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RECYCLING ASPHALT PAVEMENTS

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16. Abstract

This asphalt concrete recycling project, the first attempted by the Washington State Department of Transportation, seems so far to be very successful. The project looks good from a standpoint of economy, energy use, conservation of natural resources, feasibility of construction, and from an evaluation of the test data obtained to date.

Certain pitfalls seem to exist when using this type of a recycling process, such as selection of the proper rejuvenator, degrading of the aggregates, pollution, proper amounts of new aggregate, and other minor problems. Properly conducted preliminary testing and design can avoid a multitude of these pitfalls.

Future asphalt concrete recycling will most likely be a definite consideration in the rehabilitation of asphalt concrete highways in Washington. In fact, one project has already been scheduled for recycling in 1978 construction, with a number of additional pavements being considered for 1979 construction.

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WASHINGTON STATE DEPARTMENT OF TRANSPORTATION'S FIRST ASPHALT CONCRETE RECYCLING PROJECT - RENSLOW TO RYEGRASS

Contract No. DOT-FH-15-232

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DISCLAIMER STATEMENT

ABSTRACT

This asphalt concrete recycling project, the first attempted by the Washington State Department of Transportation, seems so far to be very successful. The project looks very good from a standpoint of economy, energy use, conservation of natural resources, feasibility of construction, and from an evaluation of the test data obtained to date.

Certain pitfalls seem to exist when using this type of a recycling process, such as selection of the proper rejuvenator, degrading of the aggregates, pollution, proper amounts of new aggregate, and other minor problems. Properly conducted preliminary testing and design can avoid a multitude of these pitfalls.

Future asphalt concrete recycling will most likely be a definite consideration in the rehabilitation of asphalt concrete highways in Washington. In fact, one project has already been scheduled for recycling in 1978 construction with a number of additional pavements being considered for 1979 construction.

SUMMARY AND CONCLUSIONS

Our first asphalt concrete recycling project seems to have been very successful based on an evaluation of the construction operations and the available test results. Of course, the degree of success will depend on the performance of the pavement over an extended period of time. Other conclusions that can be drawn from the construction and testing are:

1. Degrading of the aggregate in the removal and mixing operations was rather critical, especially the increase in the amount of material passing the #200 sieve.
2. The CMI Roto-Mill seems to be an excellent tool for this type of removal operation.
3. Construction costs and energy consumption seem to be very justifiable with this type of recycling operation.
4. The tests conducted for air pollution did not meet the specification requirements; however, because virtually no hydrocarbons were present in the source samples, it is felt that maintenance on the bag house would have solved the air pollution problems.
5. The preliminary work, including the mix design and analysis of the rejuvenators, is extremely important. Attention to these kinds of details on recycling projects has to be many times more critical than routine asphalt concrete design and construction.
6. A standard evaluation procedure is needed for determining whether a rejuvenator is adequate.
7. Crusting over of the stockpiled asphalt concrete was due to the high ambient temperatures in this area. Future work in hot areas where the material is to be stockpiled should consider requiring a crusher just prior to the cold feed.

INTRODUCTION

The increasing cost of construction materials and the desirability of conserving resources have led many road building agencies to evaluate the merits of reusing all or portions of failing or inadequate pavements as raw materials for new pavements. This process is currently referred to as "recycling". Most recycling projects to date have featured the reuse of old asphalt pavements. Some of the advantages of recycling are:

1. Conservation of aggregate and asphalt.
2. Reduction in fuel consumption.
3. Retention of original grade.

The extent to which these are true advantages in Washington State at this time depends on such things as cost, ease and speed of construction, quality and durability of recycled mix, and perhaps the environmental acceptability of all the attendant processes. These were factors that we attempted to evaluate on Washington's first asphalt concrete recycling project.

The recycled pavement project is a 4-mile, 4-lane section of Interstate 90 between Ellensburg and the Columbia River. The location is known as Renslow to Ryegrass. Only the top 0.15 feet of pavement, the wearing course, was recycled. The project was awarded to Associated Sand and Gravel of Everett.

PROJECT DESCRIPTION

The original construction of this pavement was completed in July of 1967, but not opened to traffic until November of 1968. The pavement section consisted of 0.45 feet of asphalt concrete base (Class E) topped with 0.20 feet of leveling and 0.15 feet of wearing course asphalt concrete pavement

(Class B). Specifications for these dense graded mixes are shown in Table 1. The condition of the pavement before recycling showed much structural cracking in the wheel paths and extensive transverse cracking across both lanes and shoulders. The structural cracking extended through the wearing, and sometimes into the leveling courses, but not into the base course, leading us to believe these were not base failures but structural deficiencies in the asphalt concrete. Transverse cracking extended completely through the 0.80 feet of asphalt concrete pavement.

PRELIMINARY INVESTIGATION

This pavement was considered for recycling because it was scheduled for rehabilitation, it was basically structurally sound, and we had been observing and testing it for a number of years.

The initial estimates for recycling were compared to two alternative rehabilitation procedures of a more conventional nature as follows:

A. Recycle

Remove and recycle 0.15 feet of asphalt concrete pavement on the traveled way. Overlay the entire project, traveled way and shoulders with 0.06 feet of open-graded friction course.

$537,328

B. Conventional Overlay

Overlay the entire project, traveled way, and shoulders with 0.35 feet of asphalt concrete pavement. The estimate did not include raising of the guard rail.

$857,989

C. Remove and Replace

Remove and waste the top 0.15 feet of asphalt concrete pavement on the traveled way; replace with new asphalt concrete. Overlay the entire project, traveled way, and shoulders with 0.06 feet of open-graded friction course.

$653,772

After initial estimates showed the recycling procedure to be least expensive, the next step was to determine the proportions of materials to use in the recycle process. This would include old asphalt concrete, rejuvenator, new aggregate and new asphalt, if necessary. Samples of the asphalt concrete to be recycled, approximately 200 lb each, were taken from three different locations for preliminary study. A large quantity of the material was extracted with trichloroethylene, the asphalt was recovered from solution and a gradation analysis run on the aggregate as shown on Table 2. The gradation and asphalt content were about the same as constructed; however, the asphalt had hardened considerably and exhibited much higher viscosities.

Two rejuvenators (Paxole, supplied by PAX International, and Cyclepave, supplied by Witco Chemical Company) were used in preliminary tests. Each was added in varying amounts to the recovered asphalt and changes in viscosity noted. This determined the approximate quantity of rejuvenator to mix with the old asphalt to produce an AR-4000 asphalt. These amounts were then mixed with heated "to be recycled" asphalt concrete, and the resultant mix compacted and tested for void content and stability as shown on Table 3. It should be noted that the quantity of rejuvenator required to reduce the viscosities to an AR-4000 material resulted in very low Hveem stabilities. Rather than cut down on the amount of rejuvenator, varying amounts of new 5/8 - 1/4 inch crushed aggregate were added to the mix as shown in Table 3. In effect this reduced the amount of 200 minus fines in the mix and also reduced the amount of fluids in the total mix, thereby increasing the Hveem stability.

From this basic work it was evident that the pavement could be recycled and a correct balance of materials could be found. The preliminary study gave a good starting point for plan preparation.

Additional testing prior to contract involved mixtures of the rejuvenators with the recovered asphalt cement from the roadway samples produced data shown in Table 4 and 5 which includes penetrations, viscosities, ductilities and chemical analyses in "as combined" and "after RTFC" conditions.

Four rejuvenators were included in these preliminary tests: Paxole, Cyclepave, and two supplied by Chevron U.S.A.: Tempering Fluid and Classo. These data are included in Table 4 and Table 5.

Conclusions regarding the rejuvenators after completion of these screening tests were as follows:

1. Paxole and Cyclepave are satisfactory and are comparable with respect to the amount of material required to reduce the viscosity of the old asphalt to a satisfactory point. The heat stability of the material after conditioning in an RTFC oven is also satisfactory.
2. Chevron Tempering Fluid required approximately the same quantity of material to reduce viscosities. However, the material was not very heat stable during RTFC testing as shown on the tests after this conditioning. Its C.O.C. flash point of approximately 275^{o} F was far below the flash of the other materials and could be considered dangerous when exposed to direct flame. For these reasons this rejuvenator was considered unsatisfactory for this project.
3. Approximately 2.5 times as much Chevron Classo was required to bring the 140^{o} F viscosity to the level desired compared to Paxole or Cyclepave. The larger quantity would cause the fluid content of the mixture to be very high and additional aggregate

would be required to compensate. The larger quantities of rejuvenator and aggregate required rendered Classo unsatisfactory for this pavement. This material, however, might be of benefit where there is a shortage of asphalt in the material to be recycled and/or where the asphalt is not as hard.

The preliminary investigation also involved a literature search and review, interviews with suppliers, researchers and others experienced in this new field and culminated in the recycling specifications. A copy of those parts of the job specifications that pertain to the recycling is attached as Appendix A. The roadway section is included.

Basically the plans called for removal of the top 0.15 feet of asphalt concrete roadway, leaving the inside and outside shoulders in place, stockpiling the material, reducing to a size of 1-inch minus, heating the new aggregate and old asphalt concrete in a suitable heater, mixing these materials in a pugmill with asphalt and rejuvenator and finally placing and compacting the mixture. An open-graded friction seal, placed over the entire roadway, including the shoulder areas, was specified for a finish pavement.

In the contract provisions every effort was made to tell the contractor what had to be done but not how to do it except a pugmill was required for mixing the rejuvenator and asphalt with the new aggregate and old asphalt concrete. This was to insure the best possible dispersion of new fluids and to reduce the possibility of damage to the recycling additive.

A deviation in the air quality standard was requested by the Department and granted by the Department of Ecology for approximately the first 5000 tons of production, as indicated in the specifications.

PROJECT MIX DESIGN

Tests conducted on the old asphalt concrete during the ripping and stockpiling operation consisted of extractions including aggregate gradation and asphalt content, and Abson recoveries of the old asphalt cement. Tests on the Abson recovered material included penetrations, viscosities, ductilities, and Rostler-Sternberg chemical analysis, Table 6. This information was used as part of the mix design to determine the appropriate amounts of rejuvenator, new asphalt and new aggregate to be added to the old asphalt concrete.

The goal of the mix design was to: (1) rejuvenate the asphalt cement with the addition of a satisfactory rejuvenator, (2) satisfy Hveem stability requirements by adding additional 5/8 - 1/4 inch aggregate, and (3) to add enough new asphalt to give a good low void mixture. Enough rejuvenator was added to the asphalt to reduce the viscosity from an average of approximately 30,000 poise at 140° F to about 1800 poise. By starting at 1800 poise a viscosity of 4000 poise was expected upon completion of the mixing and placing operation. This would be equivalent to our standard AR-4000W asphalt cement. The amount of rejuvenator needed was determined by plotting on a viscosity blending chart, the average 140° F viscosity of the old asphalt cement and the 140° F viscosity of the rejuvenators that were being considered, as shown in Figure 1. This gave a good starting point.

The next step in the mix design was to combine the old asphalt concrete with the rejuvenators to see how the combination reacted during routine laboratory testing. As in the preliminary testing the mixture proved to be very unstable due to high amounts of fine materials and fluids. To improve the stability 5/8 - 1/4 inch aggregate was added to reduce the proportion of fine materials, (#200 minus), reduce the amount of fluid, and open up the aggregate gradation and thereby make it less sensitive. As shown on Table 7, the stability increased with increasing percentages of 5/8 - 1/4 inch aggregate.

Based on the mix design, the final recommendation was to add 25-30% of 5/8 - 1/4 inch aggregate, up to 2% (by weight of the new aggregate) AR-4000W asphalt cement, and 15-20% Cyclepave (by weight of asphalt cement in the old asphalt concrete) to the old asphalt concrete. The actual batch percentages arrived at during the construction of the recycled mix were 71.75% old asphalt concrete, 27.5% 5/8 - 1/4 inch aggregate, 0.75% Cyclepave, and 0% new asphalt.

CONSTRUCTION OPERATION

The construction of this recycling project was awarded to Associated Sand and Gravel, Everett, Washington, on July 7, 1977, with a 60-working-day completion time. A preconstruction conference with the contractor was held on July 27, 1977, and the contractor started work the first week in August, 1977.

The bid price for removing, hauling, and stockpiling of approximately 118,000 square yards of asphalt concrete 0.15 feet thick was $0.95 per square yard. A price of $7.80 per ton was bid to heat, mix, lay, and compact approximately 12,400 tons of recycled asphalt concrete (excluding the cost of new asphalt, rejuvenator, and new aggregate).

The contractor elected to complete the removal of the top 0.15 feet of asphalt concrete before beginning any mixing and placing operations. The removal was accomplished with a CMI Roto-Mill that is manufactured by the CMI Corporation of Oklahoma City and was supplied by Eisenhour Construction Company of East Lansing, Michigan.

The Roto-Mill is a cold milling machine that has a rotary cutter assembly which is 9 feet 3 inches long and 32 inches in diameter. The grinding or cutting is achieved by 228 tungsten-carbide teeth spaced uniformly on the cutter assembly. The machine automatically picked up the milled material and deposited it in a following truck. The required 0.15 feet of pavement was removed in one pass. The operation of the machine was relatively dust free, possibly because a fine spray of water was used inside the grinding cavity. The machine is noisy and the workmen wear earplugs.

Initially the machine began operating at approximately 30 feet per minute; however, because the specified 1 inch maximum size in stockpile could not be met, the machine was slowed to 20-25 feet per minute. Slowing the machine reduced the amounts of material retained on the 1 inch sieve but did not solve the problem, so a bar was installed just in front of the teeth to hold the pavement down. This helped; however, there was still an average of 7% retained on the 1 inch sieve. The problem stemmed from the tendency of the wearing course to delaminate from the leveling course.

Two Roto-Mills were used in echelon throughout most of the project. The first was taking the maximum width of cut, 9 feet, and the second following and removing the remainder of the 12-foot lane. This was done for safety reasons due to the lanes having to be reopened to traffic at night and on weekends. There was only one time during the job that the machines were not operating together. Approximately half way through the job one machine broke a mandrel and was not functional for a couple of days.

During the removal and stockpiling, the mixing plant was set up in a pit site located at the upper end of the project, between the east and west bound lanes. Basically, the plant was a standard 4000-lb. batch plant with one additional dryer and one additional cold feed. A schematic of the plant is shown in Figure 2. One cold feed control was for proportioning the new 5/8 - 1/4 inch aggregate and the other was for proportioning the amount of old crushed asphalt concrete. The cold feed for the old asphalt concrete was a crusher feeder which the contractor felt would work better than standard cold feed equipment. It worked fairly well although it did plug occasionally and had to be watched closely.

The basic operation was to use the first dryer to heat the new 5/8 - 1/4 inch aggregate to between 500-600° F and then proportion it into the second dryer in conjunction with a cold feed for the old asphalt concrete. This proportioned mixture then tumbled through the second dryer with some additional heat being applied so that the mixture came out of the second drum at approximately 300° F. Both dryers were fired by propane fuel. The material was then elevated to the top of the standard batch plant where the appropriate amount of rejuvenator was added. The mixture was then elevated and deposited into a surge silo where it was used as required. In general, the mixing operation was running slower than the street operation. The equipment used for hauling, laydown and compaction was standard. Vibratory rollers were used to compact the recycled asphalt concrete. The rejuvenated asphalt concrete acted and handled in all respects as a virgin asphalt concrete mixture.

Some problems were experienced in combining and mixing of the various materials used. Initially a screen deck was used in the top of the batching operation but the screens were plugged by asphalt and fine materials that accumulated on the screens;eventually they were removed. Frequent plugging also occurred in the hot elevator following the second dryer and occasionally in other areas, most likely because the rejuvenator had not yet been added and the viscosity of the old asphalt was still very high, causing it to stick and build up on anything that was not heated. Those areas that were the worst for plugging were wrapped with insulation to help retain heat and keep the trouble to a minimum.

Removal of the old asphalt concrete from the stockpile proved to be a problem. The high ambient temperature caused a reduction in the viscosity of the asphalt in the upper portion of the stockpile. This reduction in viscosity was enough for the asphalt to become tacky, causing a crust to form on the surface of the stockpile which resulted in the presence of large chunks when removing material from stockpile. These chunks were as large as 4-5 feet across and 1-2 feet thick. They were broken up prior to entering the heating operation by dumping the material on the floor of the stockpile and running over it with a front end loader. This was probably not the best procedure, although it was the only one available at the time.

Another problem experienced during the construction of this recycling project was the inability to get rid of excess material passing the #200 sieve. The bag house collected virtually no fine materials during production so we were unable to get rid of any. During the 1967 construction of the pavement, the material passing the #200 sieve averaged [illegible]%. Preliminary [illegible] of the pavement, before recycling, averaged [illegible].1%. Control samples [illegible] averaged [illegible]%. Control samples of [illegible] recycled mixture averaged [illegible] passing the #200 sieve; however, this is [illegible] the addition of [illegible] of 5/8 - 1/4 inch aggregate which was relatively [illegible] of material passing the #200 sieve. If no 5/8 - 1/4 inch aggregate had been added, the calculated amount of material passing the #200 sieve in the [illegible] asphalt concrete after heating and mixing would have been 11.5%. This [illegible] that the material passing the #200 sieve increased by 2.5% during the removal and by another [illegible]% due to heating and pugmill mixing.

The [illegible] and techniques used by the contractor seem to be a very [illegible] way of accomplishing the [illegible], heating, and mixing of the re- [illegible] might not have worked as well if less than 25% new aggregate had been added because the process, for air pollution reasons, relies on a great deal of heat exchange from the new aggregate to the old asphalt concrete. If this heat exchange were minimal, the old asphalt concrete would require additional heat in the second dryer and could cause much more hydrocarbons to be given off from burning of the asphalt cement.

PROJECT TESTING

Recycled Mix Samples

During construction, tests were conducted on the recycled asphalt concrete in the Materials Laboratory. The data shown on Table 8 includes extracted grading and asphalt content; Abson recoveries of the asphalt cement plus penetrations, viscosities, ductilities and Rostler-Sternberg chemical analysis of Abson recovered binder; stabilities, cohesions, % voids and room temperature resilient modulus of the recycled mix.

Core Testing

Cores taken and tested, Table 9, to verify test information on the routine control samples did just that--verified the data. The cores were also tested for void content and resilient modulus. Three additional cores were taken from a one-quarter-mile test area located at the west end of both eastbound lanes. That test area of recycled asphalt concrete was not overlaid with open-graded asphalt concrete and will be observed for the next couple of years. The test results from those three cores showed little variation from cores taken in other areas of the project.

Air Pollution Data

Testing by the Central Regional Office of the Washington State Department of Ecology was conducted on air quality during the mixing of the recycled asphalt concrete on both this project and on a Federal Highway Administration recycling project located on SR-97 in the Blewett Pass area. Their report pertaining to air pollution on these two projects is included in this report as Appendix B.

Only two source tests were conducted on the plant during recycling operations and one test during the routing production of the open-graded asphalt concrete. All of the test results exceeded the specified maximum 0.10 g/dscf (grains/dry standard cubic foot), including the one taken during routine production. There were essentially zero hydrocarbons collected in the two source tests during recycling operations. Generally the 20% maximum opacity requirement was satisfied.

Compaction Data

Tests conducted during the placing of the recycled material included airflow (permeability) testing and nuclear density testing. Only a minimal amount of data is available on the airflow testing and will not be presented; however, the densities and corresponding void percentages as determined by the Rice specific gravities are shown on Table 10. Generally those data were within what has been suggested as a minimum limit of 92% of Rice or 8% air voids maximum.

Ride Data

Ride testing, Table 11, was done in three stages: before paving, after paving the recycled mix, and after paving the open-graded pavement. The numbers are in counts per mile. Looking only at the average test results of the original and recycled pavement, the recycled pavement was smoother.

Surface Friction Data

Friction tests were conducted with a lock-wheel trailer per ASTM E-274-77. The values shown in Table 12 for the recycled asphalt concrete appear very similar to what might be expected of new dense graded asphalt concrete.

Energy Data

Part of the contractual agreement was to document energy consumed on the recycling portion of this project. The consumption of gasoline, diesel, propane, asphalt and rejuvenator are included on Table 13. Except for the asphalt and rejuvenator, these quantities were converted to B.T.U.'s, with conversions established by the Asphalt Institute[1] as follows:

Gasoline	125,000 BTU/gal
Diesel	139,000 BTU/gal
Propane	91,000 BTU/gal
Fuel Oil #6	154,500 BTU/gal

Also included on this table is an estimated energy consumption for the two alternate procedures originally considered. The subtotaled energy values did not include either the energy required to manufacture or the intrinsic energy in asphalt and the rejuvenator. We did include the quantity used or the predicted quantity that would have been used with the alternate procedures.

As can be seen, the energy consumed with the recycling method was less than the estimated energy consumption for the two alternate methods. These alternates were estimates based on consumption of energy on the recycling job and could certainly vary with changes in operation. Method "B" is by far the most expensive with respect to energy consumption; however, Method "C", to remove and replace the top 0.18 feet of asphalt concrete, could certainly run competition with the recycling method for the least amount of energy consumed.

Chemical Analysis

The primary reason for running the chemical analysis on this project was in an attempt to gain some knowledge on the characteristics of bitumen after rejuvenating and again after subsequent "re-aging", by other than the customary physical tests.

The method of analysis used was the original Rostler-Sternberg Analysis.[3] This analysis was the basis for and is similar to ASTM D2006-70. This method defines asphalt as consisting of six fractions or groups: Asphaltenes, Nitrogens (Groups I & II), first and second Acidaffins, and Paraffins. In brief, this fractionation is accomplished by precipitation with normal pentane and then successively with sulfuric acid of increasing strength. Separation of Nitrogen Groups I & II is accomplished by precipitation with hydrogen chloride gas.

The chemical analysis and physical testing on the pavement chunks, crushed stockpile material, mixes and cores were run on material recovered from solution using a modified Abson Recovery procedure, (WSHD #220A).

Asphalt samples were tested from several phases of the recycling project:

1. Asphalt recovered from pavement chunks.
2. Asphalt recovered from pavement chunks to which rejuvenator had been added.
3. Asphalt recovered from control samples of crushed pavement.
4. Asphalt recovered from mix samples from the field during actual construction.
5. Asphalt recovered from cores taken on completion of the lift of recycled pavement (before overlaying with the open-graded friction course).

Also tested were several rejuvenators submitted by manufacturers. The average test values from the chemical analysis can be found either separately on the appropriate tables or on Table 14. It should be noted that by virtue of the numbers being averages, they will not necessarily total up to 100 percent.

In addition, four cans of asphalt cement representative of the material used on the original Renslow to Ryegrass project (Contract 8086) were analyzed for comparison purposes. These samples were "refinery" samples which we requested from the refinery some years ago. The sample cans had been stored, unopened, in the laboratory until they were tested (Dec. 1977). The material, though not used on Renslow to Ryegrass, was representative of material supplied during this same time period to three other state construction projects. Sample dates were from 10/19/67 to 11/22/67. The 1967 asphalt was also analyzed after conditioning in the RTFC oven, again for comparison purposes. It was believed that the chemical analysis on the original 1967 material would be close to the "starting point", and the RTFC conditioned material, close to the properties immediately after construction (original construction). This is a bit subjective, but nevertheless, for comparison purposes, it is interesting. The average test values can be found in Table 14.

Conclusions & Comments

Recent literature[4] on recycling asphalt pavements indicate the ratio $(N+A_1)/(P+A_2)$ should be greater than 0.4 in the recycled mix. Other literature[5] shows ranges of $(N+A_1)/(P+A_2)$ ratios correlated to "durability" characteristics

$N+A_1/P+A_2$	Durability
less than 0.4	decreasing durability
0.4 to 1.0	superior
1.0 to 1.2	good
1.2 to 1.5	satisfactory
1.5 to 1.7	fair
greater than 1.7	inferior

Making the assumption that the chemical analysis results on the original 1967 asphalt are valid, it appears that the material started out in the "satisfactory" range and worked its way to the "good" range just prior to being recycled--a direct contradiction to the condition of the pavement. It is apparent that the Renslow to Ryegrass section of pavement did not deteriorate by any mechanism which is predictable by the chemical analysis method used.

Future Testing

Future testing will be similar to tests conducted on core samples immediately after construction. Cores will be removed from the pavement at approximately one- and two-year intervals and be tested for resilient modulus, then the asphalt extracted, recovered and tested. Tests on the recovered asphalt shall consist of penetrations at 39.2° F and 77° F, viscosities at 60° F, 140° F and 275° F, ductility at 45° F and 77° F, and chemical analysis.

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TABLE TITLES

Table 1 Materials Specifications

Table 2 Preliminary Testing of Pavement Chunks

Table 3 Preliminary Mix Design

Table 4 Preliminary Testing - Rejuvenators Plus Recovered Asphalt

Table 5 Preliminary Testing of Rejuvenators

Table 6 Control Samples of Old Asphalt Concrete - After Removal

Table 7 Job Mix Design

Table 8 Control Samples of Recycled Mixture

Table 9 Cores After Recycling

Table 10 Nuclear Density Test Data

Table 11 Pavement Ride Data

Table 12 Surface Friction Test Data

Table 13 Energy Analysis

Table 14 Chemical Analysis Data

MATERIALS SPECIFICATIONS

	Mineral Aggregate 5/8 - 1/4	Asphalt Concrete Class B	Asphalt Concrete Class E
Grading (% Passing)			
1 1/4 in.			100
1 in.			90-100
5/8 in.	100	100	67-86
1/2 in.	75-100	90-100	60-80
3/8 in.	---	75-90	---
1/4 in.	0-12	55-75	40-62
No. 10	---	32-48	25-40
No. 40	---	11-24	10-23
No. 80	---	6-15	6-14
No. 200	---	3-7	2-9
% Asphalt	---	4.0-7.5	3.5-7.0
Fracture (min.)	75%	75%	50%
Sand Equivalent (min.)	---	45	45
Degradation Factor (min.)	---	30	20

Table 1

PRELIMINARY TESTING OF PAVEMENT CHUNKS

Test	Average	Range
Gradation (10 samples)		
1"	100	100
5/8"	100	100
1/2"	99	99
3/8"	92	90-95
1/4"	73	68-76
10	38	36-40
40	19	18-21
80	12	12-13
200	6.1	5.7-6.6
Percent Asphalt	6.6	6.2-6.9
Abson Recovery (2 samples)		
39.2 F Pen.	6	5-7
* 77 F Pen.	15	14-16
60 F Viscosity (Poise)	1.7×10^9	1.3×10^9-2.1×10^9
140 F Viscosity (Poise)	33,283	28,897-37,669
275 F Viscosity (Cst)	926	902-950
45 F Ductility (Cm)	0.25	0.25
Chemical Analysis (6 samples)		
Asphaltenes	34.4	31.7-39.8
Nitrogens (GpI)	8.2	6.3-9.6
Nitrogens (GpII)	21.8	18.7-25.1
1st Acidaffins	6.5	5.4-8.6
2nd Acidaffins	21.0	16.4-24.4
Paraffins	7.4	4.1-11.8

* 12 samples

Table 2

PRELIMINARY MIX DESIGN

* Rejuvenator	0	1/2% Paxole	1% Paxole	1/2% Cyclepave	1% Paxole	1% Paxole
* 5/8 - 1/4 Aggregate	0	0	0	0	10%	20%
Grading (% Passing)						
5/8	100	100	100	100	100	100
1/2	100	99	99	99	99	98
3/8	96	97	94	95	91	90
1/4	82	81	78	81	73	72
10	50	49	48	49	44	42
40	25	25	25	25	23	21
80	17	18	18	17	16	14
200	9.9	10.7	10.8	10.4	9.2	8.5
% Asphalt	6.0	6.5	6.9	6.7	6.3	6.0
Hveem Stabilometer	26	17	11	15	15	30
% Voids	4.4	3.4	3.2	3.2	1.9	3.9
<u>Abson Recovery</u>						
77 F Penetration	16	25	46	30	45	45
140 F Viscosity (Poise)	37,700	9,320	3,770	8,640	3,392	3,446
275 F Viscosity (Cst)	1,060	568	352	511	352	361

* By weight of the old asphalt concrete.

Table 3

REJUVENATORS PLUS RECOVERED ASPHALT

Initial Tests	Recovered Asphalt	Recovered Asphalt Cement Plus: 20% Chevron Tempering Fluid	20% Cyclepave and 7% New Asphalt	49% Chevron Claso	22% Paxole and 7% New Asphalt
39.2 F Pen.	6	33	25	17	30
77 F Pen.	15	81	71	43	80
60 F Visc. (Poise)	1.7×10^9	2.5×10^7	3.1×10^7	8.7×10^7	7.9×10^7
140 F Visc. (Poise)	33,283	1,674	1,802	4,341	1,614
275 F Visc. (Cst)	926	275	261	374	240
45 F Ductility (Cm)	0.25	60+	60+	6.75	60+
77 F Ductility (Cm)	---	60+	60+	45.0	60+
Chemical Analysis					
Asphaltenes	34.4	29.9	28.3	28.1	26.5
Nitrogens GpI	8.2	8.5	7.1	7.2	7.0
Nitrogens GpII	21.8	19.6	18.6	19.3	24.4
1st Acidaffins	6.5	6.8	11.7	8.2	8.8
2nd Acidaffins	21.0	25.9	25.2	28.2	24.6
Paraffins	7.4	9.4	8.5	9.0	8.6
RTFC Conditioned					
% Loss	---	4.6	1.8	0.85	2.6
39.2 F Pen.	---	12	15	10	15
77 F Pen.	---	20	37	23	37
60 F Visc. (Poise)	---	1.4×10^8	4.7×10^7	4.8×10^8	7.9×10^6
140 F Visc. (Poise)	---	25,162	5,654	15,993	4,678
275 F Visc. (Cst)	---	885	448	676	402
45 F Ductility (Cm)	---	0.75	7.75	4.5	10
77 F Ductility (Cm)	---	29.75	60+	60+	60+
Chemical Analysis					
Asphaltenes	---	33.2	30.0	29.7	28.6
Nitrogens GpI	---	4.4	7.4	2.2	2.8
Nitrogens GpII	---	25.2	21.6	22.0	25.6
1st Acidaffins	---	7.6	8.2	9.2	7.4
2nd Acidaffins	---	20.8	24.0	27.0	20.2
Paraffins	---	8.6	8.0	9.9	14.2

Table 4

PRELIMINARY TESTING OF REJUVENATORS

Test						Control Samples Cyclepave	
Chemical Analysis	Paxole 1009	Chevron Tempering Fluid	Witco Cyclepave	Chevron Claso	Witco Cyclegen M	#1	#2
Asphaltenes	0.3	9.0	0.7	11.9	4.0	0.2	0.1
Nitrogens (GpI)	3.4	4.4	6.6	1.8	13.0	---	0
Nitrogens (GpII)	21.4	11.4	8.6	16.0	17.2	14.1(N_1+N_2)	13.3
1st Acidaffins	28.6	19.6	16.6	18.2	13.6	14.9	9.5
2nd Acidaffins	45.4	35.2	45.2	42.8	32.6	48.1	50.2
Paraffins	1.1	20.0	22.1	9.4	19.9	22.7	26.9
140 F Kinematic Visc. (Cst)	229	101	118	---	2,876		
Flash Point (C.O.C.) (°F)	430	275	420	625	505		
210 F Saybolt Visc. (S.S.U.)						78	84

Table 5

CONTROL SAMPLES - OLD ASPHALT CONCRETE
AFTER REMOVAL

Test	Average	Range
Gradation (18 samples)		
1"	100	100
5/8"	100	100
1/2"	100	99-100
3/8"	96	95-98
1/4"	84	77-88
10	45	40-52
40	21	19-26
80	15	12-17
200	8.5	6.6-10.2
Percent Asphalt	6.2	5.3-7.2
Abson Recovery (3 samples)		
39.2 F Pen.	7	5-8
* 77 F Pen.	15	10-17
60 F Visc. (Poise)	1.2×10^9	9.5×10^8-1.6×10^9
* 140 F Visc. (Poise)	30,521	21,563-50,910
275 F Visc. (Cst)	966	828-1155
45 F Ductility (Cm)	0.25	0.25
77 F Ductility (Cm)	53.0	11.0-90.0
Chemical Analysis (3 samples)		
Asphaltenes	33.3	31.5-34.2
Nitrogens (GpI)	4.4	1.2-6.1
Nitrogens (GpII)	25.5	23.4-28.2
1st Acidaffins	5.7	2.2-7.7
2nd Acidaffins	19.9	18.2-22.0
Paraffins	11.2	9.0-13.8

* 16 samples

Table 6

JOB MIX DESIGN

Point	* % New Aggregate 5/8-1/4	** % New Asphalt AR-4000W	*** % Rejuvenator Cyclepave	Average Stability	Average Cohesion	Average % Voids
1	0	0	0	37	350	6.8
2	0	0	20	5	285	3.6
3	10	2	20	11	535	2.9
4	15	2	20	10	340	2.3
5	20	2	20	13	355	2.1
6	25	2	20	18	380	3.0
7	30	2	20	28	365	2.9

* % by wt. of old asphalt concrete.
** % by wt. of new 5/8-1/4 aggregate.
*** % by wt. of the asphalt in the old asphalt concrete assuming 6% asphalt.

Table 7

CONTROL SAMPLES - RECYCLED MIXTURE

Test	Average	Range
Gradation (28 samples)		
1"	100	100
5/8"	100	100
1/2"	97	95-99
3/8"	84	76-89
1/4"	65	54-70
10	37	33-40
40	19	17-20
80	14	13-15
200	8.4	7.8-9.1
Percent Asphalt	5.6	4.8-6.6
Hveem Stability	19	9-32
Cohesion	343	170-580
Percent Voids	2.2	0-4.2
Sand/Silt Ratio	4.4	4.0-4.6
Resilient Modulus (18 samples)		
0.05 Sec. (P.S.I.)	1.3×10^6	1.4×10^5-2.7×10^6
0.10 Sec. (P.S.I.)	8.4×10^5	1.2×10^5-2.0×10^6
Abson Recovery (3 samples)		
39.2 F Pen.	19	18-21
* 77 F Pen.	48	32-60
60 F Visc. (Poise)	6.2×10^7	5.3×10^7-7.2×10^7
* 140 F Visc. (Poise)	3,894	2,466-7,408
275 F Visc. (Cst)	365	332-403
45 F Ductility (Cm)	24.3	18.0-30.0
77 F Ductility (Cm)	60+	60+
Chemical Analysis (6 samples)		
Asphaltenes	30.7	25.2-34.6
Nitrogens (GpI)	4.6	2.8-6.2
Nitrogens (GpII)	22.5	20.6-25.0
1st Acidaffins	5.8	4.0-10.9
2nd Acidaffins	22.3	20.5-23.4
Paraffins	14.3	12.5-15.2

* 27 samples

Table 8

CORES - AFTER RECYCLING

Test	Average	Range
Gradation (24 samples)		
1"	100	100
5/8"	100	100
1/2"	98	94-99
3/8"	87	76-90
1/4"	68	56-72
10	38	31-42
40	20	17-22
80	15	12-16
200	9.4	7.8-10.2
Percent Asphalt	5.7	4.8-6.2
Sand/Silt Ratio	4.1	3.8-4.3
Density (P.S.F.)	147.2	140.3-151.0
Percent Voids	6.6	4.1-11.0
Resilient Modulus (24 samples)		
0.05 Sec. (P.S.I.)	4.7×10^5	3.0×10^5-6.1×10^5
0.10 Sec. (P.S.I.)	3.1×10^5	2.0×10^5-4.5×10^5
Abson Recovery (5 samples)		
39.2 F Pen.	20	16-22
* 77 F Pen.	58	40-75
60 F Visc. (Poise)	5.7×10^7	1.6×10^7-7.7×10^7
** 140 F Visc. (Poise)	2,900	2,057-5,338
275 F Visc. (Cst)	349	313-374
45 F Ductility (Cm)	32.6	24.0-46.75
77 F Ductility (Cm)	60+	60+
Chemical Analysis (5 samples)		
Asphaltenes	30.2	29.6-31.6
Nitrogens (GpI)	4.4	3.7-5.3
Nitrogens (GpII)	21.5	20.1-22.2
1st Acidaffins	5.4	4.2-6.2
2nd Acidaffins	23.0	20.9-25.9
Paraffins	15.5	14.3-17.1

* 24 samples
** 29 samples

Table 9

NUCLEAR DENSITY TEST DATA

	Eastbound		Westbound	
	Lane 1	Lane 2	Lane 1	Lane 2
Nuclear Density (Troxler Backscatter)				
Average	144.1	146.6	146.6	148.8
Range	140.3-152.7	141.6-152.9	140.1-152.7	142.8-157.0
% Voids (Calculated from Rice Density)				
Average	8.4	6.9	6.9	5.5
Range	3.0-10.9	2.9-10.0	3.0-11.0	0.3-9.3

Table 10

*PAVEMENT RIDE DATA
AVERAGE VALUES

	Before Recycling	After Recycling	After O.G.A.F.C.
Eastbound	476	470	220
Westbound	449	422	197

O.G.A.F.C. = Open-Graded Asphalt Friction Course

* Cox Modified PCA Roadmeter

Table 11

*SURFACE FRICTION TEST DATA
AVERAGE VALUES

	Immediately After Recycling	Immediately After O.G.A.F.C.	Two Months After O.G.A.F.C.
Eastbound	43	36	52
Westbound	48	33	50

O.G.A.F.C. = Open-Graded Asphalt Friction Course

* Lock-wheel testing in accordance with ASTM E-274-77.

Table [illegible]

[illegible]

	[illegible]		Alternate B (0.35-ft Overlay)		Alternate C (Remove & Replace 0.15 ft)	
	[illegible] Quantities Gallons	BTU x 10^7	Estimated Quantities Gallons	Estimated BTU x 10^7	Estimated Quantities Gallons	Estimated BTU x 10^7
[illegible]						
[illegible]						
Diesel	[illegible]	[illegible]	---	---	2,974.0	41.3
Gasoline	[illegible]	[illegible]	---	---	1,483.2	18.5
Hauling						
Diesel	[illegible]	[illegible]	---	---	2,846.8	39.6
[illegible]						
Diesel	[illegible]	[illegible]	---	---	319.2	4.4
[illegible]						
[illegible]	[illegible]	[illegible]	12,050.0	167.5	4,255.0	59.1
[illegible]	[illegible]	[illegible]	20,120.0	279.7	7,101.0	98.7
[illegible]	[illegible]	[illegible]	2,000.0	25.0	705.0	8.8
[illegible] + New						
Diesel	[illegible]	[illegible]	1,705.0	23.7	600.0	8.3
Propane	[illegible]	[illegible]	99,400.0	904.5	34,982.0	318.3
[illegible]						
Diesel	[illegible]	[illegible]	7,340.0	102.0	2,583.1	35.9
Gasoline	328.4	4.1	932.0	11.6	328.4	4.1
[illegible]						
Diesel	[illegible]	[illegible]	3,027.0	42.1	1,065.0	14.8
Gasoline	[illegible]	[illegible]	670.0	8.4	235.7	2.9

[illegible]

	Alternate A (Recycling 0.15 ft AC)		Alternate B (0.35-ft Overlay)		Alternate C (Remove & Replace 0.15 ft)	
	Actual Quantities Gallons	BTU x 10^7	Estimated Quantities Gallons	Estimated BTU x 10^7	Estimated Quantities Gallons	Estimated BTU x 10^7
Complete Mixture						
Laydown						
Diesel	270.0	3.7	768.0	10.7	270.0	3.8
Gasoline	578.2	7.2	1,644.0	20.6	578.2	7.2
Hauling						
Diesel	1,789.4	24.9	5,087.0	70.7	1,789.4	24.9
Gasoline	114.9	1.4	327.0	4.1	114.9	1.4
Rolling						
Diesel	243.0	3.4	690.0	9.6	243.0	3.4
Gasoline	165.2	2.1	470.0	5.9	165.2	2.1
Heating Fuel						
AR-4000W (Diesel)	800.0	11.1	800.0	11.1	800.0	11.1
Rejuvenator (Diesel)	1,700.0	23.6	---	---	---	---
Hauling Fuel (Est.)						
AR-4000W	58.5	0.8	6,318.0	87.8	2,223.0	30.9
Rejuvenator	705.0	9.8	---	---	---	---
*Subtotal		626.2		1,785.0		739.5
Asphalt (AR-4000W)	7.50 Tons		2,690 Tons		946 Tons	
Rejuvenator (Cyclepave)	143.51 Tons		---		---	

*NOTE: The subtotaled energy values do not include either the energy required to manufacture or the intrinsic energy in the asphalt and rejuvenator.

Table 13

CHEMICAL ANALYSIS DATA
(All Results are Averages)

Chemical Analysis	Original 1967 Asphalt	1967 Asphalt RTFC Conditioned	Pavement Chunks	Crushed Stockpile Material	Mix Control Samples	Core Samples
Asphaltenes	21.0	25.4	34.4	33.3	30.7	30.2
Nitrogen (GpI)	9.5	9.9	8.2	4.4	4.6	4.4
Nitrogen (GpII)	25.1	25.4	21.8	25.5	22.5	21.5
1st Acidaffins	10.6	6.6	6.5	5.7	5.8	5.4
2nd Acidaffins	21.3	21.6	21.0	19.9	22.3	23.0
Paraffins	12.5	10.8	7.4	11.2	14.3	15.5
$(N + A_1)(P + A_2)$	1.34	1.25	1.29	1.17	0.93	0.81

Table 14

FIGURE TITLES

Figure 1	Viscosity blending chart to determine quantity of rejuvenator
Figure 2	Schematic of the asphalt concrete plant operations

RENSLOW TO RYEGRASS
RECYCLING PROJECT
CONTRACT 0758

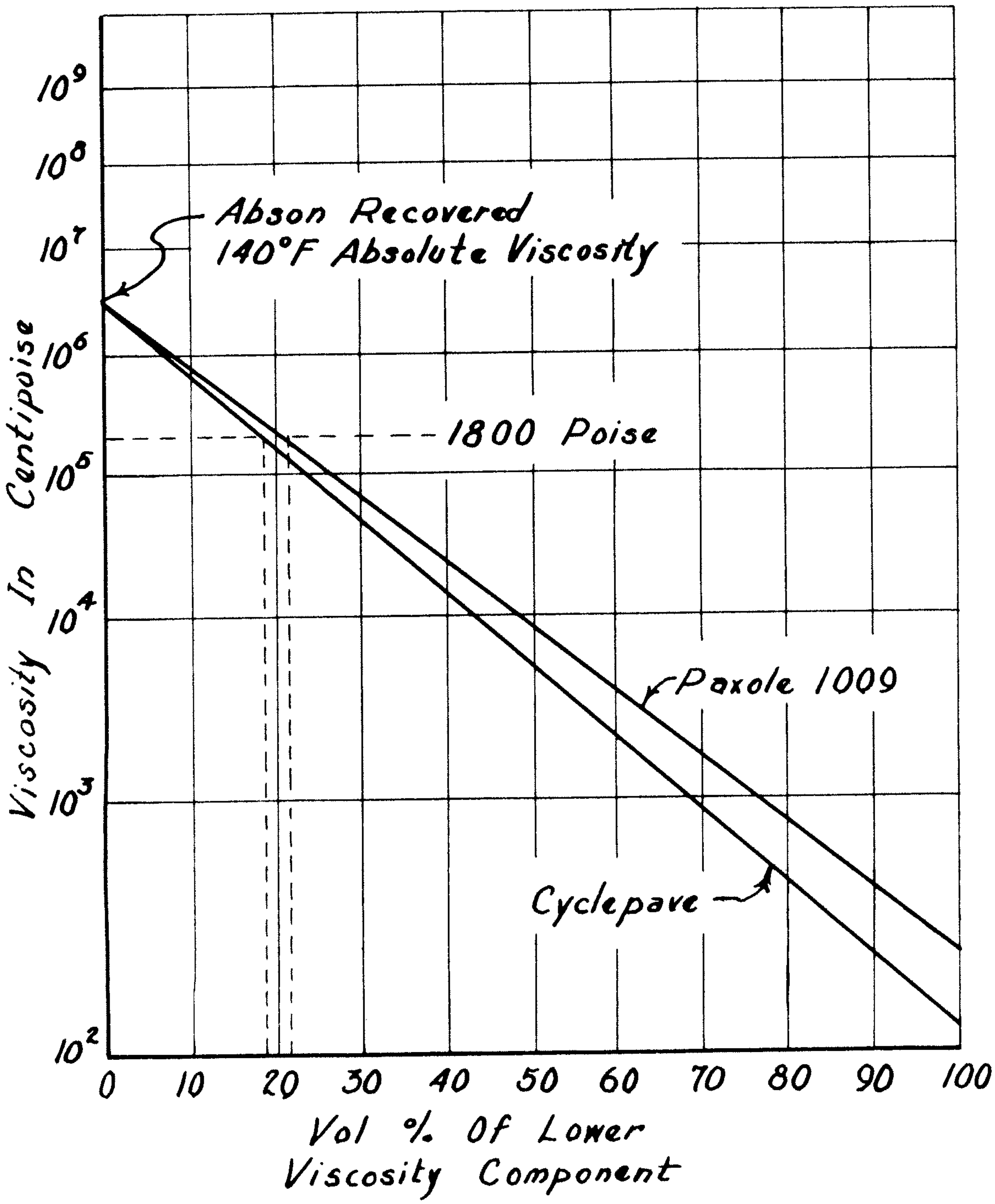
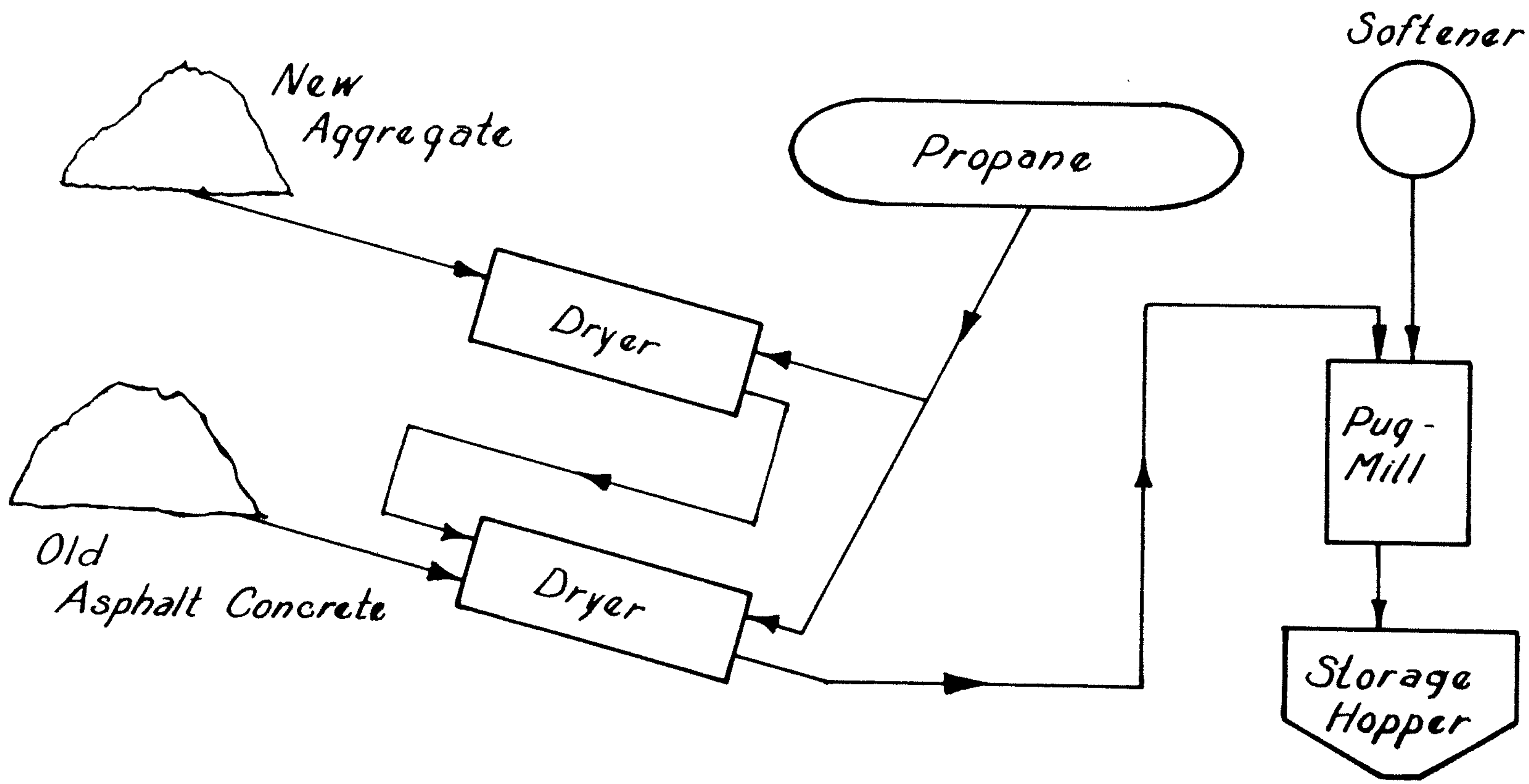


Figure 1

R. V. LeClerc, R. L. Schermerhorn,
and J. P. Walter

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION
Materials Testing Laboratory
Renslow To Ryegrass Recycling Project

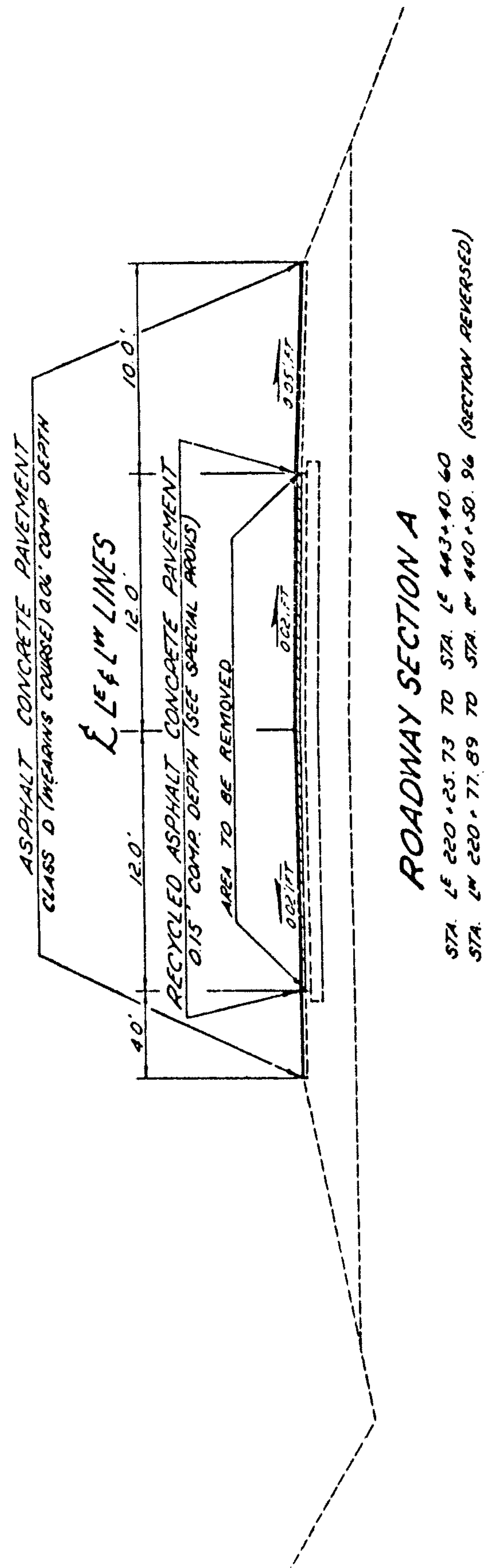


Schematic Of Plant Operation

Figure 2

APPENDIXES

Appendix A	Contract provisions pertaining to the recycle portion of this project, including basic roadway section
Appendix B	Air Pollution Report


ASPHALT CONCRETE PAVEMENT
CLASS D (WEARING COURSE) 0.06' COMP DEPTH
℄ LE & LW LINES
10.0'
12.0'
12.0'
4.0'
RECYCLED ASPHALT CONCRETE PAVEMENT
0.15' COMP. DEPTH (SEE SPECIAL PROVS)
AREA TO BE REMOVED
0.05'/FT
0.02'/FT
0.02'/FT
ROADWAY SECTION A
STA. LE 220+25.73 TO STA. LE 443+40.60
STA. LW 220+77.89 TO STA. LW 440+50.96 (SECTION REVERSED)

AIR POLLUTION REQUIREMENTS

Variance Schedule

1. All plans and specifications in the project shall be followed, unless specific authorization for deviation is received from the Engineer in writing.

2. This variance shall be effective from July 18, 1977 until November 1, 1977.

3. The variance shall be governed as follows:

   a. The most restrictive of,

      (1) Four (4) consecutive days at the start of operation in which the opacity and grain loading of the emissions may exceed 20% opacity and 0.10 grain per dry standard cubic foot.

      (2) By 3,000 tons of total production the opacity must be below 40% and by 5,000 tons of total production the opacity must be below 20% and the grain loading below 0.1 grain per dry standard cubic foot.

   b. The Central Regional Office of the Department of Ecology shall be notified immediately of any breakdown or upset in the plant operation. The notification shall include the time the breakdown or upset occurred, the anticipated time of restart, and the nature of the upset or breakdown.

   c. During the first 30 minutes of operation each day and after each breakdown, the plant is allowed to exceed the opacity and grain loading regulations.

4. This variance applies only to the emissions from the rotary drum mixer. Any dust emissions from crushing or materials handling operations is required to be minimized as the project will be located in a sensitive area.

5. All pollution control equipment shall be properly operated and maintained.

6. Source testing of the stack emissions from the plant shall be done at least 3 times during the life of the project. One test shall be during the first 4 days of operation.

ENERGY CONSUMPTION

The Contractor shall maintain cost data and consumption quantities of the energy requirements (fuel, electricity, etc.) of the recycling process to compare energy usage to that of conventional construction.

Cost data and consumption quantities shall be furnished to the Engineer as they become available to the Contractor and shall include invoices, vouchers, etc. pertaining to the recycling portion of the contract.

Records shall be segregated for each operation as follows:

1. Removal of existing asphalt concrete pavement, hauling and stockpiling

2. Crushing, heating and blending with new aggregate

3. Processing in pug mill including addition of asphalt AR-4000W and plasticizing agent

4. Application of recycled asphalt concrete mix, to roadway including hauling and rolling

Costs to the Contractor for collecting and furnishing these cost data to the Engineer shall be considered incidental to other recycling operation bid items.

Water Source
There is no water source in the vicinity of QS-S-214. The Contractor shall make his own arrangements for a source of water.

All costs involved in the procurement of water (including any necessary permits) shall be considered incidental to and included in the various unit bid items of this contract.

MEASUREMENT OF ASPHALT IN ASPHALT CONCRETE PAVEMENT
Section 5-04.4 of the standard specifications is hereby supplemented by the following:

A source for production of aggregates for asphalt concrete pavement is furnished by the State, and if the Contractor elects to use this source, the quantity of asphalt to be paid for will be the actual quantity incorporated in the mix. If the Contractor elects to provide his own source in lieu of the State furnished source, the maximum quantity of asphalt to be paid for is limited to 7.5%, multiplied by the number of tons of mix produced for the entire project.

ASPHALT CONCRETE PAVEMENT ASPHALT CONTENT
The estimated asphalt content of the mixture (or mixtures) included in this project for this type of paving and referred to in section 5-04.2 of the standard specifications is as follows:

6.8% for asphalt concrete pavement class D

ASPHALT PAVER GRADE AND SLOPE CONTROL
In addition to the requirements of section 5-04.3(3) of the standard specifications, the ski-like arrangement shall be at least 40 feet long and shall be the multiple supported type having a minimum of 8 evenly spaced points in contact with the roadway. The ski will be subject to approval by the Engineer.

REMOVING ASPHALT CONCRETE PAVEMENT
As shown on the plans, the existing asphalt concrete pavement class B wearing course shall be removed, stockpiled in QS-S-214 for recycling as specified elsewhere herein under the heading RECYCLED ASPHALT CONCRETE PAVEMENT. The estimated average depth of the existing wearing course is 0.15 foot.

Prior to or during the removal of the wearing course, the Contractor shall make a neat vertical cut through the existing wearing course along the centerline and approximately 12 feet left and right of centerline so that neat vertical edges are obtained when the wearing course is removed. The depth of removal shall be such that the entire existing layer of wearing course is removed and the surface of the existing underlying pavement (leveling) course is roughened sufficiently to insure a bond to the new recycled asphalt concrete pavement.

Any damage to the existing asphalt concrete pavement below the existing wearing course to be removed, or the adjacent shoulder area, resulting from the Contractor's operations, shall be repaired by the Contractor to the satisfaction of the Engineer, at the Contractor's expense, prior to the opening of traffic.

All costs incurred by the Contractor for performing the aforementioned described work shall be included in the unit contract price per square yard for "Removing Asphalt Concrete Pavement".

RECYCLED ASPHALT CONCRETE PAVEMENT
This work shall consist of one course of recycled plant mixed asphalt concrete placed on the prepared surface in accordance with these special provisions and the applicable requirements of section 5-04 of the standard specifications.

The recycled asphalt concrete shall be composed of a mixture of the removed existing asphalt concrete pavement, additional mineral aggregate for class B 5/8 inch to 1/4 inch, plasticizing agent, and additional bituminous material. The several aggregate fractions shall be sized, uniformly graded, and combined in such proportions that the resulting mixture meets the grading requirements of section 9-03.8(6) of the standard specifications for asphalt concrete pavement class B or an approved job mix design determined by the Engineer.

The removed asphalt concrete to be recycled shall be crushed or processed to pass a 1 inch screen, heated and blended with new aggregate 5/8 inch to 1/4 inch, then processed in a pug mill where the asphalt AR-4000W and plasticizing agent are to be added.

It is anticipated that in order to meet the requirements of section 9-03.8(6) of the standard specifications for asphalt concrete pavement class B, mineral aggregate for class B 5/8 inch to 1/4 inch will have to be added at a rate of 10 percent to 20 percent by weight of the total mixture, and paving asphalt AR-4000W will have to be added at an estimated rate of 2 percent by weight of the added mineral aggretate for class B 5/8 inch to 1/4 inch.

Also, a plasticizing agent compatible with the new asphalt and recycled asphalt concrete will have to be added at an estimated rate of 1 percent by weight of the quantity of recycled asphalt concrete. The plasticizing agent shall be a material similar to Paxole or Cyclepave and shall have been used successfully on other recycling projects, and shall produce a final mix satisfactory to the Engineer. The plasticizing agent shall be introduced into the mix at the temperature recommended by the manufacturer.

Should the Contractor be unable to meet the air pollution requirements stated elsewhere in these special provisions the Engineer may terminate the contract or direct the Contractor to complete the contract.

The exact percentages of mineral aggregate, bituminous material and plasticizing agent to be added, and the temperature of the plasticizing agent shall be regulated as directed by the Engineer.

A job mix design will be prepared by the Materials Laboratory in Olympia when a representative quantity of crushed asphalt concrete and new mineral aggregate have been produced. Samples of the asphalt AR-4000W and plasticizing agent to be used by the Contractor will also be required for the mix design. A maximum of 5 working days will be required for the initial mix design, and the Contractor is advised that production of Recycled Asphalt Concrete may not commence until the job mix design has been established. It is the intent that only one source of asphalt AR-4000W and one source of plasticizing agent be used for this project. An additional 5 days for a new mix design will be required in the event of a change in source of these materials.

Satisfactory means, either by weighing or metering, shall be provided to obtain the proper amount of plasticizing agent in the mix. Means shall be provided for checking the quantity or rate of flow of plasticizing agent into the mixer.

The Contractor shall submit to the Engineer for approval his proposed method of storing, heating, weighing or metering, and adding the plasticizing agent to the mix prior to the start of plant production.

Measurement of the plasticizing agent will be by the ton with the quantity determined by deposits and withdrawals from storage tanks located explicitly for this project.

Measurement of the Mineral Aggregate For Class B 5/8 inch to 1/4 inch will be made at the time the material is placed in stockpile.

All costs to the Contractor for performing the work described herein shall be included in the contract price per ton for "Paving Asphalt AR-4000W", per ton for "Plasticizing Agent", per ton for "Recycled Asphalt Concrete Pavement Excluding Paving Asphalt", and per ton for "Mineral Aggregate for Class B 5/8 inch to 1/4 inch". No deduction will be made for the weight of liquid asphalt, plasticizing agent, mineral aggregate or any other component of the mixture.

ROUGHENING ASPHALT CONCRETE PAVEMENT

Prior to re-laying the recycled asphalt concrete pavement, the Contractor shall roughen the surface of the existing pavement upon which the recycled concrete is to be placed. The roughening shall be accomplished by an approved heater scarifier, an approved cold planer, or other equipment approved by the Engineer. The roughening shall be sufficient to insure a bond to the new recycled asphalt concrete pavement. Roughening accomplished during removal of the existing asphalt concrete pavement with equipment specified herein or approved by the Engineer will be accepted as fulfilling this requirement providing the roughened surface is acceptable by the Engineer just prior to relaying the recycled asphalt concrete pavement.

All costs to the Contractor for performing the aforementioned work shall be included in the unit contract price per square yard for "Removing Asphalt Concrete Pavement".

TACK COAT

A tack coat of CSS-1 shall be applied to the roughened surface prior to paving with recycled asphalt concrete. The rate of application shall be as directed by the Engineer.

ASPHALT RECYCLING - AIR POLLUTION VIEWPOINT

Alan Newman, Central Regional Office
Washington State Department of Ecology

During the summer of 1977, there were two paving contracts performed that involved the removal and relaying of an existing asphalt-concrete pavement. The first contract was let and administered by the Federal Highway Administration and involved 5.6 miles of SR 97, just south of the summit of Swauk Pass. The other contract was administered by the Washington State Department of Highways and involved 4.6 miles of eastbound and westbound lanes of I-90, just west of Ryegrass Summit.

In both paving projects, the pavement was removed from the roadway by CMI milling machines which removed the pavement to a specified depth and ground it to a specific maximum size in the process. The milling machines incorporate their own dust control system of water sprays. The sprays provide adequate dust control.

After being stockpiled, the two pavements that were removed for recycling exhibited different characteristics. The pavement at Swauk Pass compacted and became hard after a short period of time. The Swauk Pass pavement needed to be loosened by a bulldozer equipped with scarification equipment in order to make it loose enough to be handled by a front end loader. The pavement at Ryegrass compacted and hardened also, but was loose enough to be handled by a front end loader.

The Federal Highway Administration contract was executed by J. C. Compton of McMinnville, Oregon. They used a Barber-Greene DM 75 drum mix asphalt concrete plant to process the recycled pavement. The plant was essentially unchanged with the only major difference being an enclosed burner chamber such that no flame entered the drum. The pollution control equipment consisted of two low pressure drop venturi scrubbers in parallel, using a common stack. The water flow at the time of the source test was about 60 gpm, which I had raised to about 100 gpm the following day.

There was only one source test taken of this operation. The results of the test indicate that the plant was in compliance with the required particulate standard of 0.10 g/dscf, but an excessive amount of hydrocarbons were condensed out of the test samples. The excessive hydrocarbons caused a high opacity plume to be generated in the area of the plant that was occasionally visible from the highway and continuously from the air. The plume was extremely difficult to read because of the veering wind and "puffy" nature of the plume. No formal opacity readings were made because of the above difficulties, but when observed at the time of the source test, the plume opacity ranged from 20% to 100%, with most of the plume about 60% to 80%. A change in the plasticizing agent dropped the opacity to the 40% to 60% range.

I have several ideas about the origin of the hydrocarbon emissions from this plant. They are as follows:

1. The "youth" of the pavement removed and recycled. The hydrocarbon content was almost identical to what it was when it was originally placed; thus more was available to be volatilized.

2. The mixing of the recycled asphalt and cold new aggregate and its entrance to the drum in the hottest zone of the dryer (next to the burner).

3. The additive materials used.

4. The basic concept of a drum mix plant.

5. The need for more sophisticated emission controls to eliminate the hydrocarbons.

Of the above ideas, I believe that the most probable causes for the hydrocarbon emissions are a combination of items 1, 2, 3, and 4. The "youth" of the pavement means that the asphalt fraction still contained relatively large amounts of volatile hydrocarbons that had not yet been volatilized by natural processes while the pavement was on the road. Thus, the heat from the burner could be enough to volatilize those remaining in the pavement.

The effect of the high temperature in the drum on the plasticizing agent (a "light" oil composition) and the new liquid asphalt cannot be discounted as a contributor to the hydrocarbon emissions. The difference in plume opacity between using and not using the Standard Tempering Fluid (viscosity about SAE 10 weight) amounted to about a 10-20% decrease in opacity and 0.03 g/dscf in the amount in the stack. I have no data to confirm the supposition, but I believe that the use of Cyclepave (a viscosity about SAE 90 weight) as the tempering fluidin addition to providing an observed 20% reduction in plume opacity probably caused a reduction in the hydrocarbon emissions of about 0.02 g/dscf over the Standard Tempering Fluid.

The Washington State Department of Highways job was performed by Associated Sand and Gravel Company, Inc., of Everett. They used a 4000# Standard Steel batch plant with a model RA 15-40 Dustex bag house. The batch plant was adapted to recycling the old pavement by removing the aggregate screens and minimizing the number and amount of obstructions in the tower, adding a second drum dryer to the system to superheat the new aggregate, and using the main drum dryer to add some heat and mix the recycled material and hot new aggregate.

There were three source tests made at this plant. The first two tests were made while the plant was processing the recycled material, and the last test was done while processing a standard mix. The results of these tests in order are as follows: 0.520 g/dscf, 0.252 g/dscf, 0.560 g/dscf. All of the particulate levels were above the 0.10 g/dscf level they were to meet. There were about a dozen defective bags replaced between the first and second tests. No maintenance of the bag house was noticeable between the second and third tests.

There was essentially zero hydrocarbons collected in the two source tests during the recycle portion of the project. I believe that this stemmed from the manner in which the material was heated, the location where the new asphalt and oil additives were added to the hot recycled material, and the fact that the pavement was older and "dryer".

The third source test was done as a compliance test of the plant, which had never before been tested, and to determine what, if any, effects the recycled material had on the emissions. Because of the lack of maintenance to the bag house, any conclusion about what the effects the recycled material had on the plant stack emission is impossible to make. The fugitive emissions from stockpiles and materials movement were higher from the recycle job than the standard mix job. This is because of the need for two different stockpiles and loading belts to feed the two dryers.

For future projects that recycle asphalt pavement in this state, I make the following recommendations so that air pollution effects will be minimized:

1. Only pavements failing from age or brittleness should be recycled. This will minimize the production of hydrocarbons from the recycled pavement when it is heated.

2. New asphalt oil and additive oils should not be added in a region with hot air flows (such as in a drum mix plant). This will minimize the chance for the oils to become volatilized.

3. All permits and variances involved with future recycling jobs should be issued only to contractors so as to facilitate the serving of any enforcement actions needed. This will require that the agency letting the contract have the contractor selected and contract signed 30 days in advance of the date work is to start if no variance is needed, and 60 to 90 days in advance of the date work is to start if a variance is needed.

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