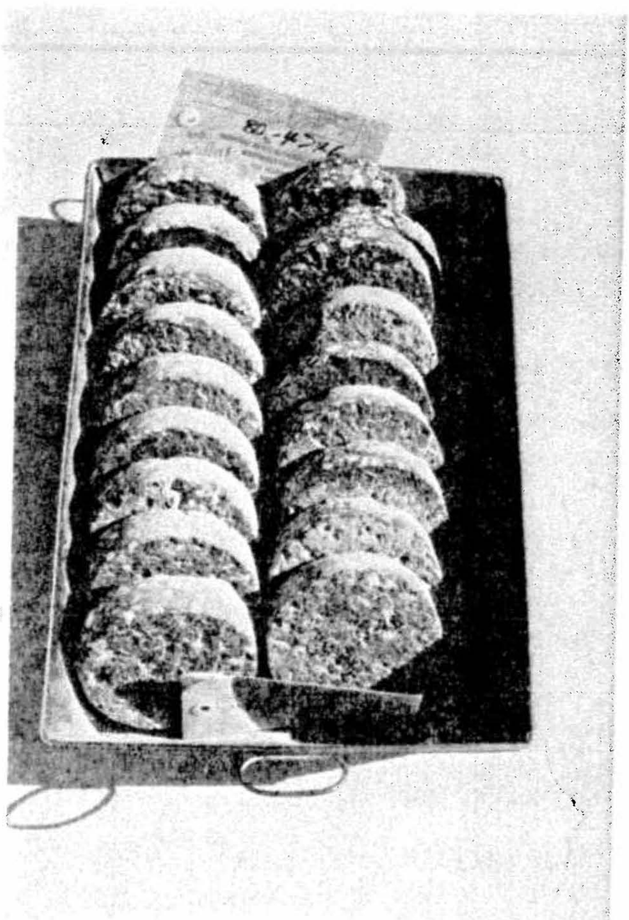


Figure 8
Preliminary cores.

FIGURE 9
Blending Curves Using 150-200 Penetration Grade Asphalt

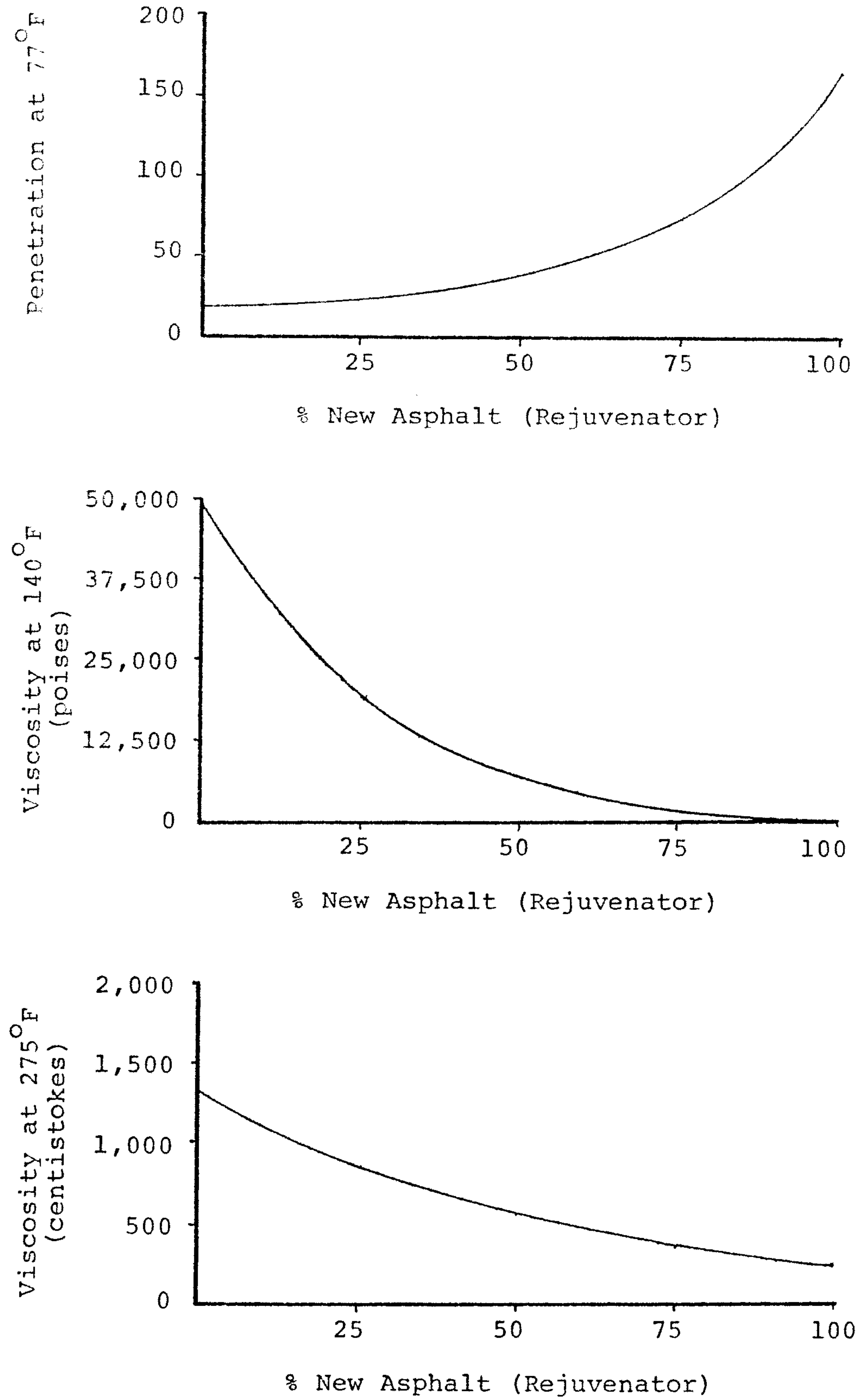
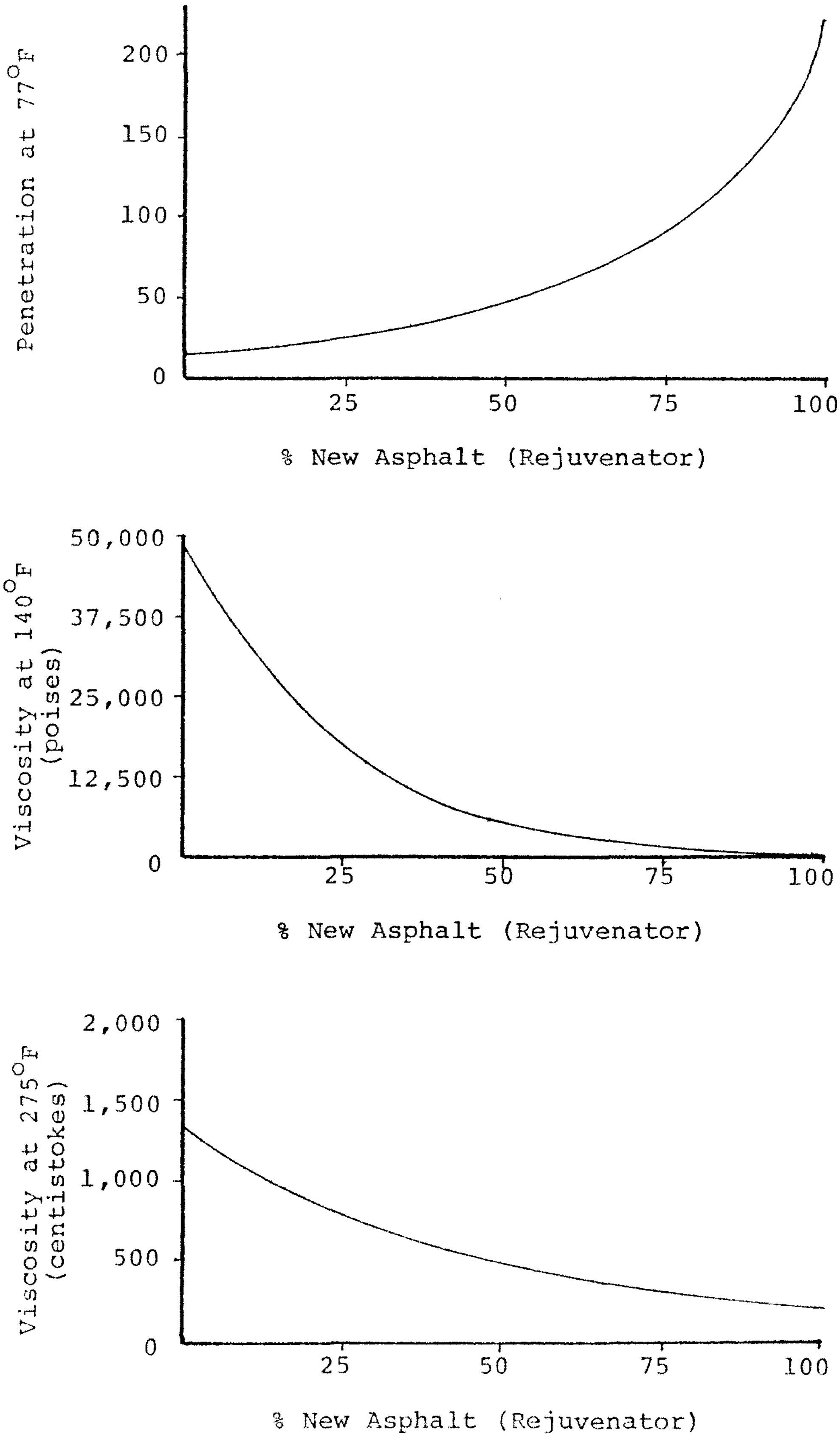


FIGURE 10
Blending Curves Using 200-300 Penetration Grade Asphalt



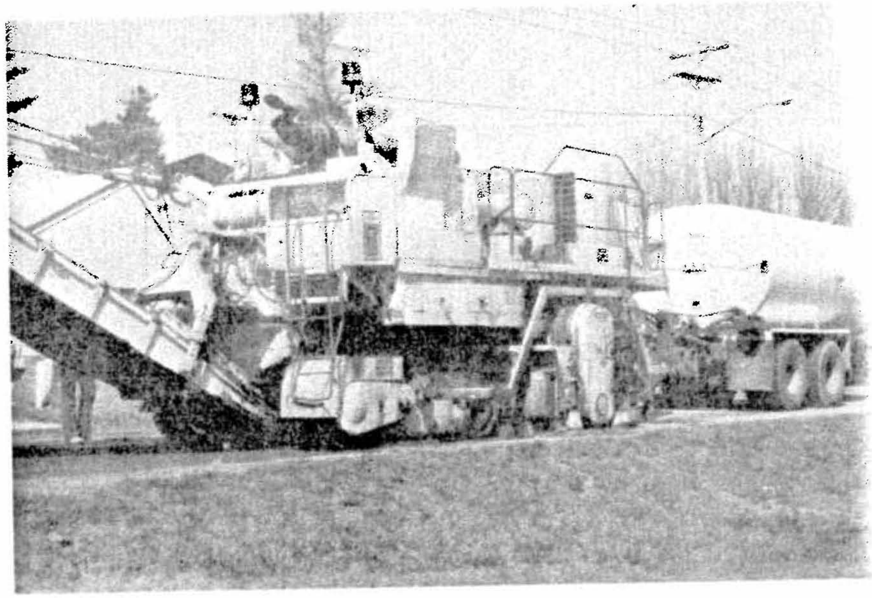


Figure 11
CMI PR750 Roto-Mill.

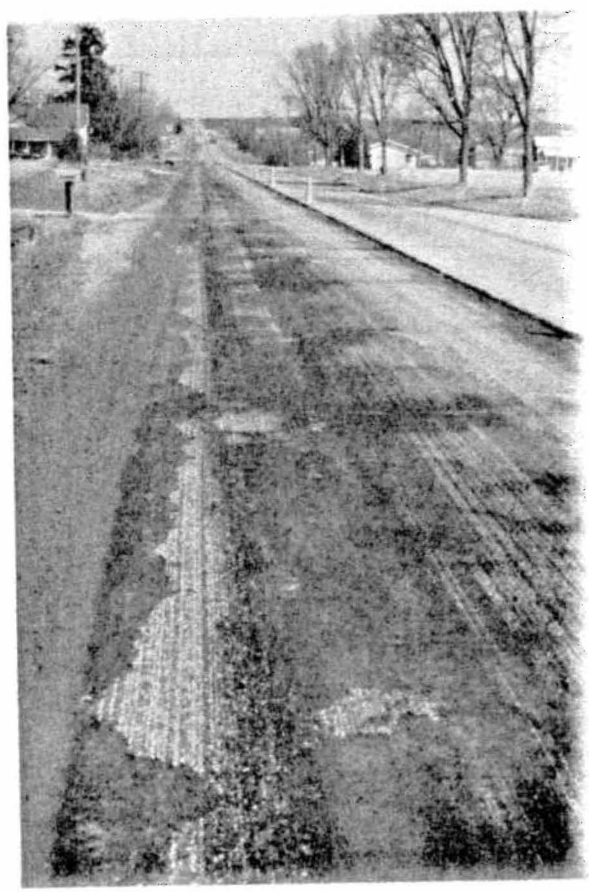
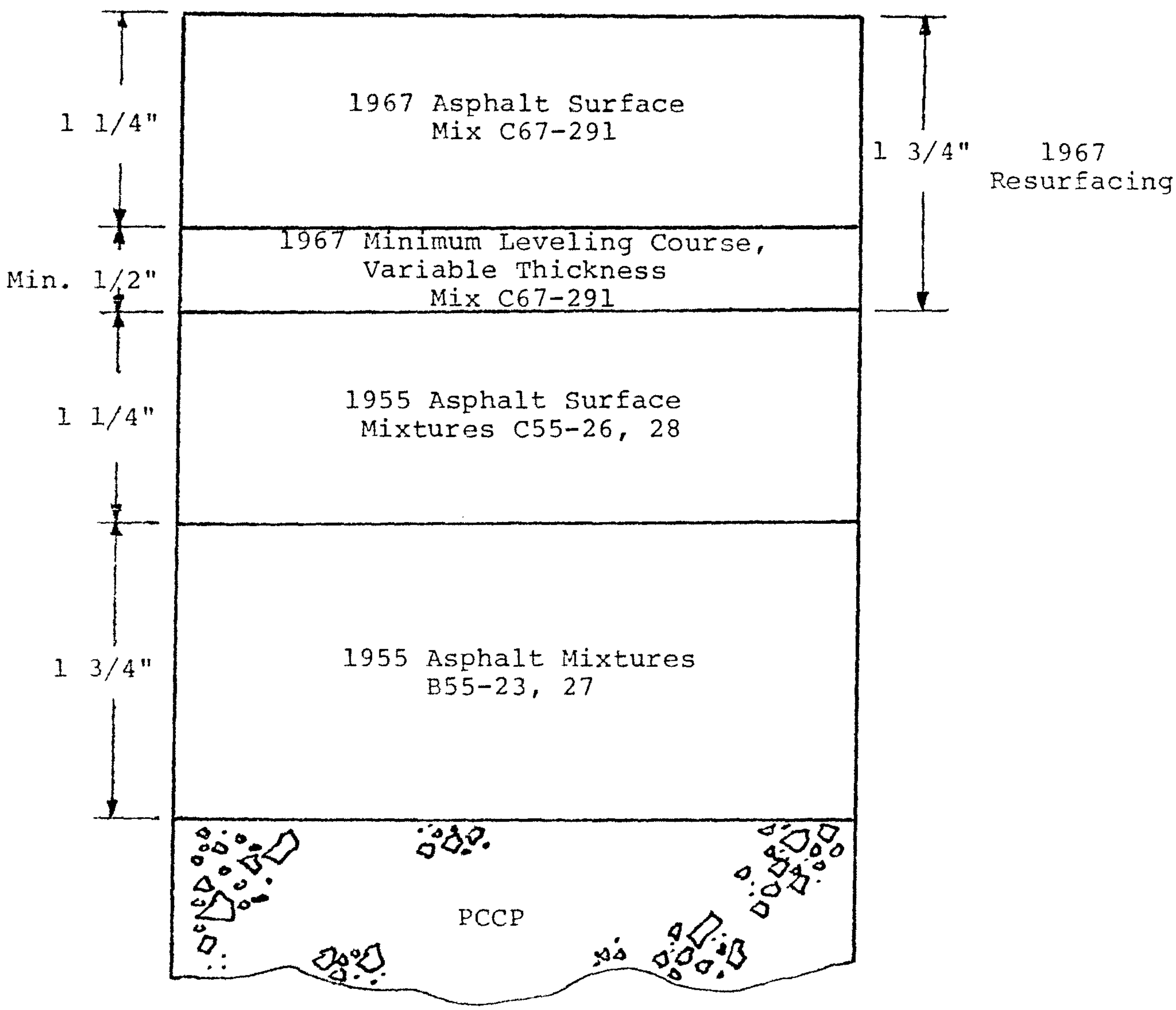


Figure 12
Thin layers of old mix.

FIGURE 13

Detailed Cross Section
Existing Layers of Pavement



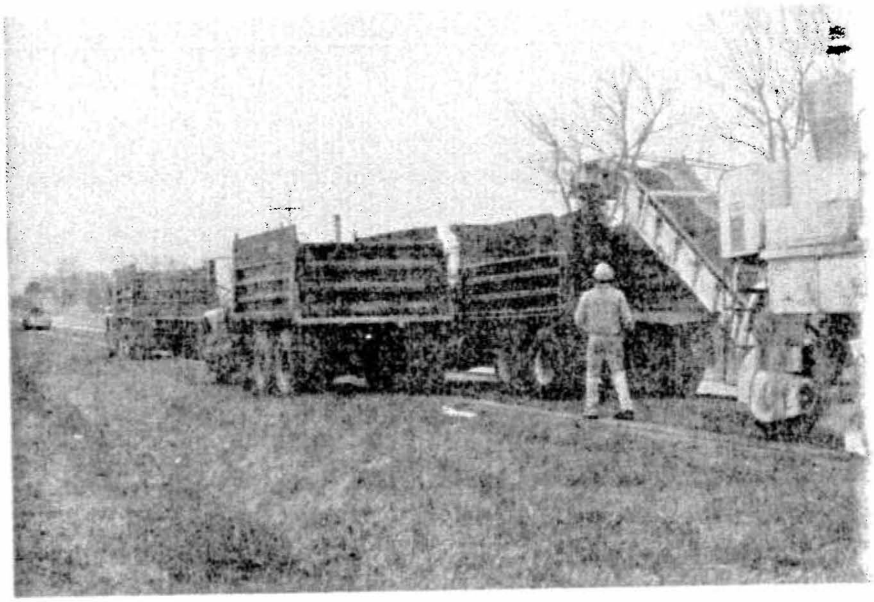


Figure 14
Roto-Mill Loading trucks with reclaim.

Figure 15
Stockpile of reclaim at MHTD lot.

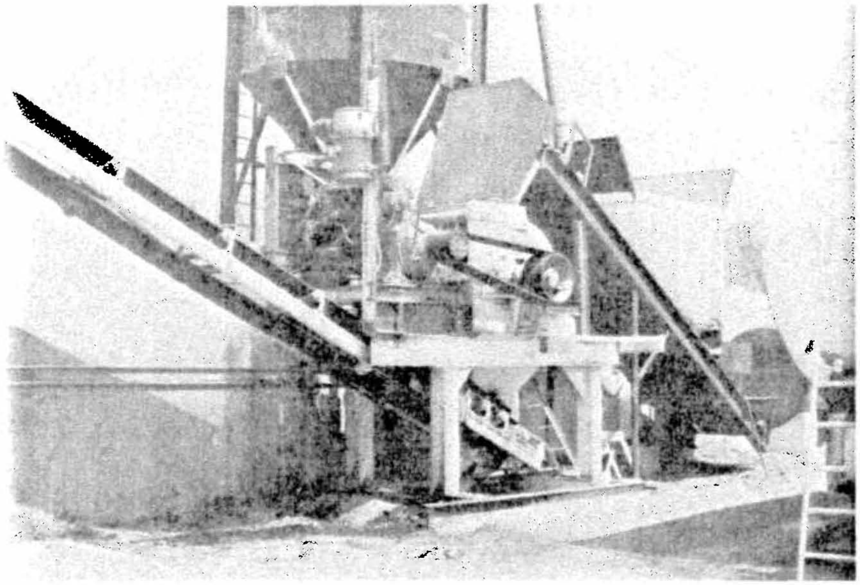


Figure 16
Hammer Mill used to process reclaim.

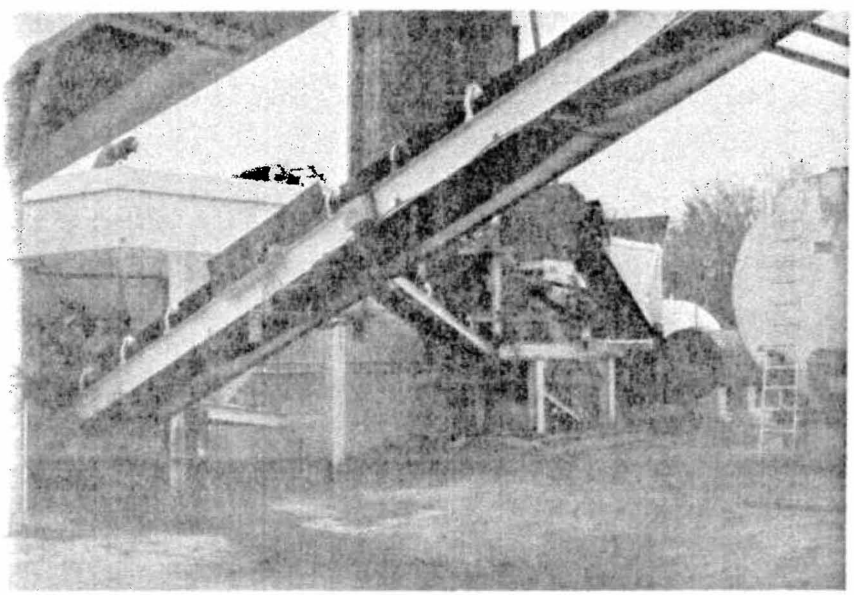


Figure 17
Reclaim belt scale conveyor.

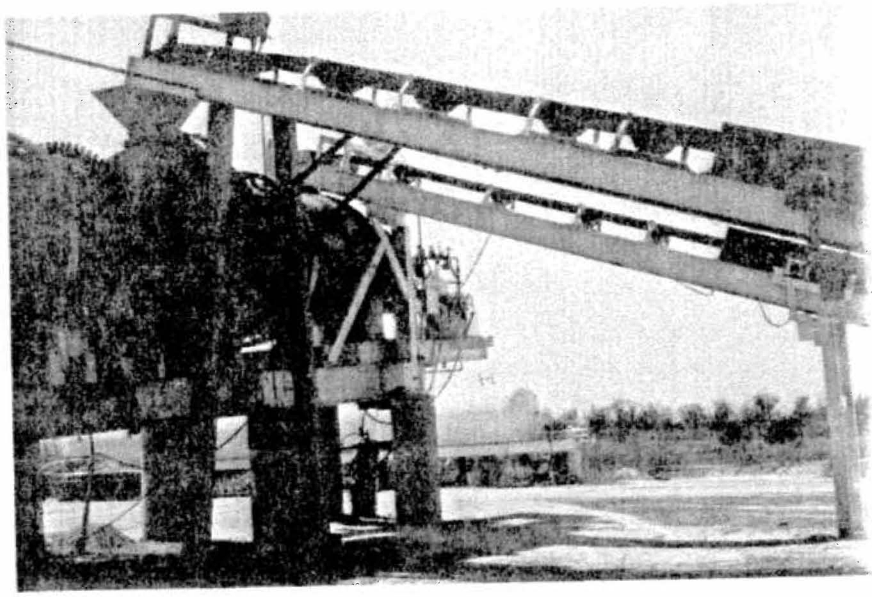


Figure 18
Recycle collar on drum mix plant.

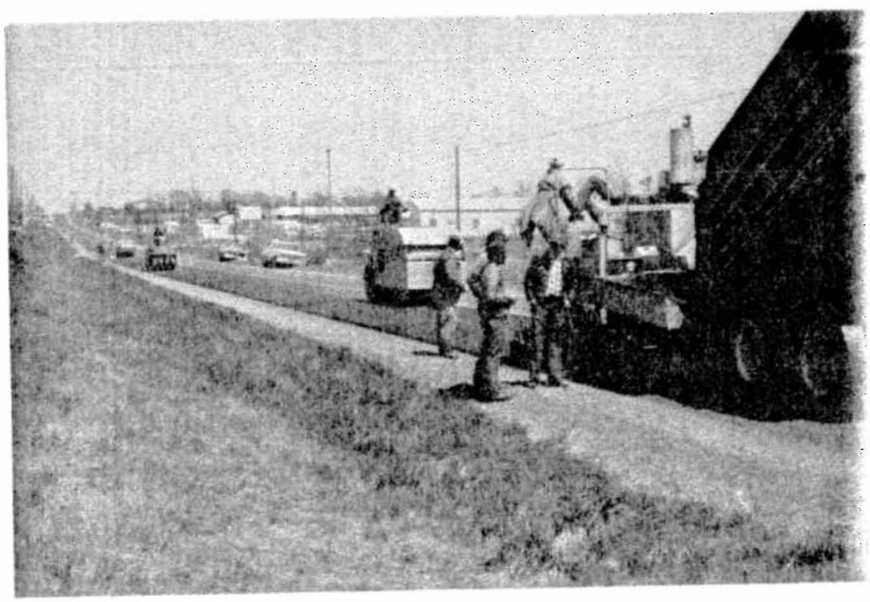


Figure 19
Compaction of Mix Number C82-63 (Recycled).

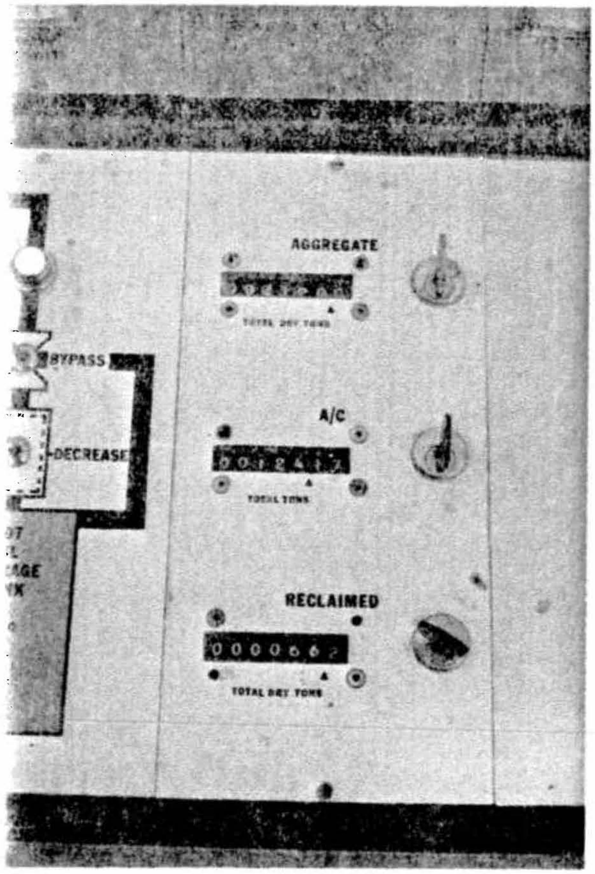


Figure 20
Plant totalizers.

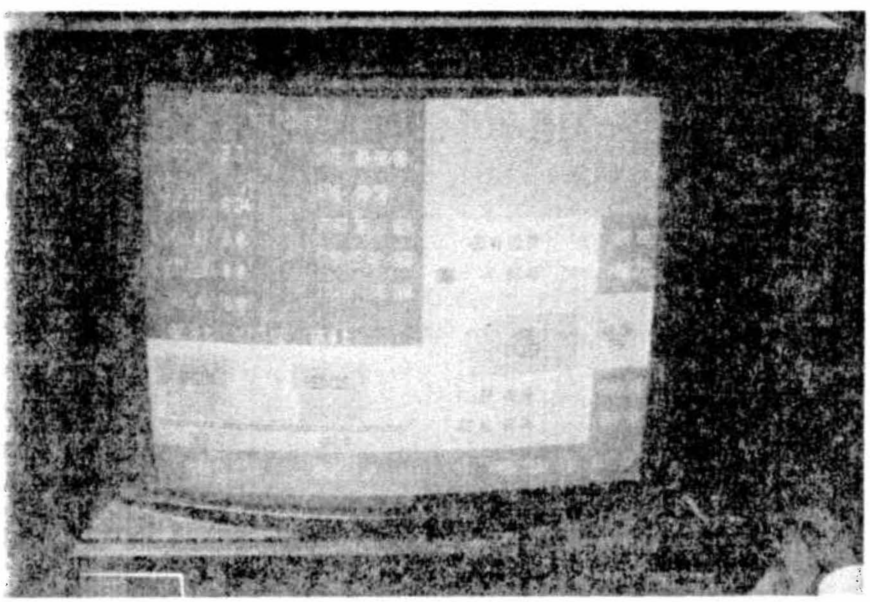


Figure 21
Visual display of plant production.

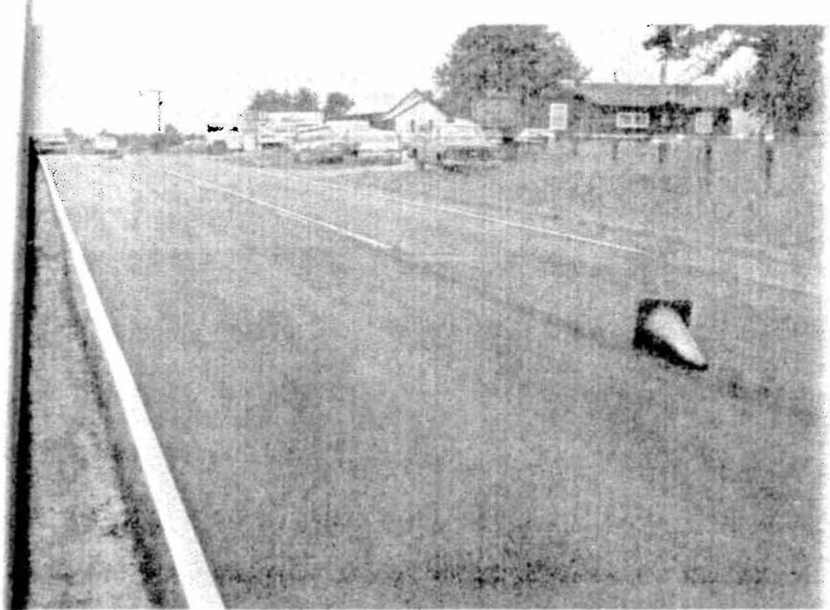


Figure 22
Recycle and control mix joint. Recycle mix in upper portion, control mix in lower left hand portion.

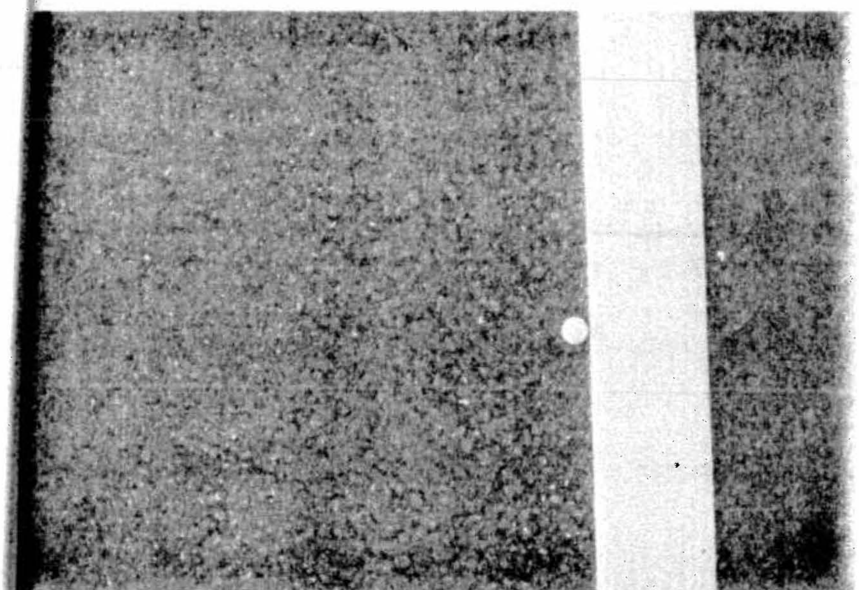


Figure 23
Surface texture of C82-57, control mix.

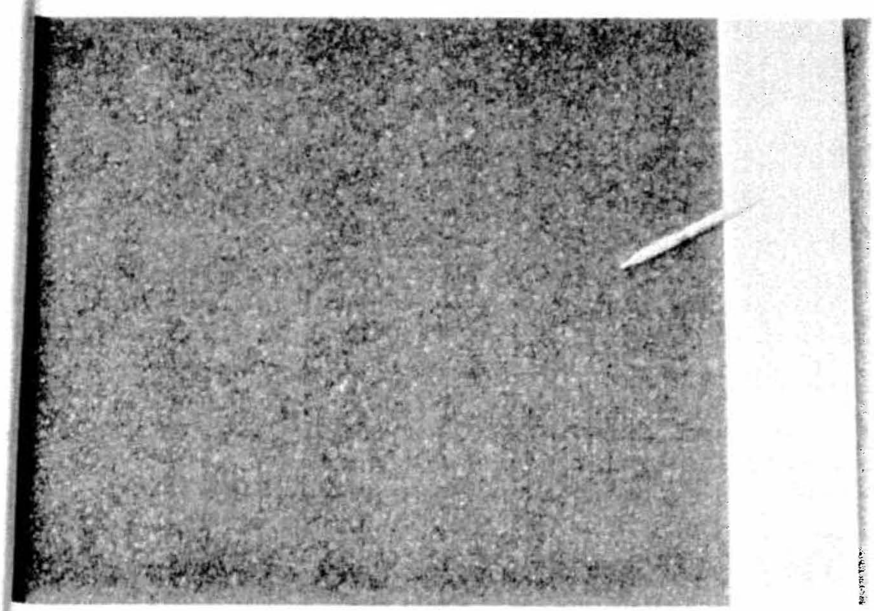


Figure 24
Surface texture of C82-63 (Recycled).

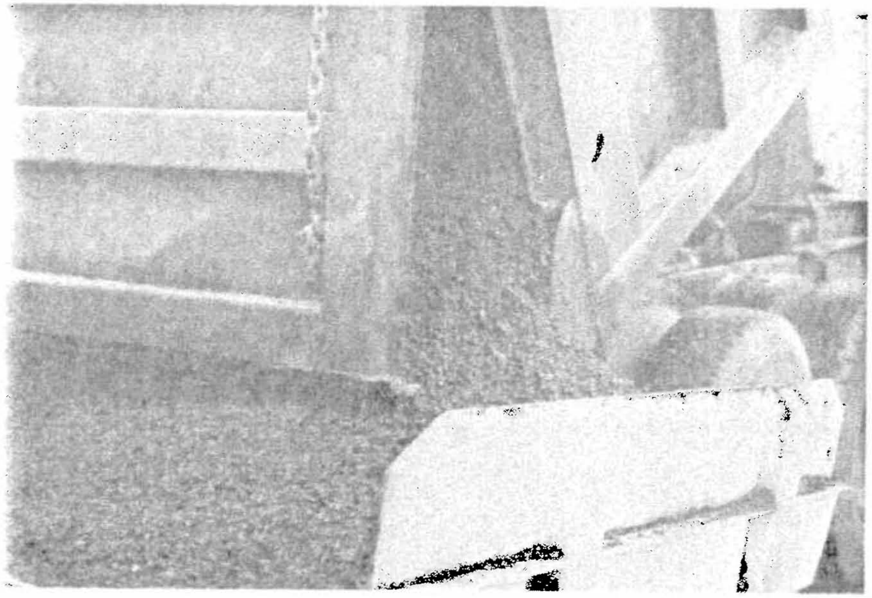


Figure 25
Control mix delivered to paver.

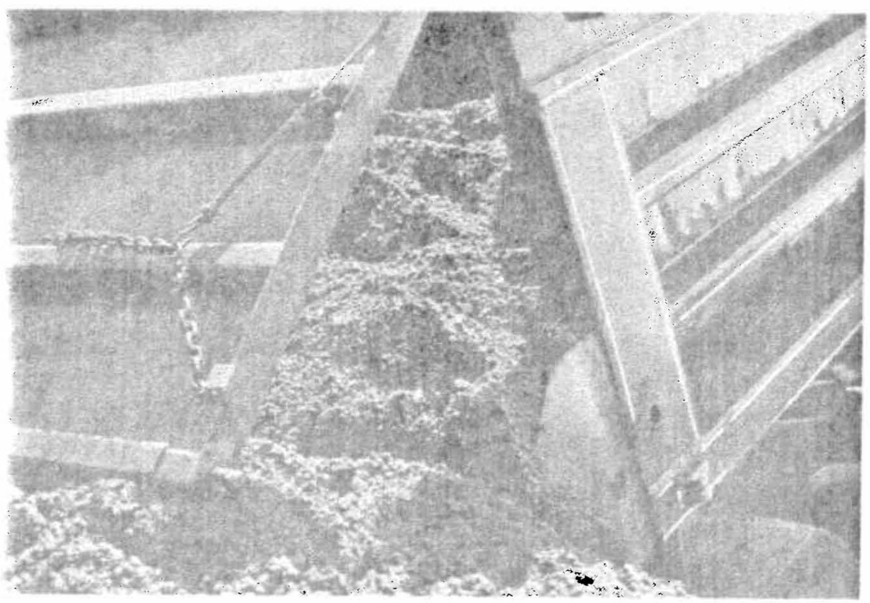


Figure 26
Recycled mix delivered to paver.

H. TEMPORARY PAVEMENT MARKING

Section 622 of the Standard Specifications is hereby modified to require the use of machine applied traffic paint and glass beads as stated in Sub-section 622.2.8 in lieu of reflective tape. All items set out in Section 622 which are applicable to the use of traffic paint as temporary pavement marking shall remain in force.

I. REMOVAL OF EXISTING BITUMINOUS SURFACE

1. Description.

This item shall consist of improving the profile and cross slope of an existing bituminous surface to the depths indicated on the plans, and the removal and disposal or stockpiling of the removed materials (reclaim) at the locations shown on the plans or specified elsewhere in the contract.

2. Equipment.

The equipment for profiling and removing the pavement surface shall be a power operated, self-propelled planing machine or grinder capable of removing, in one pass, a thickness of bituminous surface to the specified depth and providing a uniform profile and cross slope across the entire pavement surface. The equipment shall be self-propelled with sufficient power, traction, and stability (rigid suspension, non-pneumatic tires) 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 within ± 1/8 inch by referencing from the existing pavement by means of a ski or matching shoe or from an independent grade control and shall be controlled by an automatic system for controlling grade, elevation, and cross slope at a given rate.

The machine shall be equipped with means to control dust and other particulate matter created by the cutting action. It shall also have effective means of removing cuttings from the pavement and discharging them into a hauling unit all in one operation.

3. Construction Methods.

The pavement surface shall be removed to the depth, width, grade, and cross section as shown on the plans, or as directed by the engineer.

The pavement surface shall be removed and planed around and over manholes, utility valves, and drainage appurtenances within the limits of the work as directed by the engineer. Any damage to manholes, valves, or drainage appurtenances by the removal and planing operation shall be the responsibility of the contractor to correct.

The pavement planing operations shall be regulated by an automatically controlled grade leveling and slope control device approved by the engineer. The device shall provide control for producing a uniform surface to the established grade and a cross slope conforming to the requirements of the typical section. The device shall also be equipped with the necessary controls to permit the operator to adjust or vary the slope as directed by the engineer.

Loose material not picked up by the milling machine shall be swept or broomed and picked up immediately behind the milling operation in curb and gutter sections and in areas where loose material would be undesirable on the shoulders. In areas with earth or stabilized aggregate shoulders, small amounts of loose material not picked up by the milling machine may be swept to the shoulders. The cuttings removed by the milling machine shall be stockpiled or disposed of as specified elsewhere in these Special Provisions or on the plans.

4 Measurement

Measurement for removal of the existing pavement surface will be computed to the nearest square yard. Final measurement will not be made except for authorized changes during construction, or where appreciable errors are found in contract quantity The revision or correction will be computed and added to or deducted from the contract quantity.

5 Basis of Payment.

The accepted quantity of removal of existing bituminous surface will be paid for at the contract unit price.

J RECYCLED ASPHALTIC CONCRETE

1 Description

This work shall consist of recycling material which was removed by the process and to the limits specified elsewhere in the contract The reclaimed material shall be combined with new mineral aggregates and asphalt cement in such proportions that the combined mixture meets the grading requirements, within specified tolerances, of the job mix formula. The mixture shall be placed on a prepared base or underlying course in conformity with the lines, grades, thicknesses and typical cross sections shown on the plans.

All applicable provisions of Sec 403, Asphaltic Concrete Pavement, and Sec 404, Bituminous Mixing Plants shall apply except as altered in this Special Provision.

2 Materials

All materials shall conform to Division 1000, Materials Details and specifically as follows:

	ITEM	SECTION
Asphalt Cement		1015.5
New Material:	Coarse Aggregate	1002.1
	Fine Aggregate	1002.2
	Mineral Filler	1002.3

The engineer will designate the grade and amount of asphalt cement after examination of the reclaim and new mineral aggregates the contractor proposes to furnish Preliminary laboratory testing indicates asphalt cement Grade 200-300 or AC 2.5 will be required, but the right is reserved by the engineer to designate the grade at the time the job mix formula is tested and approved

3 Reclaimed Material.

The reclaimed material shall be reduced to a maximum size of 100% passing a 1-1/2" square sieve by the removal operation, a separate crushing operation, or a combination thereof Scalping off of occasional oversize chunks without further reduction will be permitted The removal and any further reduction operations shall be performed in such a manner as to minimize aggregate fracture in the reclaimed material. The contractor shall make his own estimate of the quantity of reclaimed material to be hauled to his plant site for recycling and to the designated sites specified elsewhere in the contract

4. Stockpiling Reclaimed Material.

No haul units or loading equipment shall be permitted to operate on the reclaim stockpile. Equipment used to charge the bituminous mixing plant bins shall be operated so as to prevent contamination and consolidation of the reclaim. Regardless of the method of storage and handling the reclaim shall be kept free of all contaminants.

5. Composition of Mixture.

The reclaim, the new mineral aggregates including filler, if needed, and asphalt cement shall be combined in such proportions that the composition by weight of the recycled mix is within the range specified. The recycled mixture shall comply with the applicable requirements of Sec 403.3, Composition of Mixture, for Type C Asphaltic Concrete Pavement except as hereinafter altered in this Special Provision.

6. Job Mix Formula.

When a representative quantity of reclaim has been placed in the stockpile, the contractor shall obtain in the presence of the engineer samples of asphalt cement, minus 1-1/2" sieve reclaim, and the proposed new aggregate fractions for tests. The samples shall be of the size designated by the engineer and shall be submitted to the Laboratory at least 30 days prior to preparing the mixture on the project. The contractor shall also submit for the engineer's approval a job mix formula for the recycled mixture to be supplied for the project. The job mix formula shall include the type and sources of all materials and shall state a definite percentage for reclaim and each new aggregate fraction.

Preliminary laboratory testing indicates recycled mixture containing approximately 50% reclaim and 50% new mineral aggregates with the addition of approximately 2.5% new asphalt cement which will also serve as a softening agent will comply with the applicable requirements of Sec 403.3, Composition of Mixture, for Type C. A minimum of 30% reclaim will be required. A maximum of 50% reclain will be permitted provided job mix formula requirements, and environmental regulations of other agencies can be met. The engineer may adjust the quantities as necessary to obtain the required characteristics of the mixture. The percentages of reclaim, new mineral aggregates, and asphalt cement to be used will be designated by the engineer at the time the job mix is approved. When unsatisfactory results or other conditions make it necessary or should a source of material be changed, a new job mix formula may be required.

7. Gradation Control.

The gradation of the reclaim will be determined when the job mix formula is approved. The gradation of the reclaim on the approved job mix formula shall be used along with gradation of the new mineral aggregates determined from samples taken from the hot bins or cold feed bins if a dryer drum type plant is used in determining compliance with Sec 403.3.6 except (d), (f), and (g) shall not apply.

8. Equipment.

A dryer drum type mixing plant with modifications for the addition of recycled material may be used. The modifications for the addition of this material shall meet the approval of the engineer. The dryer drum plant and the proportioning of recycled material shall comply with Sec 404.5, Requirements for Dryer Drum Mixers.

Batch or continuous mixing plants shall comply with Sec 404.3 and 404.4 except as hereinafter provided. A separate cold feed shall be provided for the reclaim. Vibrators may be required on the reclaim feed gate if continuous proportioning is used. The reclaim may be introduced through a dryer or may be introduced into the mixing unit of the plant immediately after proportioning. Regardless of the method of introduction to the mixing unit, the reclaim shall be accurately proportioned by weight or volume within 2% of the quantity of reclaim required.

Sec 404.2.4 After the second sentence add, "The maximum temperature specified above for mineral aggregate fractions may be increased as necessary in recycled mix to obtain the specified temperature of the recycled mixture at time of placement".

Sec 404 6 2 2 Delete the last sentence

Sec 404 6 2 3 1 Delete this section in its entirety and substitute the following:

Sec 404 6 2 3.1 The new dry hot mineral aggregates, reclaim, mineral filler, if needed, and asphalt cement shall be accurately proportioned in the quantities required by the job mix formula.

Sec 404 6.2 3 2 Delete this section in its entirety and substitute the following:

Sec 404 6 2 3 2 The new mineral aggregates and reclaim shall be charged into the weigh hopper in a sequence that will avoid segregation The new mineral aggregates and the reclaim shall be mixed dry for not less than 15 seconds. The dry mixing period shall start when all of the new mineral aggregate and reclaim have been charged into the mixer and end when the introduction of the asphalt cement begins. After dry mixing, the asphalt cement shall be charged into the mixer in a manner that will uniformly distribute the asphalt over at least 3/4 the full length of the mixer. The time required to add the asphalt shall not exceed 15 seconds. Wet mixing shall begin at the introduction of the asphalt cement and continue for at least 30 seconds, or longer if necessary to produce a complete and uniform coating of the particles and a thorough distribution of the asphalt cement throughout the aggregate. The wet mixing period shall end when the discharge gate is opened. The dry and wet mixing times shall be as specified by the engineer

9 Construction Requirements

The recycled mixture shall comply with the requirements of Sec 403 9 through 403.17 3 except as hereinafter provided.

Sec 403 11 1 Delete the second sentence and substitute the following:

The contractor may construct each course in any number of layers he chooses; but no individual layer shall have a compacted thickness greater than 3 inches for Type B mixture, and 2 inches for Type A, Type C or Recycled mixture.

Sec 403 12 Delete the last sentence and substitute the following:

Type C or Recycled mixture shall be used for the spot wedging and for the leveling course.

Sec 403 14 5 Delete the last two sentences and substitute the following:

The direct transmission nuclear method of test will be used for Type C or Recycled mixtures placed in layers 2 inches thick or thicker, and for Type B mixtures only when used in lieu of plant mix bituminous base in layers 2 inches thick or thicker The backscatter nuclear method of test will only be used for Type C or Recycled mixtures constructed in layers less than 2 inches thick

10 General Requirements

The recycled mixture shall comply with the requirements of Sec 403 18 through 403.22.2 except as hereinafter provided.

Sec 403.19 Delete the first sentence and substitute the following:

At locations designated in the contract or as specified by the engineer, approaches shall be primed in accordance with Sec 408, and surfaced with Type C or Recycled asphaltic concrete.

Section 403.22.1 Delete this section in its entirety and substitute the following:

Section 403.22.1 Measurement of asphalt cement added to the reclaim and new mineral aggregates, to the nearest 0.1 ton for the total tonnage used in the accepted work, will be determined by the use of job mix formula applied to the weight of accepted mixture of mineral aggregate, reclaim, and asphalt cement.

Sec 403.22.2 Delete this section in its entirety and substitute the following:

Sec 403.22.2 Measurement of the weight of mineral aggregate plus reclaim, to the nearest ton, will be determined by subtracting the weight of the new added asphalt cement from the weight of the mixed mineral aggregate, reclaim, and asphalt cement.

11. Basis of Payment

The requirements of Sec 403.23 of the Standard Specifications shall apply except as hereinafter provided.

Sec 403.23.4 Delete the last sentence and substitute the following:

The quantity of material used in the leveling course will not be paid for as a separate item but will be paid for at the unit price for each of the pay items included in the contract for Type C or Recycled Asphaltic Concrete.

12. Excess Reclaimed Material

Any remaining reclaimed material not used in the work shall be hauled to a stockpile site designated in the contract and shall become the property of the Commission. Reclaim shall be kept free of all contaminants. Costs of loading, hauling, and stockpiling excess reclaimed material shall be considered completely covered in unit bid prices for other items of work.

K. SPECIALTY ITEMS

The following items shall be considered as Specialty Items as mentioned in Section 108.1.1 of the Standard Specifications:

Section 620 Inlaid Marker

L. CONTROL SECTION DEMONSTRATION PROJECT NO 39

A control test section will be constructed on this project. The beginning and ending station of the control section may be adjusted in the field by the engineer to meet field conditions, a distance not to exceed ± one station from that specified. The control section shall be completed in an expeditious manner and in the same construction season as the remainder of the project.

1.0 This section shall be constructed from Station 1694+21 to 1588+61.

2.0 This section shall consist of Type C asphaltic concrete pavement meeting the requirements of the Standard Specifications, Section 403 and its supplements and shall be placed to the length, width and thickness shown on the plans.

2.1 Composition of Mixture. The mixture on the control section shall be composed of the same aggregates as used in the recycled asphaltic concrete except that all aggregates shall be virgin aggregates and no recycled or reclaimed material will be used The grade and amount of asphalt cement used will be determined by the engineer based on trial mix samples

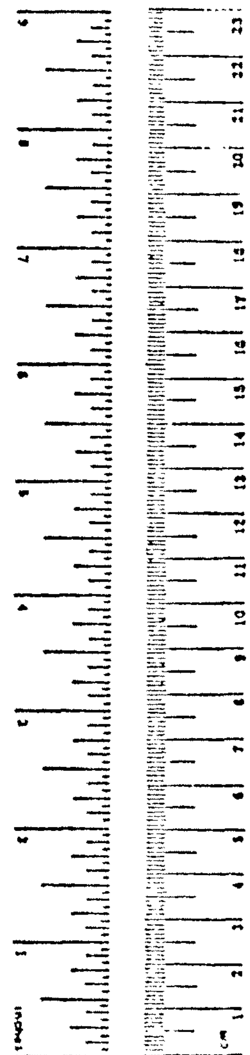
M DRYER-DRUM MIXING

Dryer-drum mixers will be permitted in accordance with Section 404.5 for asphaltic concrete on this project.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F