I 94
BATCH PLANT RECYCLING

John E. Norton

Bituminous Technical Services Unit
Testing Laboratory Section
Testing and Research Division
Research Report No. 78 TB-21

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Michigan Department of Transportation
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Lansing, April 1979

ACKNOWLEDGEMENT

The initiating of the project by the Federal Highway Administration and the support of the Michigan Department of Transportation management was greatly appreciated. Appreciation is also due to the Testing and Research Division for their expertise, the Construction Division for project supervision, and the Design Division for the plans and specifications.

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SYNOPSIS

A 2.5-mile portion of eastbound I 94 from LaPorte Rd to US 12 in Berrien County was recycled as a base course by using the batch plant-heat transfer method. The recycled mixture was comprised of a 50-50 blend of the existing 5-in. bituminous concrete pavement and an equal volume of the existing aggregate base. A little over 2 percent of 200-250 penetration asphalt cement was added to provide for the desired increase in recovered penetration.

The recycled mixture was used for 10-in. of bituminous base course. The base was surfaced with 130 lb/sq yd of leveling, 120 lb/sq yd of wearing, and 100 lb/sq yd of open graded asphalt friction course.

The recycling process necessitated only minor alterations to the batch plant. A feeder bin and conveyor belt were added to feed the reclaimed pavement into the weigh hopper. There were no major problems encountered in the mixing or placing of the recycled base course, and both the appearance and test results were similar to conventional mixtures.

The economic savings on this project amounted to approximately 34,500 tons of new aggregate and 204,000 gallons of asphalt cement. The cost of the recycled base amounted to \$14.93/ton; whereas, the 1978 average price for bituminous base equals \$15.57/ton.

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INTRODUCTION

Because of the interest in investigating the feasibility of hot mix recycling methods, the Michigan Department of Transportation let a project in June 1978, for hot mix recycling using a batch plant. The Department felt that the experience gained in trying this concept, along with a separate drum mixer recycling project constructed in 1978, would help develop the expertise needed to further the art of hot mix recycling.

With the excellent results obtained on the Maplewood, Minnesota batch plant recycling project (1), Michigan felt it was feasible to let a similar recycling job. A 2.5-mile section of eastbound I 94 in Berrien County (LaPorte Rd to US 12) was selected because of the excessive fatigue cracking in the existing pavement. Another reason for selecting this project was that this area of the state has a very limited supply of new aggregates which made the recycling more feasible and somewhat more economical. With these two conditions, the recycling offered the best viable design for this section of I 94 with an ADT of 19,000. The other option of resurfacing with 2 to 3 in. of bituminous concrete would have extended the pavement life only a few years before the cracking in the existing surface would have reflected and resulted in the same condition that was faced at the onset.

A design was selected using a 50-50 blend of reclaimed versus virgin material. Because of the feeling of Department personnel that the existing aggregate base was contributing to the pavement failure, it was decided to utilize this aggregate for the virgin portion of the recycled mixture. The existing pavement consisted of a 5-in. thickness, composed of binder, leveling, and wearing courses. The plans called for removing the existing pavement and reducing it to 95 percent passing the 2-in. sieve by either rotary reduction or plant crushing. The virgin portion was obtained from removing 6-in. of the existing aggregate base course.

The recycled mix was to be placed 10 in. thick in a minimum of three lifts and resurfaced with 130 lb/sq yd of bituminous concrete leveling course 25A, 120 lb/sq yd of bituminous concrete wearing course Type C, and 100 lb/sq yd of open graded asphalt friction course as shown on the typical cross-section (Appendix A). The Department opted for the more conservative approach using the recycled base course on the first project because of the high traffic volumes (ADT of 19,000 and the measured commercial percentage of 24 percent).

Figure 1. Covered stockpile of reclaimed pavement material.

Figure 2. Method of feeding reclaimed material to the weigh hopper.

CONSTRUCTION

The recycling contract was awarded to Rieth-Riley Construction Co., Inc., of Battle Creek, Michigan. They moved their 6,500-lb H&B portable batch plant to a site adjacent to the project. For this project, the Department allowed the contractor use of limited access right-of-way, permitting him to go through openings in the right-of-way fencing. Rieth-Riley used this option and located their plant on the north end of the project with access to the expressway. The existing 5-in. pavement was removed with a single pass of a CMI Rotomill. The rotomilling in a single-pass operation was quite surprising considering our experience on previous expressway recycling that required two passes of the machine for similar pavement thickness. The single pass gave us a very uniformly graded material which alleviated any separate stockpiling or blending of the reclaimed pavement. There was also some concern of possible problems that could be encountered because of the various aggregates used in the original construction and the later widening and resurfacing. The original pavement and the widening used natural aggregates, but the resurfacing utilized blast furnace slag in the wearing course. The possible problem of variations in the asphalt content of the different pavement layers were eliminated with the single-pass operation of the Rotomill. The contractor used a CMI Trimmer to remove the existing aggregate base. The 6-in. base was easily removed in a single pass and transported to the plant site.

The recycling process consisted of drying the aggregate base and superheating it to a temperature of 600 to 650 F so that when the ambient temperature reclaimed pavement is added in the 50-50 blend, the resultant temperature of the recycled mixture is in the range of 200 to 280 F. The only modification needed on the existing plant was to devise a method for feeding the reclaimed pavement to the weigh hopper (Fig. 1). Rieth-Riley elected to feed the reclaimed material by means of a conveyor belt to an opening in the weigh hopper. The belt was controlled by an interlocking system tied to the plant scales and controls which ensured the uniform proportioning as stated in the "Special Provision for Recycling Bituminous Pavement, Heat Transfer Method" (Appendix B).

A recommendation also stated in the special provision was that the contractor cover the stockpile of reclaimed bituminous material to minimize variations in the moisture content. The reduction in the moisture content in the reclaimed material results in a fuel savings with the lowered required new aggregate temperatures; this relationship is shown in Appendix C, "Influence of Moisture Content in Reclaimed Material versus Required New Aggregate Temperature," (2). Rieth-Riley not only tarped the salvaged stockpile (Fig. 2) they elected to also tarp the virgin material so that more complete fuel savings could be realized.

The recycled mixture consisted of 49 percent reclaimed pavement, 48.8 percent virgin aggregate, and 2.2 percent 200-250 penetration grade asphalt cement. The contractor superheated the virgin aggregate (salvaged existing aggregate base) to 600 F and deposited it in the hot bins without any oversize screening or sizing of the aggregate. The superheated aggregate was then fed into the weigh hopper where the reclaimed material was added to begin the heat transfer process. The next step was depositing the combined aggregate and reclaimed in the pugmill and mixing for an actual dry mix time of 10 seconds. The 'actual mix time' means a 10-second mixing period after the aggregate and reclaimed material are completely charged into the pugmill.

After the dry mixing period, the asphalt cement was added and mixed for a period of 30 seconds and then transferred to a 100-ton surge bin for the completion of the heat transfer prior to hauling the paving site. The recycled mix was then placed and compacted with conventional paving equipment. A mix temperature of 260 F was selected, and since density was successfully obtained, and a mixture that proved workable, that temperature was used for the entire project.

Later, during the construction, the proportions were changed to increase the reclaimed aggregate to 55 percent. Even with the increased proportion, there was no apparent problem encountered in producing an acceptable mixture. Although there were neither stack emissions nor opacity tests conducted, the stack never showed any visibly excessive pollution. On all future recycling projects, the Department is requiring the contractor to provide the necessary scaffolding for the monitoring of the stack emissions.

SAMPLING AND TESTING

On this project, the Marshall Mix Design was deleted for the recycled base course. A field design adding 2.2 percent asphalt cement to the combined virgin aggregate and the reclaimed material was used so that we would end up with 4.7 percent combined asphalt in the recycled mixture. Appendices D and E, "Summary of Bituminous Field and Laboratory Test," and "Quality Control Charts," show both the field and laboratory test results. As shown on the control charts, the asphalt cement content field average of 4.7 percent with a standard deviation of 0.34 and the laboratory average of 4.6 percent with a 0.37 standard deviation show that the recycled mixture was more uniform than anticipated. This is substantiated in the other charts for the 3/8-in., No. 8, No. 30, and No. 200 sieves. Considering the methods and gradation specifications that were allowed for the removal of the existing pavement and aggregate base, the gradation results of the recycled mix were remarkably uniform.

Also included in Appendix E is a control chart of the penetrations of the asphalt cement that was added and the recovered penetrations extracted from the recycled mixture. The project was started with 120-150 penetration and after six days it was switched to 200-250 penetration grade asphalt cement to increase the recovered penetrations. The average recovered penetration of 53.6 dmm is considered quite low when equating recovered penetration with pavement life. These results may be considered somewhat misleading because of the theory that not all of the asphalt in the reclaimed is to be considered as being part of the binder in the reclaimed mixture. It is felt that only 80 to 90 percent of the asphalt in the existing pavement should be considered as being available asphalt in the binder portion of the recycled. The remaining 10 to 20 percent would be considered as being part of the aggregate portion of the mix. In the Modified Abson Recovery Test, the penetration results include that 10 to 20 percent of the hardened asphalt that adheres to the aggregate particles. This results in a much lower recovered penetration which may mistakenly lead an observer to predict shorter pavement life for the hot mix recycling.

As shown in Appendix F (Marshall Test Results on Recycled Mixture) the Marshall results are quite impressive. The stabilities of 2,056 lb and 2,447 lb flows of 12.5 and 13.5, and V.M.A. of 15.1 is well within the range of acceptable results for a high traffic volume pavement. The air voids of 2.2 percent are a little lower than ideal, but considering that the recycled base would be covered with leveling, wearing, and open graded surfaces, it was quite acceptable. If the recycled material was intended as a wearing course, the selection of the virgin aggregate would have become more critical. We would have selected an aggregate that would result in 3 to 5 percent air voids in the surface course of the recycled.

ENERGY-RESOURCE SAVINGS

On this project, there were no fuel savings when comparing the fuel consumption in superheating the virgin aggregate with the fuel estimated for a conventional pavement consisting of 100 percent virgin material. The

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only fuel savings (and this cannot be measured) is in the reduced moisture contents in the virgin and reclaimed material achieved from tarping the stockpiles. The reduction in moisture content allowed the contractor to reduce the temperature of the superheated virgin aggregate.

We realized complete resource savings on using the existing pavement and aggregate base for our recycled mix. There was no need to use new aggregate in the recycled base, which in this area of the state is quite desirable because of the absence of quality aggregates. There was also a savings of asphalt cement with the reduction of 2.5 percent when compared with a conventional base course using all virgin aggregate. On this project approximately 34,500 tons of new aggregate and 204,000 gallons of asphalt cement were saved.

Cost

The following are the unit prices bid by Rieth-Riley Construction Co., Inc.:

Removing 5-in. Bituminous Surface (Road Surface)	57,471 sq yd at $ 1.75 =	$100,574.25
Removing 2-1/2-in. Bituminous Surface (Shoulders)	10,943 sq yd at $ 1.25 =	13,678.75
Removing 6-in. Aggregate Base	57,471 sq yd at $ 0.74 =	42,528.54
Removing 2-1/2-in. Aggregate Base	10,943 sq yd at $ 0.74 =	8,097.82
Bituminous Base Course (Recycled)	34,325 tons at $ 8.31 =	285,240.75
Asphalt Cement	683 tons at $95.00 =	64,885.00
Total for Recycling		$515,005.11

The removed bituminous surfaces equate to 17,310 tons and the removed aggregate base equals 10,121 tons; therefore, the costs of removing the materials would be $6.60/ton and $2.70/ton, respectively.

The following is the determination of the cost per ton of recycling the mixture.

Salvaged Bituminous	$6.60/ton x 0.50 x 0.978 =	$ 3.23
Salvaged Aggregate	$2.70/ton x 0.50 x 0.978 =	1.30
Asphalt Cement	$95.00/ton x 0.022 =	2.09
Recycling	$8.31/ton =	8.31
Total Per Ton		$14.93

This compares with the approximately $16.00/ton that new bituminous base would have cost.

CONCLUSIONS

The following conclusions can be drawn from the I 94 recycling project.

1) The use of a batch plant is a viable alternate to the drum mixer in recycling bituminous pavements. The only limitation is a maximum of 55 percent reclaimed in the recycled mixture.

2) Only minor modifications are needed to convert conventional batch plants into recycling plants. A method of feeding the reclaimed material to the weigh hopper is all that is needed.

3) The rotary reduction method of removing and sizing the reclaimed material produces quite uniform gradations. This eliminates the additional handling of the material necessary with the option of using a crusher.

4) The addition of 200-250 penetration grade asphalt cement yielded recovered penetrations lower than desired, but still was considered satisfactory for a base course mixture.

5) The cost of $14.93/ton for the recycled base is very reasonable, considering an average 1978 unit price for bituminous base course of $15.57/ton.

6) Removing and using the existing cracked bituminous pavement eliminates the problem of reflective cracking. Also, needed additional base strength was provided.

RECOMMENDATIONS

1) In projects proposing recycled material for a wearing course, serious consideration must be given to the virgin aggregate selection. An aggregate must be selected so that when combined with the reclaimed material the Marshall criteria will be met.

2) The selection of the bituminous material to be added is also very critical. For wearing courses the desired recovered penetration may dictate even softer asphalt than 200-250 penetration grade. The refinement of rejuvenating agents may provide the desired increase in recovered penetration.

3) Although the batch plant recycled concept cannot meet the increased reclaimed portion of the drum mixers, the projects let in the near future should be limited to 50-50 blends. This limitation allows for a more competitive environment since less than 10 percent of the plants in Michigan at this time are drum mixers.

4) On a future bituminous recycling project, test sections with different rejuvenating agents should be provided to measure both acceptability and what agents best fulfill the needs of Michigan's recycling program.

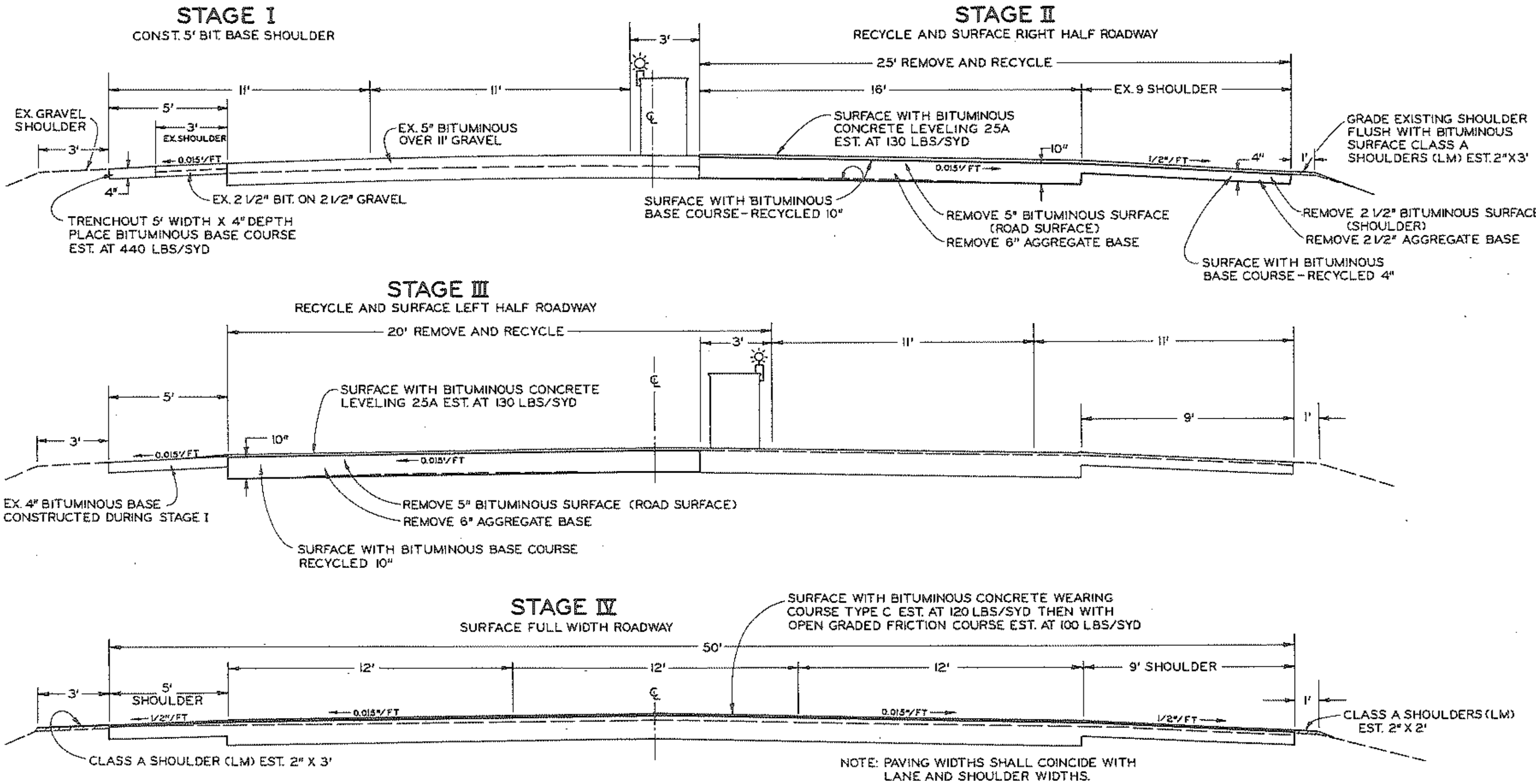
REFERENCES

1. "State-of-the-Art: Hot Recycling," NAPA, May 1977.

2. Barber-Greene Asphalt Construction Conference, 1978.

APPENDIX A

TYPICAL CROSS SECTIONS



Typical pavement and shoulder cross-sections.

APPENDIX B

SPECIAL PROVISION FOR RECYCLING BITUMINOUS PAVEMENT HEAT TRANSFER METHOD

MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
RECYCLING BITUMINOUS PAVEMENT
HEAT TRANSFER METHOD

Description: This work shall consist of recycling the existing bituminous pavement and an equal volume of the existing aggregate base through a batch type asphalt plant utilizing the heat transfer method of recycling. The recycled material will be placed on the roadway and surfaced with a 4.12 bituminous concrete leveling and wearing course as shown on the plans or in the proposal.

Materials: The bituminous material to be added shall be asphalt cement, penetration grade 120-150 or 200-250.

Removing Bituminous Surface: The equipment used for the removal of the existing bituminous surface shall be an approved rotary reduction machine having positive depth control adjustments in increments of one-half inch and capable of reducing material which is at least 4 inches in thickness. The machine shall be of a type designed by the manufacturer specifically for reduction in size of pavement material, in place, and be capable of reducing the pavement material to a maximum size of 2 inches. The cutting drums shall be enclosed and shall have a sprinkling system around the reduction chamber for pollution control. The rate of forward speed must be positively controlled in order to ensure consistent size of reduced material. The machine must be equipped with an accurate tachometer which is mounted in full view of the operator. As an alternate method, the existing pavement may be removed and crushed to the maximum 2 inch size. After the material is reduced to the maximum 2 inch size, it will be stockpiled at the asphalt plant site. To aid the Contractor in controlling the mixture temperature, it is recommended that the salvaged bituminous stockpile be covered to minimize variation in moisture content. The control of maximum size of the salvaged bituminous pavement will be that size that will, when heated in the recycled mixture, break down to original maximum aggregate size.

Removing Aggregate Base: The portion of the aggregate base specified on the plans will be removed and hauled to the asphalt plant site, and placed in a separate stockpile. The aggregate shall be removed in such a manner as to minimize degradation. After removing the Salvaged Aggregate, the existing aggregate base shall be bladed, or scarified and bladed, if necessary, to remove irregularities in the grade, as directed by the Engineer. The surface shall then be thoroughly compacted to a minimum of 95 percent of maximum density prior to placing the recycled mixture.

Mixing of Recycled Material: A batch type plant will be required for the mixing of the 50 percent salvaged bituminous pavement and the 50 percent salvage aggregate. The plant shall be modified so that the salvaged aggregate can be superheated to a temperature required to produce a resultant mix temperature of 220-280° F after adding the ambient temperature salvaged bituminous mixture. The mixture proportions shall be adjusted to provide a workable mix as directed by the Engineer. The plant shall also be modified to feed the salvaged bituminous mixture to the aggregate weigh hopper in a manner to assure uniform proportioning. If excessive moisture is present in the salvaged bituminous surface, it may be necessary to provide means of venting the pugmill to allow the moisture to escape. The plant shall at all times conform to local and state air quality standards. The Contractor shall submit, prior to the award of the contract, an acceptable proposal for preventing excessive air pollutants.

The recycled mixture shall be placed in accordance with the requirements specified in Section 3.05. The material shall be placed in 3 inch maximum lifts unless the Contractor can demonstrate the capability to obtain the required cross-section, within allowable tolerances, after compaction, by placing it in thicker lifts. The maximum lift thickness allowed will be 5 inches. Placing the material in lifts thicker than 3 inches must be approved by the Engineer.

The top course of the recycled mixture shall be controlled by a traveling stringline not less than 30 feet in length or a preset stringline, as directed by the Engineer. Cross slopes for both pavement and shoulders shall conform to those shown on the typical sections.

Any surplus material shall become the property of the Contractor. Standard clause 2.08.07.

Method of Measurement:

Removing Bituminous Surface (5 inch and 2-1/2 inch) - The removal of the existing bituminous surface will be measured in square yards. This item will include removal, transportation to the plant site, crushing, if required, and stockpiling at the plant site.

Removing Aggregate Base (6 inch and 2-1/2 inch) - The removal of the aggregate base will be measured in square yards. This item will include removal, transportation to the plant site, and stockpiling.

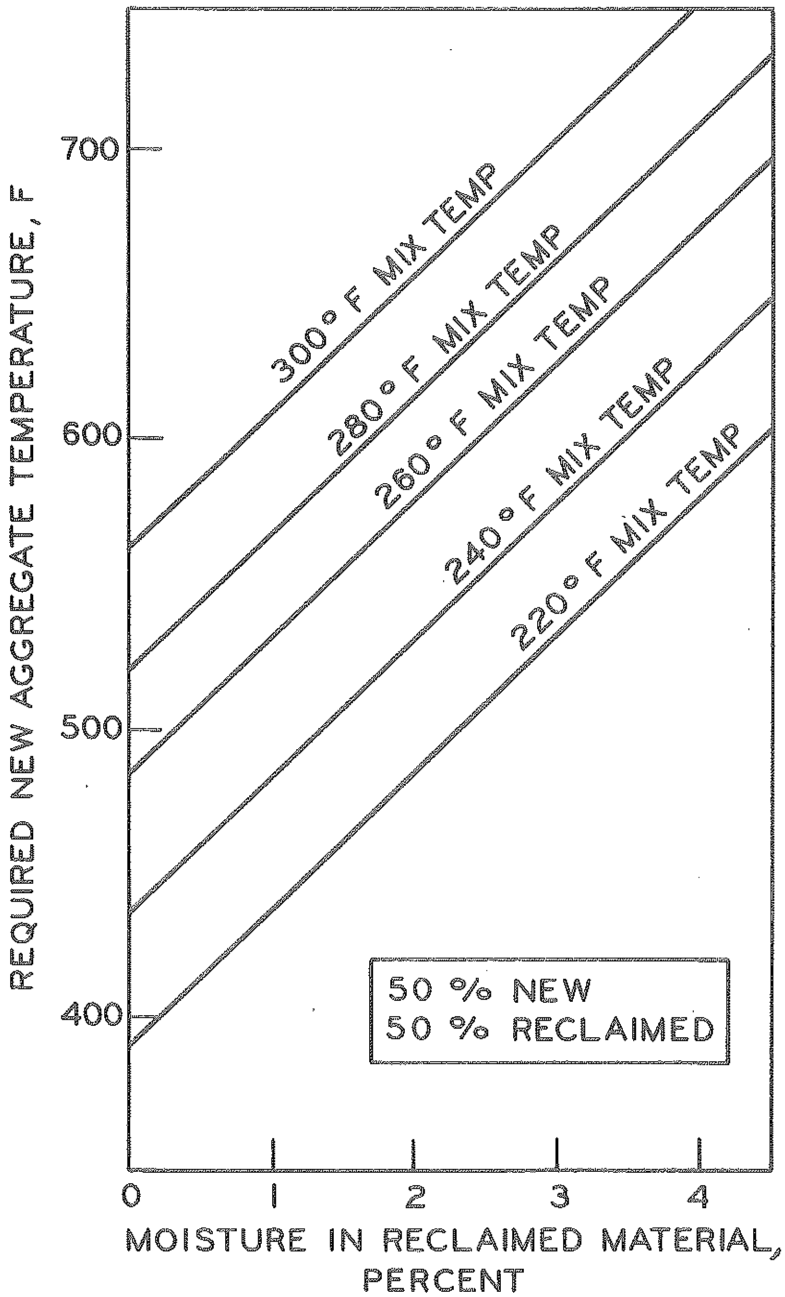
Asphalt Cement - The asphalt cement will be measured in tons delivered to the plant site, and incorporated into the recycled mixture.

Bituminous Base Course (Recycled) - The recycled bituminous base course will be measured in tons. This item will include the heating, mixing, transportation, and paving of the combined salvaged aggregate and bituminous mixture.

Pay Item	Pay Unit
Removing 5-inch Bituminous Surface (Road Surface)	sq yd
Removing 2-1/2-inch Bituminous Surface (Shoulders)	sq yd
Removing 6-inch Aggregate Base	sq yd
Removing 2-1/2-inch Aggregate Base	sq yd
Asphalt Cement	ton
Bituminous Base Course (Recycled)	ton

APPENDIX C

INFLUENCE OF MOISTURE CONTENT IN RECLAIMED MATERIAL VERSUS REQUIRED NEW AGGREGATE TEMPERATURE



Aggregate temperature requirements for recycling asphalt pavement in batch plants assuming:

1) No heat loss in elevator or bins.
2) No heat supplied by added asphalt.
3) Five percent asphalt in recycled material.

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APPENDIX D

SUMMARY OF BITUMINOUS FIELD AND LABORATORY TEST RESULTS

SUMMARY OF BITUMINOUS FIELD & LABORATORY TEST RESULTS

1856 (11/75)

PROJECT IR 11014-12607A	LOCATION I 94, New Buffalo	BITUMINOUS Base (Recycled) COURSE ( )
CONTRACTOR Rieth-Riley Const. Co., New Buffalo	PLANT NUMBER 410-11 PROJECT ENGR. D. Morse	INSPECTOR W. Smith
STONE ( ) Recycled	SAND ( )	
MINERAL FILLER ( )	BITUMEN 120-150 & 200-250 Energy Coop., E. Chicago	1976 STD SPECS

DATE SAMPLED		9-6-78			9-6-78			9-7-78			9-7-78			9-8-78			9-9-78				9-11-78				Supp
SAMPLE NO.		4918	4919	BB-1	5325	5326	BB-2	5327	5328	BB-3	5329	5330	BB-4	5331	5332	BB-5	5333	5334	5335	BB-6	5336	5337	5338	BB-7	
MIX	BIT. %	4.4	4.5	4.0	5.1	4.3	4.7	3.8	4.0	4.7	4.3	3.4	4.7	4.3	5.1	4.8	4.7	4.7	4.9	4.7	4.6	4.7	5.0	4.6	
AGGREGATE GRADATION PER CENT PASSING	1 1/2																								
	1	100	100	100			100			100	100	100	100	100	100	100	100	100	100	100	100	100		100	
	3/4				100	100		100	100														100		
	1/2																								
	3/8	80.3	82.8	70.7	81.5	78.7	80.6	80.8	76.7	83.8	67.9	67.8	69.0	83.4	85.5	85.8	81.1	80.1	82.8	84.1	77.6	78.7	82.4	69.8	
	4																								
	8	41.3	44.3	38.0	44.2	42.3	44.1	44.0	43.3	48.5	37.6	38.2	39.2	42.3	42.8	43.8	40.4	43.5	44.9	44.0	39.0	39.2	40.3	33.6	
	16																								
	30	27.6	28.6	24.7	27.9	27.2	27.7	28.8	28.7	30.9	25.5	26.3	26.0	26.3	26.3	26.4	25.2	28.1	29.9	28.4	24.8	25.2	25.6	21.6	
	50																								
	100																								
	200	5.7	6.0	4.1	5.7	5.3	4.4	6.5	6.2	5.1	4.9	5.7	3.7	6.3	5.9	4.7	4.9	5.9	6.0	4.8	5.5	5.8	5.7	4.0	
AVG. HOT BINS CA	P8																								
	P200																								
AVG. HOT BINS FA	P8																								
	P200																								
MIN. FIL-LER	P8																								
	P200																								
MIX DESIGN	BIT. %																								
	P 8%																								
	P 200%																								
PLANT DATA	BIT. %																								
	CA %																								
	FA %																								
	FILLER %																								
ASPH TESTS PEN	ORIG.	136			X			133			X			142			138				142				
	REC.	44			47			42			42			45			50				53				
MIX TEMP. F		240			240			240			---			---			245				240				
TONS MIX		315			691			647			488			1430			1216				593				
		Method B			Method A			Method C			Method C			Method A			Method B				Method B				

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DATE SAMPLED	9-11-78			9-13-78			9-15-78			9-16-78				9-16-78			9-19-78			9-19-78				Supp
SAMPLE NO.	5339	5340	BB-8	5341	5342	BB-9	5343	5344	BB-10	5345	5346	5347	BB-11	5348	5349	BB-12	5350	5351	BB-13	5352	5353	5354	BB-14	
MIX BIT. %	4.3	4.2	4.4	4.9	4.6	4.9	4.5	4.7	4.8	4.7	4.6	4.6	4.8	4.1	3.8	3.9	4.7	4.8	4.9	4.4	4.6	4.5	5.1	
AGGREGATE GRADATION PER CENT PASSING 1 1/2																								
1			100			100	100	100	100		100		100	100	100	100	100	100	100			100	100	
3/4	100	100		100	100					100	98.5	100								100	100	98.2		
1/2																								
3/8	80.2	77.3	80.8	82.8	78.5	80.9	80.5	86.8	85.8	83.9	82.9	82.2	86.7	73.8	70.3	69.6	83.4	84.6	83.2	83.2	79.3	78.1	89.6	
4																								
8	40.6	40.0	41.5	42.1	40.8	41.7	43.7	46.2	47.7	46.9	45.6	45.7	49.8	37.7	35.1	35.6	45.5	45.6	45.5	43.6	40.9	40.7	48.2	
16																								
30	25.1	24.5	24.5	27.6	26.6	26.5	26.6	28.4	28.0	28.1	27.5	28.1	28.9	24.6	23.2	22.6	22.9	27.8	26.6	29.1	26.0	26.4	29.2	
50																								
100																								
200	5.9	5.8	4.5	7.0	6.7	5.6	6.0	6.7	5.2	8.4	6.1	8.4	7.2	6.3	6.1	4.7	6.9	7.0	5.3	6.9	6.0	6.1	5.2	
AVG. HOT BINS CA P8																								
AVG. HOT BINS CA P200																								
AVG. HOT BINS FA P8																								
AVG. HOT BINS FA P200																								
MIN. FIL-LER P8																								
MIN. FIL-LER P200																								
MIX DESIGN BIT. %																								
MIX DESIGN P 8%																								
MIX DESIGN P 200%																								
PLANT DATA BIT. %																								
PLANT DATA CA %																								
PLANT DATA FA %																								
PLANT DATA FILLER %																								
ASPH TESTS PEN ORIG.	X			142			234			235				X			236			--				
ASPH TESTS PEN REC.	53			48			52			54				54			58			54				
MIX TEMP. F	260			255			265			260				--			270			--				
TONS MIX	1011			1299			1843			1876				--			2922			--				
	Method C			Method A			Method C			Method B				Method A			Method A			Method C				

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DATE SAMPLED		9-20-78			9-27-78			9-28-78			9-28-78			
SAMPLE NO.		5355	5356	BB-15	5685	5686	BB-16	5687	5688	BB-17	5689	5690	5691	BB-18
MIX BIT. %		5.0	5.1	5.0	5.1	5.1	5.5	4.0	4.3	4.7	4.5	4.5	4.9	4.6
AGGREGATE GRADATION PER CENT PASSING	1 1/2													
	1	100	100	100	100	100	100	100	100	100	100	100	100	100
	3/4				97.6	98.3		96.3	98.3		95.9	97.8	98.5	
	1/2				94.4	95.4		80.1	83.1		81.3	83.1	90.5	
	3/8	82.1	83.2	84.7	89.4	91.2	90.3	69.6	72.2	78.8	72.5	71.9	82.3	71.8
	4													
	8	41.6	42.4	43.1	49.5	49.8	51.3	35.5	35.6	40.3	36.4	35.5	41.6	36.3
	16													
	30	25.8	26.2	25.7	31.8	32.0	31.4	20.7	20.8	22.3	20.6	20.8	23.6	20.5
	50													
	100													
	200	6.8	6.6	6.6	6.7	7.0	5.2	5.6	5.6	5.1	5.3	5.4	5.9	4.5
AVG. HOT BINS CA	P8													
	P200													
AVG. HOT BINS FA	P8													
	P200													
MIN. FILLER	P8													
	P200													
MIX DESIGN	BIT. %													
	P 8%													
	P 200%													
PLANT DATA	BIT. %													
	CA %													
	FA %													
	FILLER %													
ASPH TESTS PEN	ORIG.	276			262			234			X			
	REC.	64			68			65			50			
MIX TEMP. F		260			240			265			--			
TONS MIX		853			1446			2235			--			
		Method C			Method C			Method C			Method B			

DATE SAMPLED		9-29-78			9-29-78			10-2-78				Supp
SAMPLE NO.		5692	5693	BB-19	5694	5695	BB-20	6461	6462	6463	BB-21	
MIX BIT. %		4.2	4.4	4.3	4.8	4.7	5.0	4.6	4.6	4.5	4.3	
AGGREGATE GRADATION PER CENT PASSING	1 1/2			100								
	1	100	100	96.0		100	100	100	100	100	100	
	3/4	96.8	96.5		100	97.1						
	1/2	83.9	86.7		88.9	89.0						
	3/8	75.0	76.1	75.1	82.1	80.3	82.0	79.2	80.9	76.9	70.8	
	4											
	8	40.2	41.7	40.8	42.7	41.2	41.5	39.1	39.0	37.6	35.0	
	16											
	30	24.0	25.2	24.2	23.6	23.1	22.5	22.9	23.2	22.8	21.1	
	50											
	100											
	200	5.9	6.1	5.0	5.9	5.5	4.5	5.8	6.1	5.9	4.8	
AVG. HOT BINS CA	P8											
	P200											
AVG. HOT BINS FA	P8											
	P200											
MIN. FILLER	P8											
	P200											
MIX DESIGN	BIT. %											
	P 8%											
	P 200%											
PLANT DATA	BIT. %											
	CA %											
	FA %											
	FILLER %											
ASPH TESTS PEN	ORIG.	283			X			223				
	REC.	62			56			74				
MIX TEMP. F		245			--			240				
TONS MIX		3294			--			1505				
		Method A			Method A			Method B				

1856 (11/75)

SUMMARY OF BITUMINOUS FIELD & LABORATORY TEST RESULTS

PROJECT IR 11014-12607A	LOCATION I 94, New Buffalo		BITUMINOUS Base (Recycled) COURSE ( )
CONTRACTOR Rieth-Riley Const. Co., New Buffalo	PLANT NUMBER 410-11	PROJECT ENGR. D. Morse	INSPECTOR W. Smith
STONE ( ) Recycled		SAND ( )	
MINERAL FILLER ( )		BITUMEN 120-150 & 200-250 Energy Coop., E. Chicago	1976 STD SPECS

DATE SAMPLED		10-3-78			10-4-78			10-4-78				10-5-78			Supp
SAMPLE NO.		6455	6456	BB-22	6457	6458	BB-23	6464	6465	6466	BB-24	6459	6460	BB-25	
MIX	BIT. %	4.6	4.6	4.9	5.2	5.3	5.1	4.6	4.7	4.9	4.7	4.6	4.7	4.5	
AGGREGATE GRADATION PER CENT PASSING	1 1/2														
	1	100	100	100	100	100	100	100	100	100	98.1	100	100	100	
	3/4														
	1/2														
	3/8	82.4	81.8	76.9	86.9	87.1	86.7	80.0	83.6	87.4	77.5	79.4	81.8	75.7	
	4														
	8	43.7	42.6	44.3	46.7	46.5	46.6	42.5	44.3	45.9	41.1	43.4	44.3	38.9	
	16														
	30	26.2	25.8	22.4	28.8	26.6	25.8	25.1	26.8	26.9	23.9	27.4	25.8	24.8	
	50														
	100														
	200	5.9	5.7	5.0	6.5	6.5	4.8	5.7	6.1	6.1	4.6	6.8	6.4	4.9	
AVG. HOT BINS CA	P8														
	P200														
AVG. HOT BINS FA	P8														
	P200														
MIN. FIL-LER	P8														
	P200														
MIX DESIGN	BIT. %														
	P 8%														
	P 200%														
PLANT DATA	BIT. %														
	CA %														
	FA %														
	FILLER %														
ASPH TESTS PEN	ORIG.	216			X			217				205			
	REC.	45			44			48				67			
MIX TEMP. F		240			245			---				245			
TONS MIX		1738			3143			---				1527			
		Method C			Method A			Method B				Method C			

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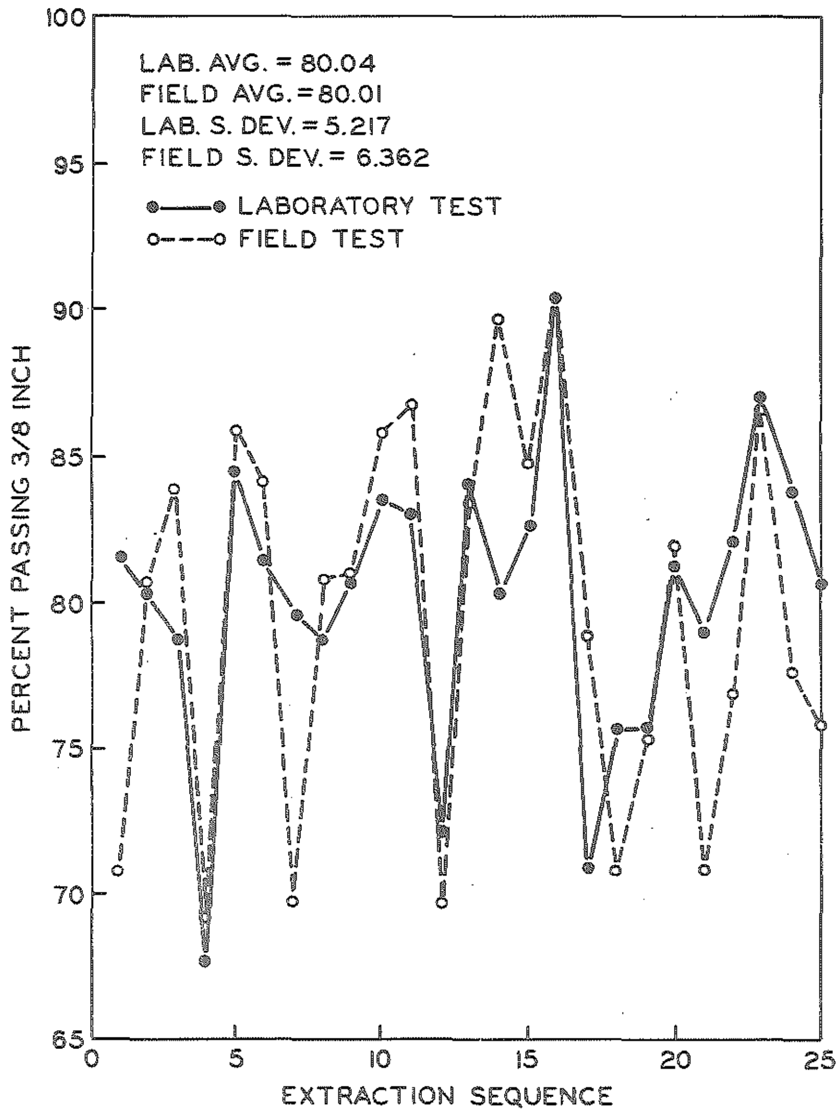
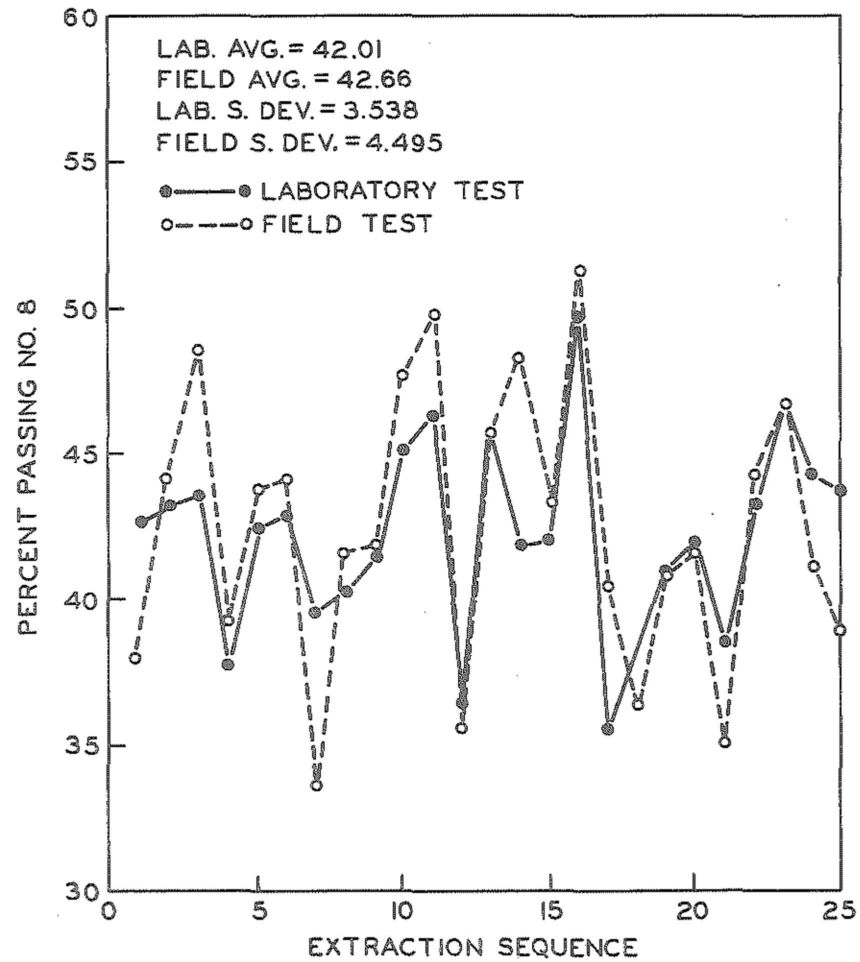
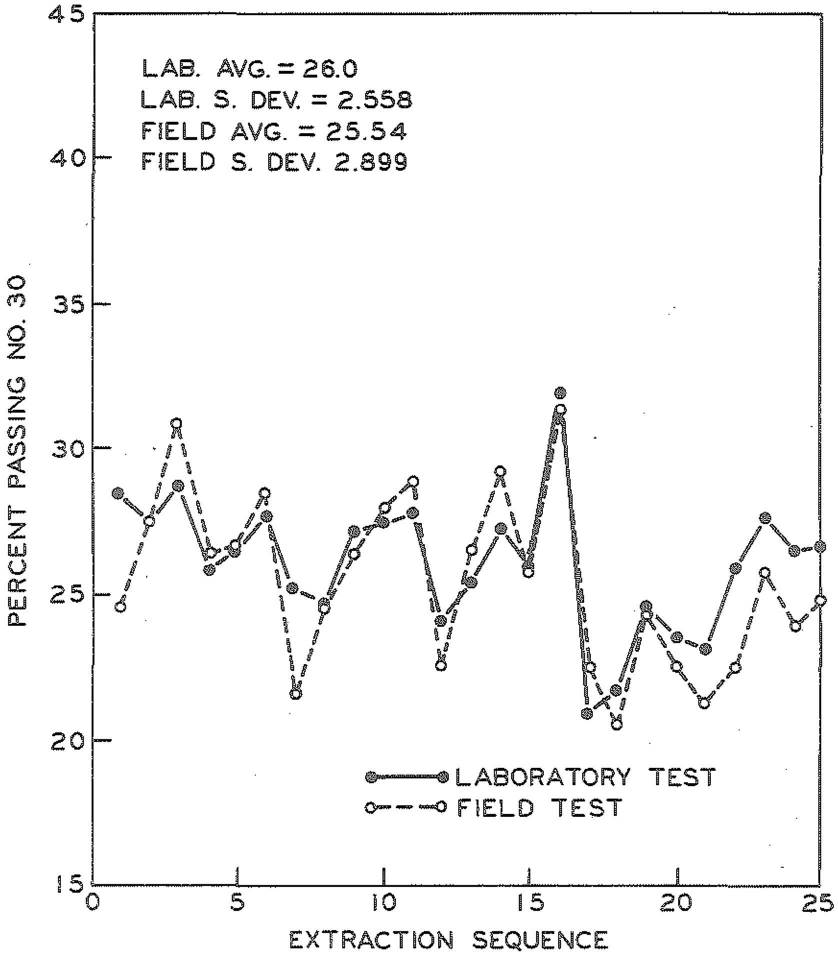
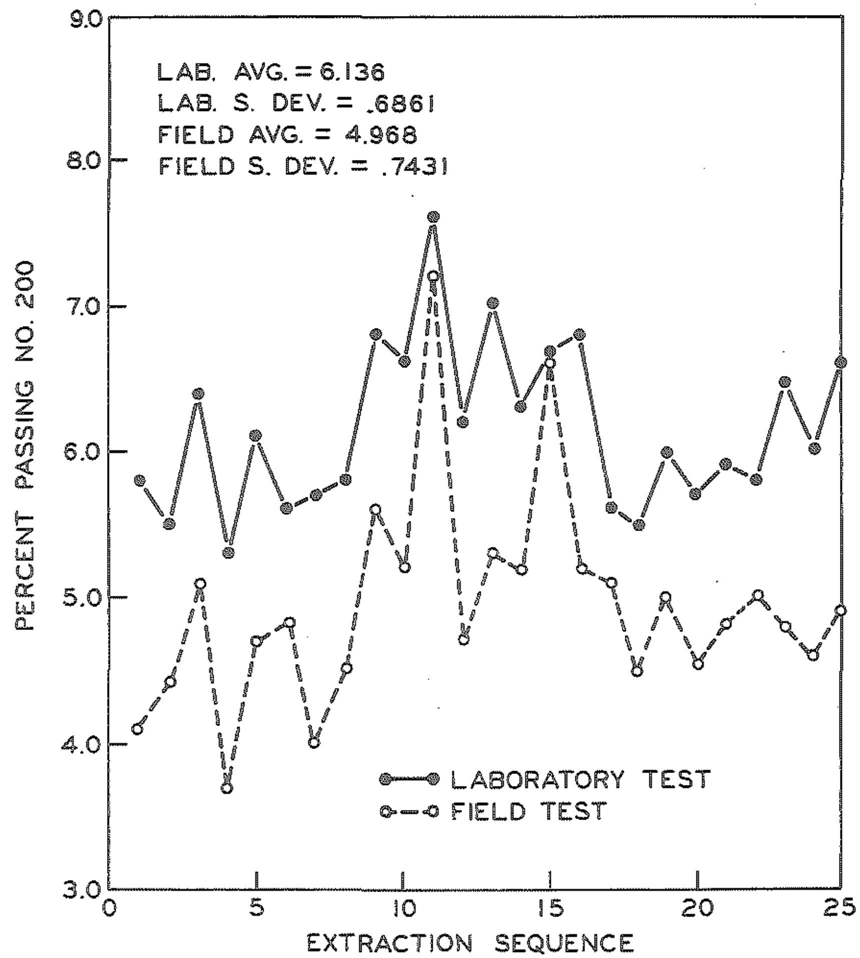
APPENDIX E

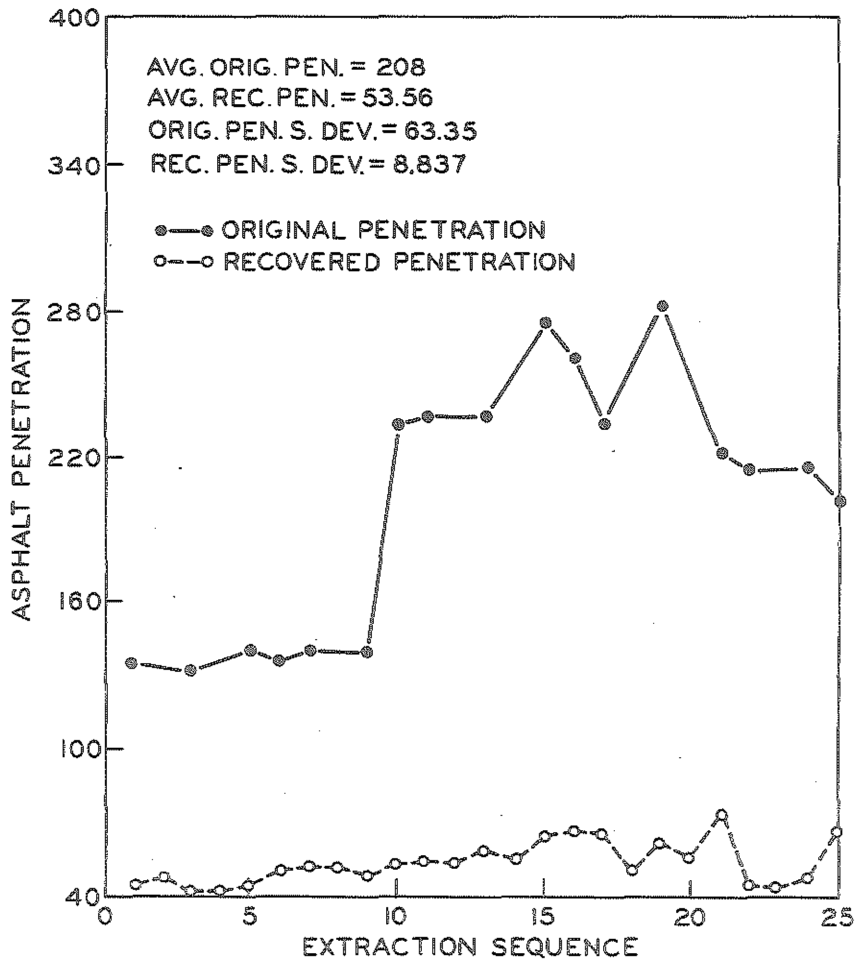
QUALITY CONTROL CHARTS

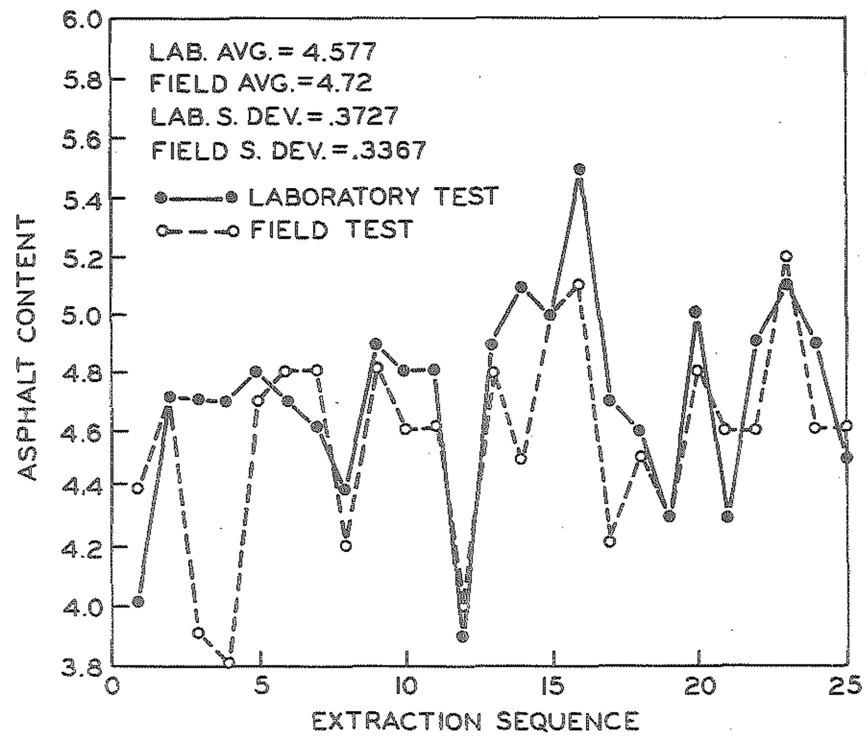

LAB. AVG. = 80.04
FIELD AVG. = 80.01
LAB. S. DEV. = 5.217
FIELD S. DEV. = 6.362
LABORATORY TEST
FIELD TEST
PERCENT PASSING 3/8 INCH
EXTRACTION SEQUENCE
100
95
90
85
80
75
70
65
0
5
10
15
20
25


LAB. AVG. = 42.01
FIELD AVG. = 42.66
LAB. S. DEV. = 3.538
FIELD S. DEV. = 4.495
LABORATORY TEST
FIELD TEST
PERCENT PASSING NO. 8
EXTRACTION SEQUENCE
60
55
50
45
40
35
30
0
5
10
15
20
25


LAB. AVG. = 26.0
LAB. S. DEV. = 2.558
FIELD AVG. = 25.54
FIELD S. DEV. 2.899
PERCENT PASSING NO. 30
EXTRACTION SEQUENCE
LABORATORY TEST
FIELD TEST


LAB. AVG. = 6.136
LAB. S. DEV. = .6861
FIELD AVG. = 4.968
FIELD S. DEV. = .7431
PERCENT PASSING NO. 200
EXTRACTION SEQUENCE
LABORATORY TEST
FIELD TEST


AVG. ORIG. PEN. = 208
AVG. REC. PEN. = 53.56
ORIG. PEN. S. DEV. = 63.35
REC. PEN. S. DEV. = 8.837
ORIGINAL PENETRATION
RECOVERED PENETRATION
ASPHALT PENETRATION
EXTRACTION SEQUENCE
400
340
280
220
160
100
40
0
5
10
15
20
25


LAB. AVG. = 4.577
FIELD AVG. = 4.72
LAB. S. DEV. = .3727
FIELD S. DEV. = .3367
LABORATORY TEST
FIELD TEST
ASPHALT CONTENT
EXTRACTION SEQUENCE
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
0
5
10
15
20
25

APPENDIX F

MARSHALL TEST RESULTS ON RECYCLED MIXTURE

1931 (N9/77)

REPORT OF TEST

BITUMINOUS MIXTURE DESIGN DATA
(Computer Design)

Control Section Identification	General
Job No.	
Laboratory No.	78 B-5380 through 5387
Date	September 28, 1978

Type of Mix BITUMINOUS AGGREGATE RECYCLED MIX Date Tested September 13, 1978
Intended Use Base Course Specification 3.05, 1976 Std. Specs. Supp.

MATERIALS USED

Material	Type	Source	Pit Number	Apparent Specific Gravity	Bulk Specific Gravity	Absorption Percent
Asphalt	120/150	American Oil Co., Detroit		1.025		
I 94	Pavement	Rieth-Riley Const., New Buffalo		---	---	---
Dense Agg.	22A	Rieth-Riley Const., New Buffalo		---	---	---

Marshall Test Results:		
Laboratory No.	78 B-5380/5383	78 B-5384/5387
Marshall No.	1122/1125*	1126/1129**
Actual S.G.	2.426	2.425
Theo Max S.G.	2.480	2.480
Air Voids, %	2.18	2.22
VFA, %	85.6	85.4
VMA, %	15.1	
Stability, lb	2056	2447
Flow. 0.01''	12.5	13.5
Aggregate Gradation Calculated Cumulative Percent Passing		
3/4-inch	100.0	
1/2-inch	91.9	
3/8-inch	82.2	Same
No. 4	59.1	
No. 8	43.4	
No. 16	35.2	
No. 30	29.3	
No. 50	20.5	
No. 100	10.4	
No. 200	7.4	
Mixture Prop., %		
Crushed Pavement	48.9	48.9
20AA	48.9	48.9
Bitumen	2.2	2.2

* Butter mixture
** Mixture Number 2
Project No. IR 11014/12607A

cc: File
D. F. Malott
R. A. Welke
J. Norton
M. Reeves (2)
F. Carian (3)

Signed [signature]
Engineer of Testing