EXPLORATORY STUDY OF HOT-IN-PLACE RECYCLING OF ASPHALT PAVEMENTS VOLUME II

APPENDICES

by

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16. Abstract

Hot-in-place recycling (HIR) is a method for rehabilitation of asphalt pavements. Potential for cost savings and resource preservation are high because existing pavement materials are processed on-site, with only the addition of small amounts of recycling agent.

The Oregon Department of Transportation (ODOT) constructed HIR projects in 1992 and 1993. In September 1992, ODOT contracted with Oregon State University (OSU) to evaluate the HIR projects, synthesize existing information on HIR, and develop guidelines for HIR use. This report summarizes the information developed during the study:

a) Construction equipment used on ODOT HIR projects is discussed.
b) Field data from six HIR projects are presented.
c) Results of a limited laboratory investigation of HIR are presented.
d) Proper project selection was found to be extremely critical to HIR success. A selection procedure is presented.
e) Based on information from the field studies and a limited laboratory testing program, a recommended mix design procedure is presented.

This report is in two volumes. Volume I includes the body of the report, Volume II includes the appendices.

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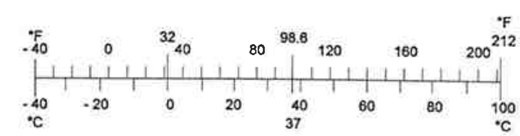
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

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



* SI is the symbol for the International System of Measurement

(4-7-94 jbp)

EXPLORATORY STUDY OF HOT-IN-PLACE RECYCLING OF ASPHALT PAVEMENTS VOLUME II

LIST OF APPENDICES

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APPENDIX B: MIX DESIGN PROCEDURES USED IN THE LABORATORY STUDY

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Appendix A

ODOT HIR CORRESPONDENCE

Cobine Memo on HIR Project Selection
Project Manager's Narratives for the Six ODOT HIR Projects
Letters and Memos Relevant to HIR in Oregon

STATE OF OREGON INTEROFFICE MEMO
DEPARTMENT OF TRANSPORTATION - OFFICE OF OPERATIONS 378-6528

FILE: CON

DATE: December 28, 1992

TO: Region Construction Engineers
District Managers

FROM: Wayne F. Cobine
Manager, Office of Operations

SUBJECT: Hot-in-Place Recycle (HIR) Projects
Recommended Selection Process

The 1992 construction season included several HIR projects. Some were successful, some were not, but we learned something from all of them. The continued successful use of this technology requires that we learn (as opposed to run) from our mistakes.

Based on our experience with HIR to date, we have the following conclusions and recommendations.

Conclusions

- Preliminary engineering to evaluate the suitability of a site for HIR and to develop the mix design was inadequate on all jobs in 1992.
- Heavily patched pavements with internal stripping and/or delamination in the top 3-4 inches are not good candidates for HIR. These pavements typically hold moisture and therefore require excessive heating, resulting in a brittle mix, low in asphalt which is very susceptible to raveling.
- Polution control is poor to marginal and the DEQ will not be as lenient in '93 as they were in '92 when examining this process.
- Adding material in one direction only results in a poor match at the meet line and affect drainage characteristics.
- Most of the projects hardened the asphalt.
- Sections of fairly uniform older pavement recycled well, with excellent bond between the recycled layers and the underlying asphalt concrete.

Region Construction Engineers
District Managers

Recommendations

- Perform the recommended minimum investigation prior to selecting a job for HIR or don't do HIR. Get help in examining job sites from Pavement Design and/or Operations and Materials. They are both very willing to help and will help you maximize the potential for success.

- Do enough coring on the job to assure that you do not have significant amounts of stripping and/or delamination in the top 3-4 inches of the mat. Log and photograph all of the cores and supply them to Materials for evaluation.

- Select sites in low population, rural areas where the potential smoke and polution problems will have minimum impact.

- Include a light fog or sand seal in the contract for jobs planned as a wearing surface. This will seal the surface and help minimize raveling.

- If it is your desire to add crown, then figure and include a bid item for added new mix. You will obviously need to add the mix in both lanes.

- Follow the attached sampling and testing protocol.

- Try to select jobs that performed well but are now wearing out due to age and – traffic, these "good old" pavements make the best candidates. Remember the GiGo principle (garbage in-garbage out) applies directly to HIR.

IJH:dp
regidist.ijh

Attachment

cc: Tom Lulay
Jim Huddleston
Tony George

PROPOSED SAMPLING AND TESTING PROTOCOL for HOT IN-PLACE RECYCLE PAVEMENTS

Prior to hot in-place recycling a pavement several important materials issues must be resolved. It is critical to know the grade of recycling agent we should use and an approximate addition rate. It is important to know if additional new aggregate or mix should be added to the existing mix. It is also important to know if we should add anti-strip additives to the recycling process.

We feel at this stage of implementing HIR that we should become familiar with performance properties of the mix also.

Reconnaissance of the proposed project is essential. It is important to identify broad variations in the pavement that will be recycled. These variations may include changes in original paving mix throughout the project, extensive patching, or areas of extensive stripping. Each area represented by a different material or different recycling situation should be sampled.

On-site observation by a knowledgeable person is best, both Pavement Design and Materials are available to assist in a reconnaissance.

SAMPLING PROTOCOL

We recommend that sets of four 6" cores be taken across the lane to be recycled. These sets should be unique to a lane even if two adjacent lanes will be recycled. This is because recycling passes will be discrete by lane. Hopefully Pavement Design and Materials will have the ability to designate sampling sites.

Each pavement condition, as described above, should have one or more sets of cores. In the absence of major changes in pavements, we propose a sampling frequency of one set of cores for every lane-mile. One additional core should be taken between each set of four to further evaluate stripping and delamination. These should be taken in the wheel track.

EVALUATION PROTOCOL

The pavement cores should be visually evaluated along with the site reconnaissance information to determine if the project is a good candidate. Special attention must be given to areas of delamination and/or stripping.

As noted previously, cores should be taken in the wheel tracks and in distressed areas to get a true representation of in-place conditions.

TESTING PROTOCOL

Based on a review of the cores and reconnaissance information the Materials group will select representative sets of cores for testing.

Each set of four cores make up one sample. Each sample selected will be evaluated for:

- In-place density and void percentage.
- Viscosity of existing asphalt.
- Gradation of the mix.
- Potential stripping of the mix.
- Stability of the mix.

These tests will tell us what recycling agent to include, if there are sufficient voids to allow additional recycling agent, if additional aggregate should be added to increase voids or stability, and if an antistrip agent should be added. Cost for testing each set of cores will be approximately $800. The amount of testing could be reduced based on initial test results.

This reconnaissance and sampling should be done prior to final site selection. Testing should be done before the Special Provisions are finished. This would allow for including the grade of recycling agent in the contract. This is important because the cost of recycling agents ranges from $150-$300 per ton. Early testing would also allow for including added aggregate and/or antistrip agents in the bid quantities. These should be included as anticipated items on all HIR projects.

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1/4/93
SAMP&TES

NARRATIVE
DISTRICT 13 HOT IN-PLACE RECYCLE (HIR)

OLD OREGON TRAIL M.P. 265.5 TO 272.1
WALLOWA LAKE HWY M.P. 0.16 TO 1.19
M.P. 2.66 TO 5.10

UNION COUNTY

PRIME CONTRACTOR: GORDON PAVING CO. INC.
TEMPORARY PROTECTION AND DIR. OF TRAFFIC: L&B CONTRACTING AND HORIZON FLAGGING.

START DATE: 19 MAY 1992
ENDING DATE; 19 JUNE 1992

Scope of Purpose of Project:
This project was made up of the ten foot shoulder along the Old Oregon Trail Freeway, (I-84), from M.P. 265.5 to 272.1 on both the East and West bound lanes, and the travel lanes of the Charles Reynolds rest area. The project also included the twelve foot travel lanes from M.P. 0.16 to M.P. 1.19 and M.P 2.66 to 5.10 on the Wallowa Lake Highway. These sections were badly deformed and deficient in strength. The section on the I-84 ten foot shoulder also showed some severe stripping of the old AC pavement. The purpose of the project is to correct these deficiencies.

Traffic Control:
Traffic control on I-84 was achieved by using temporary barrels and closing the 10 foot shoulder and right lane during construction with the use of a sequential arrow board. Flaggers were also used at interchanges. This method ran quite well and according to plan. Traffic control for the Wallowa Lake Hwy from M.P. 2.66 to 5.10 was accomplished by creating a one lane road around the equipment and using a pilot car to keep the flow of traffic and cut down on waiting time. When the HIR plant moved into the intersection of Hunter Lane and Wallowa Lake Hwy., traffic was detoured through on the Cove Hwy., and Pierce Lane. Hunter Lane traffic was detoured down Fruitdale Lane. As before this method was very effective. The Wallow Lake Hwy., section from M.P. 0.16 to 1.19 was controlled by routing traffic into the open lanes of the five lane road around the equipment. The use of roving flaggers at each business approach and intersection cut down the amount of traffic using the highway. By leap-frogging the flaggers, traffic was very effectively controlled. The intersections at Grande Ronde Mall and Cove Ave. - Monroe Street were temporarily placed on flashing yellow signals. Again traffic control went very smoothly.

Problems and Observations:The project was delayed and hampered by problems during the recycle process. Below is a breakdown of the observations made in the field during recycling of the old pavement.

Testing and Research: A major problem that occurred on the I-84 ten foot shoulder and M.P. 2.66 to 5.10 on the Wallowa Lake Hwy was the fact that not enough testing or research was incorporated into the project to determine the actual condition of the existing roadway material and underlying layers. There were two major problems caused by lack of research. In the 10 foot shoulder area the AC was stripped of asphalt content to the point that recycling the material did not produce a quality product within specifications. The second problem was that the existing AC was delaminated between layers of old overlays. The non-bonded sections of roadway would create a thin layer of stripped material made up of fine uncoated aggregate. This would mix with the recycled AC during the recycling process causing variances in the amount of oil needed for proper coating of the recycled material. This problem was increased on the Wallowa Lake Hwy section by a large amount of water between the delaminated layers causing the HIR process to falter due to lack of heat in the recycled mixture. The water acted as a thermal barrier between layers. Temperature differences of 20-30 degrees were noted behind the paver. Naturally this problem affected the ride of the finished product. The delamination problem was found when grinding began. Previous core drilling did not show the delamination.

Weather Conditions: During the construction process, weather hampered the contractor periodically throughout the job. The contractor lost approximately one week of work due to inclement weather. Wind and rain were the main cause of time lost on the job. The air temperature combined with a 15 to 30 mph wind dropped the temperature of the mix below specification causing a stop work order to be issued. The contractor was allowed to start work in the month of May when temperature variances and rain are quite frequent.

Design and Equipment Problems: From the start of the job to the completion of the HIR, the contractor was delayed by equipment failure. Total lost time was approximately two weeks. Much of this I felt was from lack of maintenance from various crew members on the HIR plant. I was informed that no maintenance was performed on the equipment during down time. A large part of the problem for the contractor was in the way the equipment was designed. The HIR plant consisted of three sections. The lead consisted of a preheater which was followed by a heater scarifier unit and then another heater scarifier unit. The last unit was pushed by a paver which was fed by a pugmill.

I felt that the biggest problem in the poor quality of the ride was that the number three machine was pushed by the paver. This caused a problem with the ride because the grinder would stop if it cut deeper than one and three-quarter inches. When the grinder stopped the paver tracks would come off the ground causing a hump in the paving panel.

Another problem with the design was the pugmill setup. The paddle setup for the pugmill at the start of the job was inadequate. The pugmill did not get proper mixing of the recycled material. This was evident by uneven temperatures in the mat behind the paver.
A third problem that occurred involved the automatic leveling devices for the paver. The contractor never had the automatics up and running on both sides at any one time. This was due to constant breakdown and lack of support from the producer.
The last problem that affected the ride of the product was the amount of depth that the machinery could grind effectively. The job specifications called for a two inch grind. As stated previously, during operation of the HIR mill at this depth the machinery would slow down or bind up to the point of detriment of the product and machinery. This was also caused by the type of material being ground and the delamination of the pavement. During inspection of the process it was noted that the best operating depth was one and three-quarter inches.

Temperature: One of the greatest concerns on the project was the temperature of the mix at lay down. The temperature varied considerably on the mat due to several problems. The main cause of temperature drop was the delamination problem and the water trapped between layers. Another problem causing temperature changes was the speed at which the contractor moved during operation. Optimum temperatures were not maintained if the contractor was allowed to operate too fast. Specifications for temperature of the material were stated as: "The heated and scarified material shall have a temperature in a range between 230-degrees F and 290-degrees F as measured immediately behind the scarifier. The Engineer will select the temperature within these limitations, and the mixture shall not vary from this selected temperature by more than 23-degrees F and shall remain within the above limits." The specifications further stated: "The combined material shall be thoroughly mixed and then automatically fed into the asphalt concrete paver which will spread and strike off the material to the required thickness, grade and cross-section at a minimum temperature of 230-degrees F." Temperature ranges behind the scarifier were consistent. However, temperatures behind the paver varied from 180-degrees F to 270-degrees F. Again this was mostly due to the areas of delamination but colder weather would affect the material to a lesser extent. A good quality product was achieved at a temperature of 220-degrees F.

Recycling Agent: The amount of recycling agent incorporated into the product varied according to the amount of asphalt in the existing material. The recommended amount of RA-25 in the mix was too high. The Pyro-Paver representative set the amount of agent added to give a quality product. The amount of agent still has to be monitored due to different amounts of asphalt in patch jobs or older chip seals.

HIR Freeway Shoulders

In addition to the problems detailed above, the viscosity of the oil in the freeway shoulder recycled mix was a problem. The old AC was very hard and brittle, and although the recycling agent did improve this some, it was not enough to dispel concerns over thermal cracking. Also, the shoulders were in very poor shape and there was a lot of concern about safety of the motoring public.

Since the HIR process was not producing a satisfactory end product, it was decided by the Project Manager and Region to make a change. The old pavement was removed by cold planing. The chips were hauled by Maintenance Forces to a State stockpile and stored for use elsewhere. A new mat of Class "B" AC was then inlaid to form a smooth, safe freeway shoulder. A contract change order was prepared to reduce the quantities of HIR and recycling agent and the monies saved, plus the contingencies, were used for the cold planing and class "B" AC.

Conclusion: In conclusion I would stress the following proposals:

1. HIR work should not be allowed to start prior to the month of June. This would increase the chances for favorable weather and a higher quality product.
2. Change the design of the machinery so that the paver is independent of the rest of the unit. This would help the quality of the ride.
3. Maintain the temperature specifications as they are written but instill more caution into inspectors during HIR process for weather conditions, existing AC material and speed of the HIR process.
4. Put more research into the proper amount of recycling agent used in the HIR process.
5. Put more research into sections of highway that are to be recycled. This would include more extensive core drilling and testing of existing material.

I believe that the HIR process will be beneficial to the department if the above problems can be solved. The process is more economical and efficient when running smoothly, than previous methods. I can also see a large advantage in using the process for pre-level courses.

C11176

CLEAR LAKE - OLD MCKENZIE HWY
August 27, 1992

NARRATIVE

SCOPE

Located on HWY 126 from MP 3.6 to MP 19.81, this project was classed as surface preservation consisting of a nominal 2" full-width grindout and repaving of the existing A.C. surface. The existing roadway was very rutted and showed extensive cracking due to extreme freeze-thaw conditions. Much of the existing pavement was covered with maintenance blade patching. The pavement was replaced using a four component hot-in-place recycle system designed and manufactured in Canada by Pyro-Tech Inc. This is a relatively new procedure for Oregon.

CONSTRUCTION

The contractor was J.C. Compton from McMinnville, OR. The subcontractor for the recycle work was Pacific Pavement Recycling from Seattle, WA. Work began at MP 18.4 with a test grind approximately 750 feet long in the southbound lane. The recycle equipment was new, delivered directly from the manufacturer to the project. About eight days were lost due to equipment breakdown, two of which were due to problems with the paver. The contractor's original schedule showed 26 days. The project took 57 days to complete which exceeded the specified completion time by 12 days. One day was given on CCO 3 for an extra pass of recycle at Sahallie Falls access road. Approximately 10 days were lost to rain or wet conditions.

The four component recycle system works as follows: 1) a pre-heater unit heats the surface of existing asphalt to about 300 degrees insuring to a depth of at least 1" to 1-1/4". 2) the "A" unit follows with another heating unit and a 12-foot wide grinder. The grinder removes the first inch of pavement. The "A" unit also adds a specified percentage of rejuvenating agent [WITCO RA 25] to the grindings. This mixture is placed in a windrow at a temperature of 235-290 degrees. 3) "B" unit follows closely behind, and similar to the "A" unit, carries a heating unit and a second 12-foot grinder that removes another inch of pavement. 4) These two windrows are combined into one, picked up by a paddle conveyor and dropped into the hopper of a standard paving machine. "A" unit is self-propelled but the "B" unit is pushed by the paver. If the existing asphalt needs to be augmented, new virgin mix can be added to the process by either a hopper on the "B" unit or by dumping directly into the windrow between the "A" and "B" units. This was not necessary on this job.

All heating is done with propane-fired infrared heaters. A mperature of 200-230 degrees was maintained behind the screed of the paver, and the mix was compacted using two tandem steel rollers. Experimentation was done by varying the amount of RA-25, roller patterns, and other equipment changes. These are documented and noted on the as-constructed plans and will be evaluated to provide information for future projects.

DESIGN AND CONSTRUCTION PROBLEMS

The biggest unknown on this job was the add rate for the rejuvenating agent for the changing AC conditions. With the extensive patching done to the existing surface, the laboratory could only determine a beginning percentage from the core samples. Based on the amount of rejuvenating agent needed to achieve desired viscosity, the "mix design" called for 0.7% to 1% RA 25 by weight. The project began with 0.7% but it soon became evident that the mix would go to zero voids and probably flush. The mix slumped in the windrow at this add rate. The percentage was lowered to 0.5% on the average with minor adjustments based on field conditions. The need for a lower rate was confirmed by the Pyro-Tech personnel and their experience with the product.

Acceptance of compaction was by roller specification with a pneumatic breakdown roller required. However, the surface was subject to "picking" with the pneumatic. Varying the ballast, heat and pattern did not seem to decrease the problem. Breakdown by the pneumatic roller was discontinued. The steel-wheeled rollers produced an acceptable product with no apparent "tenderness", bridging, or tearing of the mat in high supers or steep grades.

Compaction tests were taken for informational purposes. These were taken at various locations along with corresponding samples of the mix. Hopefully this will give us a data base with which to design future mixes. However, a nuclear compaction specification may be difficult to achieve due to the variability of existing pavement. British Columbia does daily coring to check compaction.

The end product resembles a very fine "C" mix. The reason appears to be two-fold. There is a certain amount of breakage of the aggregates in the recycle process depending on the original quality of the rock. Also blade patches over the years used an old "C" mix design that is finer than current mixes. The net result gives a road surface that looks fine and slick. Skid resistance tests will be performed in the fall of 1992.

The recycle process works well at vertical grades up to about 10%. On steeper grades, the paver has difficulty pushing the "B" unit and tries to ride up causing ripples in the surface. To alleviate this problem on areas where grades exceeded 10%, the train was moved ahead, turned around, and ran downhill against traffic. This presented no serious traffic problems.

Except for some ripples, the ride is fairly good. With only a 2-inch treatment, there is no opportunity to take out any major irregularities. Between the grinding heads and the paver, though, wheel ruts and some super problems can be corrected. Additional corrective work can be done ahead of the process by blade patching.

BRIDGES

There were four bridges on this project. The three with asphalt surfaces were recycled with no difficulty. One bridge had a concrete surface. The recycling ended just prior to the bridge and continued after. The joints were sawcut and filled with a poured joint sealer.

TRAFFIC CONTROL

Temporary protection and direction of traffic was performed as a "moving" work zone configuration which allowed the "train" to move at it's average speed of 10 - 20 feet per minute. Signing was as per Dwg. 2202 of the plans for 2-way, 2-lane rural highways. A pilot car was used to move traffic safely through the work zone because of the many corners and narrow stretches of roadway encountered. Overall traffic control was very good with no problems experienced. Temporary signing was coordinated on a daily basis and the contractor did a good job organizing the flagging in a manner to provide a "non-stop" operation of the train. This surface compacts quickly allowing traffic to run on the surface within 30 to 40 minutes of lay down.

FIRE DANGER

The contractor chose to start the project early in the season to avoid the fire danger associated with late summer. This highway goes through National Forest land and the Forest Service was very concerned about the process particularly since major fires were burning in nearby Sisters. The recycle process is not a hazard but it does present the perception of a fire danger. In order to ease concerns, we agreed to take the precaution of watering down roadside vegetation when the fire danger reached Level 2 or higher.

The Forest Service also wanted the specifications on future projects through Forest land to contain excerpts from their fire protection codes. Although our contractor was cooperative and very attentive to the fire protection requirements, the Forest Service has had poor experiences in the past with contractors.

PROJECT COSTS

Construction cost for this project is $620,368.62. Estimated cost to do this project with a 2" "B" Mix A.C. overlay is $1,125,000. This represents a savings of approximately 45% over the cost of a conventional overlay process.

CONCLUSION

Overall the work was organized and proceeded well. The equipment suffered breakdowns and "new machine" bugs which marred performance. The finished product however, was a resurfaced roadway produced at a comparatively low cost and should function well. This process shows real potential for the future.

PROJECT MANAGERS CONSTR NARRATIVE
JUMPOFF JOE - N. GRANTS PASS
CONTRACT 11065
PACIFIC HWY JOSEPHINE COUNTY
LARRY CARSON, PROJECT MANAGER

On July 10, 1991, Contract 11065 was awarded to Hamilton Construction Company for construction of grading, paving, structures and signing. Construction work included raising two structures over the interstate. A Preconstruction Conference was held at the City of Grants Pass Conference Room on 7/17/91. The attached bar chart shows the sequence of the major items. Work began on 7/29/91.

20 Contract Change Orders were written:

CCO 2 was requested by the contractor to change the oil in the 'B' A.C. mix from PBA 2 to PBA 5.

CCO 3 was requested by the contractor to change the gradation spec on the 1/4-10 aggregate in the asphalt mix.

CCO 4 was written to change the method of measurement on the ditch linings from cubic yard to lineal feet.

CCO 5 was requested by the contractor to change the rock size from 1 1/2" to 3/4" in the structural concrete. Deck concrete remained at 1 1/2".

CCO 6 was written to change the 'B' A.C. inlay to an 'F' A.C. inlay.

CCO 7 was required to increase the temporary striping pay quantity.

CCO 8 was required to rotomill the existing paving to base paving elevation at each of the bridge ends.

CCO 9 was requested by the Oregon Fish & Wildlife Division to install a fish spawning area under the Jumpoff Joe Creek structure.

CCO 10 was required to extend 18" culverts at the Hugo overcrossing. Pipes were not shown on the plans.

CCO 11 was written to reconstruct several M-E inlets that were staked in error.

CCO 12 was required to construct a footing for approximately 100 feet of barrier.

CCO 14 was required to remove existing asphalt to base paving elevations at the Stage 2 bridge ends.

CCO 15 was required to reimburse the contractor for additional work involved in the uneven loading of Bent 5 at Highland Avenue.

CCO 16 was required to modify the bridge rail on Highland Avenue. Modification included dowel installation and stage construction.

CCO 17 was written to extend the stripe removal bid item.

CCO 18 was required to extend the flagger bid item.

CCO 19 was required to install mono-directional recessed pavement reflectors.

CCO 20 was requested by the contractor to change the method of measurement for the "F[illegible]h Latex" bid items to meter count.

Six Extra Work Orders were written:

EWO 1 was required to install drainage slots for the 'F' Mix inlay.

EWO 2 was required to repair eroded embankment slopes.

EWO 3 was required to do Class II preparation on the bridge decks.

EWO 4 was requested by the Region Geologist to place ditch lining and rock inlay at Bent 5, Joe Creek.

EWO 5 was requested by the State to repair damage to a beam on the Hugo overcrossing.

EWO 6 was required to grind a bump at Sta 113 Southbound beyond what was required of the contractor.

Three State Force Orders were written:

SFO 1 was for permanent striping.

SFO 2 was required to install "Building Better Roads" signs.

SFO 3 was required to install a traffic counter.

There were 12 adjustments:

Adjustments 1-6 were for asphalt escalation.

Adjustment 7 was a deduction for inadequate recycling agent.

Adjustment 8 was a deduction for the wrong recycling agent supplied.

Adjustment 9 was for On the Job Training.

Adjustment 10 was payment for pave bond added to the 'F' A.C. Mixture.

Adjustment 11 was a deduction for the expense of a State weigh witness supplied.

Adjustment 12 was written to reimburse the State for engineering costs involved in the Highland Avenue Bent 5 footing failure.

There were 9 subcontractors on this project:

Copeland Paving	TP&DT, Grading, Paving
Alexander-Martin	Guardrail
Genpave International Inc	Hot Recycled Asphalt
Triad Steel, Inc	Reinforcement
Foress Sign Company	Signs
Road Repair & Recycle Inc	Rotomill & Diamond Grinding
J.P. Construction	Flaggers
H2O Contractors	Temporary Striping & Stripe Removal
Anderson Erosion Control	Seeding & Mulching

There were Bid Item final quantities both under and over those originally estimated. None substantially affected the total project cost. However, the result was a cost underrun.

TEMPORARY PROTECTION & DIRECTION OF TRAFFIC: Additional TP&DT measures had to be provided for the shoulder widening at the bridge ends. Additional temporary barrier had to be provided to allow construction of the roadway widening. Extensive rotomilling had to be done at the bridge ends after the A.C. overlay was removed from the bridge decks. The existing travel lanes had to be tapered back from the bridges to allow traffic to descend approximately 4" to the concrete deck level. Due to the complexity of closing down two overcrossings, additional signing had to be provided to aid in the detour of traffic. Two flaggers were used at the paving operation with lane closures set in place proceeding the day's operations. The exception to the above was at the base of Sexton Mountain Pass, where 4 flaggers were used; 2 for slow down and 2 at the paving operation. A message board was also used at the summit.

ROADWORK: The embankment quantities for the shoulder widening at Joe Creek and Louse Creek were under estimated, causing an overrun of the embankment bid item. Josephine County Road Dept requested that we extend the roadwork on Highland Avenue approximately 200' on each end. Josephine County was billed directly by the contractor for the work outside our original project limits.

STRUCTURE: There were 4 structures widened and 2 structures raised. The bridge widenings proceeded well, with very few problems. The Hugo bridge raising went very well, with no significant problems. The Highland Avenue raising, however, had several major problem areas. The first was an uneven load which caused a redesign of the jacking plan. During the jacking, a footing failed at Bent 5. This failure required some substantial repair work, the cost of which was borne by the contractor. The bridge rail on Highland had to be redesigned to provide more support. Additional dowels were added and the construction was staged to prohibit the removal of all the rail at the same time.

ASPHALT PAVING: There was a problem getting a satisfactory "B" Mix design for the inlay work; therefore, a change order was written specifying an "F" A.C. inlay. The paving on Merlin Hill was done at night. While every effort was made to provide enough light to insure a satisfactory product, the end result was less than satisfactory. Many areas within the night paving operation had to be ground.

LATEX OVERLAYS: The latex overlays were done in two stages on each bridge. The exceptions were the Highland and Hugo structures, where the roadway was closed for the overlay work. The Hugo structure was done with a 9 sack mix. The bridge was re-opened to traffic after approximately 48 hours. There was some difficulty obtaining a strong enough mix design, but there were no problems encountered during the actual laydown operation. Strength tests were satisfactory. Due to the poor condition of the bridge decks, a considerable overrun of the latex quantities was necessary to build back a satisfactory grade.

HOT IN PLACE RECYCLE: Hot in Place Recycle is an experimental means of pre-heating an existing asphalt surface, milling it to a 2" depth and placing the mixture with a standard paving machine. A petrochemical rejuvenator is used to revitalize the mixture. The subcontractor was Genpave, a Canadian Company. The recycling was delayed while the company settled problems at U.S. Customs. Genpave had their Prepaving Conference on July 7, 1992 and began operations during the evening of the same day. They paved at night in the Merlin Hill vicinity, as specified. The remainder of the work was done during daylight. The Hot in Place Recycle was completed on July 26, 1992.

The first test sample of recycled mixture failed the viscosity requirement necessitating the need to take core samples for the first two miles of work. No conclusive data was received from the core samples. The first sample of rejuvenator failed. The State Materials Lab Report stated there appeared to be diesel in the mixture and not cyclogen "M" (RA25), the specified rejuvenator. The second sample of rejuvenator contained cyclogen "M" and passed specifications requirements. Certifications for cyclogen "M" were inadequate for the amount of rejuvenator used. Some non-spec cyclogen "L" was used, although the total of cyclogens "M" and "L" never equaled the amount used.
A price reduction of $27,065.81 was used for inadequate recycle agent adjustment and $916.00 for wrong recycle agent adjustment. These adjustments were necessitated due to not having enough certifications to cover the amount of rejuvenators used and the use of non-certified rejuvenators.

SAFETY: Numerous problems were encountered during the night paving operations, the lack of enough light to safely perform the operation being paramount. The travelling public seemed to be disoriented by the lights on the paving operation, with some motorists following the trucks into the paving line. Two contractor employees were injured during paving operations. One had two fingers severed when his hand got caught in a drive sprocket during the night Hot Recycle operation. The other employee was hit and seriously injured while setting cones on the centerline during the night paving. An employee of the bridge contractor was injured when he fell approximately 20' after he cut off the snap tie he was belted to. There were several motor vehicle accidents during the project. One was due to a truck being rear ended by a car when the truck stopped to view the operation. Another was when a tractor and trailer hit a car door as a passenger opened his door (hit and run).

During the second paving season, the paving crew and the State personnel experienced flu like symptoms when exposed to the heated A.C. mixture. The problem was traced to the Pavebond Additive to the oil. The contractor and State supplied respirators to the employees exposed to the fumes. Most of the contractors employees discontinued use of the respirators because of the excess heat and the lack of visibility. Several of the contractors employees have experienced some ongoing respiratory problems and have filed SAIF claims. State Materials Section is conducting a research project to see if the use of Pavebond is to be continued.

Another safety problem was the extreme fire danger. The Oregon Department of Forestry required two fire trucks on the project during recycle operations. One small fire was caused by the operator. There were also problems with the air emission controls working. The operation had to be shut down twice while the controls were fixed. The Grants Pass Fire Department called once, complaining of foul air.

STATE OF OREGON

INTEROFFICE MEMO

TO: John Scofield
Specifications Engineer

DATE: Jun. 3, 1991

FROM: Roger A. Miles
Pavement Design Group Leader

SUBJECT: Pavement Core Evaluation for
Jumpoff Joe - N. Grants Pass
Pacific Hwy No. 1
Josephine County

OREGON STATE HIGHWAY DIVISION
PROJECT MANAGER
RECEIVED
1991

Test results have been obtained for four locations on the subject project. The cores were evaluated for aggregate gradation, asphalt content, and recovered asphalt properties. As anticipated, the results for all four samples are very comparable. The test results for each individual sample are tabulated on the attached summary. However, for the sake of simplification, the average values are used for the following analysis. It is felt that neither accuracy or predictability are sacrificed by the use of averaged values.

In TABLE 1 the average gradation and asphalt content of the four samples are compared to those of typical, current "B" and "C" AC mixes.

SIEVE SIZE	CURRENT TYPICAL "B" MIX	AVERAGE CORE VALUES	CURRENT TYPICAL "C" MIX
3/4"	96	100	100
1/2"	80	92	98
3/8"	70	81	86
1/4"	57	66	62
#4	49	56	51
#10	28	35	29
#40	11	15	12
#200	5	6.0	6.0
ASPHALT CONTENT	5.5	6.0	6.0

TABLE 1

Comparison of Aggregate Gradations
and Asphalt Contents

As indicated in the above table, the gradation of the existing pavement is consistently finer than a typical current "B" mix and finer than a typical "C" mix below the 1/4" sieve. While no gradation analysis has been conducted yet, it's felt that some 3/4"-1/4" and a lesser amount of 1/4"-#10 would need to be blended into the mix to achieve something resembling a current "B" mix.

The addition of a reclaiming agent would add a minimal amount of residual asphalt (maximum 0.3%) and is felt to have negligible impact on the performance characteristics of the mix. Current design criteria call for a P #200/asphalt ratio of 1.2 or less. Assuming that the asphalt content were increased by the above mentioned 0.3 percent and the P #200 content was unchanged, the ratio would be 0.95, well within the acceptable range.

The average properties of the recovered asphalt compared to typical values can be found in TABLE 2.

	PROJECT CORES	NEW PBA-2 ASPHALT	TYPICAL 20 YEAR OLD ASPHALT
KINEMATIC VIS.	930	N/A	N/A
ABSOLUTE VIS.	14,350	4,000	100,000
PENETRATION	32	40	25

TABLE 2

Recovered Asphalt Properties vs.
Typical Asphalt Properties

As shown in the above table, the average penetration value for the core samples are slightly softer than what might typically be anticipated, but not unusually so. The absolute viscosity however, is substantially lower than would be normally be expected in a pavement of this age. It should be noted though, that typical absolute viscosity values for recovered asphalts can and do fall anywhere within a very wide range (10,000 - 200,000).

Considering the above data, the existing AC surfacing appears to be very uniform in all the properties evaluated. The gradation is finer than what would normally be designed today and the asphalt content is equal to or slightly higher than current standards. The asphalt binder is somewhat softer than might typically be expected in a pavement two decades old.

(JUMP2.MEM)

cc: Jim Bilderback, Region Geologist
Duane Christensen, Project Development Engineer
Tom Edwards, Roadway Design Supervisor
Jim Gix, Region Engineer
Rob Paul, Project Manager
Bill Quinn, Materials Engineer
Jack Sullivan, Roadway Engineer
Rob Paul, Project Manager

STATE OF OREGON

INTEROFFICE MEMO

C11065

TO: Robb Paul
Project Manager

DATE: June 26, 1991

FROM: Tony George, P.E. *Tony George*
Roadway Materials Engineer

SUBJECT: Evaluation of Bituminous Cores for Hot-Inplace Recycle, Jumpoff Joe Creek - N. Grants Pass Section, C11065

After reviewing the test data evaluated from the 6" bituminous cores, it appears this project is suitable for Hot-Inplace Recycle.

Four stations were evaluated for extraction and recovered asphalt. The test data indicates the pavement to be uniform in gradation, asphalt content, viscosity, and penetration. Having a uniform existing pavement will provide the contractor the best opportunity in a recycling effort.

Also, we have reviewed the data to determine the best recycling agent to use. It is our recommendation to use RA 25 for this project. By plotting on the average viscosities from the four selected sites, it appears the best starting percentage would be 5% by weight of binder. From this you can calculate the rate of addition in gallons per square yard.

This should provide us with a resulting mix that is completely rejuvenated, that will not have an excess of asphalt, and the compaction should resemble the existing mat in % voids.

If you have any questions about our decision, please feel free to call Dick Dominick or myself at 378-2621.

Attachment

PROJECT MANAGER
RECEIVED
JUL 1 1991

TG\DW:aw
TG\Paul.mem

cc: Bob Aldrich
Al Vohland

Oregon

DEPARTMENT OF TRANSPORTATION

Highway Division

December 2, 1992

FILE CODE:

Dr. David F. Rogge
Dept of Civil Engineering
Apperson 111
Oregon State University
Corvallis, OR 97331

David:

I'm sorry this is late but we just finished determining a price reduction on this work. The two reasons for the reduction was the contractor's use of cyclogen "L" (RA5) at the beginning when cyclogen "M" (RA25) was specified, and then the low application rate (average for job was .20% vs .35% that we specified).

I hope this information will help in the evaluation of this product. one thing to remember on this job is that we overlaid this with 2" of "F" Mix asphalt.

If you need any more information, give us a call and we will be glad to help in any way.

Yours truly,

Larry E. Carson
Project Manager

DWB:mh

C11036

TANGENT - HALSEY SECTION

ALBANY - JUNCTION CITY HIGHWAY

LINN COUNTY

SCOPE

This project was classed as a surface preservation consisting of a hot-in-place A.C. surface recycling of existing asphalt pavement on the Tangent - Halsey Section of the Albany - Junction City Highway (ORE 99E) in Linn County. The existing surface was old, weathered with longitudinal and transverse cracking between old maintenance patches and overlays, stripping and flushing. The lane width varied from 12 feet to 10.5 feet.

Miscellaneous work consisted of bridge sawcuts, the installation of bi-directional yellow type 1 pavement markers and the placing of shoulder aggregate. A stripping problem necessitated the addition of a sand seal.

The contract was awarded March 19, 1991 to Genpave International Inc., a Canadian firm with offices in Seattle, WA. The recycle portion of the work was completed on September 2, 1992. The work was started a year late by mutual agreement between the contractor and the State. The project finally began on August 3, 1992 with the recycle portion completed on September 2, 1992 and second notice issued on November 6, 1992 after the completion of the remaining work.

CONSTRUCTION

Work began at M.P. 8.08 with a test strip of approximately 700 feet in the southbound lane. The recycle equipment was 4 seasons old. About 8 work days were lost because of equipment breakdowns, 6 of which were due to emission control burnouts. Another day was lost to rain. The contractor's schedule indicated 12 days to completion; however, the recycle portion alone took 31 days to complete.

The recycle equipment consisted of a preheater and two heater/scarifiers manufactured by Pyrotech of Canada. The recycle mixture was laid with a standard Barbur-Greene paver. The preheater was a 26-foot trailered unit with propane-fired burners riding one foot above the pavement surface that heats the asphalt to about 280 degrees across a 12 foot width.

The preheater was followed by the first heater/scarifier, the "A" unit which is 57 feet long and self-propelled with infra-red heaters. The "A" unit heats the pavement surface to 300 degrees penetrating about one inch into the AC. The milling heads scarify off 1 to 1-1/4 of softened AC, windrow the material and add a 340-degree rejuvenating agent. The rejuvenating agent, RA-5, was metered as a percentage of the total asphalt mixture.

The "A" unit was followed by the second heater/ scarifier, the "B" unit. The "B" unit was 49 feet long and pushed by the paver. It picks up the windrow left by the "A" unit, transferred the material over its infra-red heater bank while heating and scarifying an additional 1 inch depth of pavement for a total of 2 inch depth of recycled mixture. The windrowed materials are collected and mixed, then conveyed to the hopper of the paver. The temperature range behind the screed of the paver was of 200 - 250 degrees.

Compaction on this project was accomplished with a pneumatic roller for breakdown followed by vibratory and static passes of a steel roller. Nuclear density testing was done only for information. Acceptance under the specifications was by visual inspection.

TRAFFIC CONTROL

Traffic control and signing was performed as per Dwg. 2202 and worked well. There was some initial reluctance from the contractor to follow these standards. Being from Canada, they were not accustomed to using pilot cars and had bid the item at $1.00 per hour. Once in operation, though, the British Columbian recycle crew was impressed with the degree of safety in the construction zone and the control over the flow of traffic created by using pilot car and flaggers.

DESIGN AND CONSTRUCTION PROBLEMS

Since hot-in-place recycling is a new process to Oregon, learning the process as well as some of the nuances to its performance on our roads with our asphalt products was necessary. In hindsight, there were problems that occurred that could and should have been answered in the design stage.

The primary question is the suitability of the road for the process. This section was one of the first to be scoped for recycling. However, the pavement was old and weathered with a large percentage of blade patching. The reasoning for choosing this section was to test the capabilities of the hot recycle process. The asphalt existing in the pavement was stripped and aged. What asphalt was present was partially burned up by the heaters, leaving less to be rejuvenated. The result was dry-looking mix which was vulnerable to the traffic picking out the fines. Some areas immediately began raveling and had to be patched back in with new mix.

The fix we used for the dry recycled mix was two-fold. First, virgin Class "C" AC was added by having a belly-dump truck inserted into the train between the "A" and "B" units. The new mix was added to the windrow at approximately 15% by weight, supplementing the asphalt content of the existing pavement for the northern 4.25 miles of the northbound lane. After the recycling was finished, we had the ravelled areas patched then added a sand seal to the entire project. A CSS-1 asphalt was used with just enough sand to blot the excess asphalt. This was to cap the surface and keep any potential problem areas from ravelling. The disadvantage of adding mix was that the additional material formed a longitudinal drop-off which required shoulder aggregate placement. It also created an uneven meet line at centerline. The sand seal seems to be performing very well, preventing what could have been a major loss of the recycled pavement.

A latent problem we discovered was that the pavement at the bottom of the blade patches had become stripped and delaminated. The scarifiers of the recycle equipment exposed sections or pockets of loose rock which in turn prevented the recycled mixture from bonding. These areas also ravelled out and had to be patched. In an effort to minimize the damage of exposing these loose pockets, we attempted to run thin in those areas and not open them up. However, the subsurface delamination was so random and hard to spot from the surface conditions that our efforts to miss them were only marginally successful.

Although cores and grindings were taken on this project during the location phase, they were used to ascertain the type of rejuvenator to be used and mix qualities. When a section of highway is being considered for recycling, we recommend that more extensive coring be done with particular attention to the subsurface qualities of the pavement. The ministry of transportation in Canada will core every quarter mile. Frequent coring would also give more complete information on the percentage of rejuvenator to add. Our add rates were approximate and had to be visually adjusted for the fluctuations in the existing pavement. This type of on-the-spot adjustment would still be necessary, but would help reduce the wide margin of "guessing."

The heaters and milling heads of these machines are set at 12 feet. Because much of the lane widths were less than 12, we had to reduce the scarifying path to eleven feet to accommodate the variable width of the roadway and to keep the meet line from occurring in the wheel track of the southbound lane. While the contractor could pull the outside teeth from the scarifier, the widths of the heater banks could not be reduced; therefore, the northbound lane from fogline to edge of pavement was subjected to the same intense temperatures of the heater banks as the travel lane. This heat aged the asphalt in the pavement needed for bonding the recycled mix to the existing pavement, causing transverse cracks at the fogline seam. It also resulted in a certain width in the center to be recycled twice. Obviously, highways with lane widths less than 12 feet are not good candidates for this process. Also, highways with no paved shoulder or a wandering edge of pavement will not obtain the best results from recycling.

CONCLUSION

In terms of how we like to see a project go, this one was less that successful. We had some significant problems to overcome. However, in terms of the dollars spent to achieve a significant extension of the pavement life versus the cost of overlay or reconstruction, we were very successful even with the added costs. And of course, in terms of the knowledge and experience we gained on hot-in-place recycling, this project was valuable.

When we as an agency experiment with new technologies, we need to carefully choose the candidates for the process. Recycling is not a miracle cure for 30-year old pavement well past its useful life. It is, however, an excellent cost-saving application to extend the life of fatigued pavement. The appropriate time to use the process, though, is when there's enough left in the pavement to save and there are no other problems like delamination or base failure. The natural reaction to apparent failures when trying a new technology is to withdraw from that process. I would urge that we not abandon the hot-in-place recycling technology. It has a very useful place in our arsenal of tools, and not just for base applications. With the knowledge we've gained on this and other recycle projects this year, we have the data to better apply this technology. Now we need the projects on which to use the knowledge we've gained.

Mary O. Martin Wright

NARRATIVE REPORT

DISTRICT 4 RECYCLE (1992)
CONTRACT NO. 11195

PURPOSE AND SCOPE

This project is part of District 4's surface preservation program. The purpose of the project was to extend the life of the existing pavement through hot in place recycling and to correct a number of encroachments in the clear zone.

Unit "A" is on Pacific Hwy. West. It begins a milepoint 86.23 (the southern terminus of the Marys River - Kiger Island Dr. project) and ends at milepoint 95.63 (the Bruce Rd. intersection). Total length is 9.4 miles. Unit "B" is on the Corvallis - Newport highway. It begins at milepoint 29.2 and ends at milepoint 31.40 for a length of 2.2 miles. This unit is a 3 lane section, encompassing the Cline Hill climbing lane and the tapers back to 2 lanes at each end.

AWARD

The project was awarded to Kiewit Pacific on May 14, 1992 for $521,929.00. Construction started on August 18, 1992.

CLEAR ZONE WORK

The contractor mobilized a small crew to take care of the clear zone encroachments on unit "A" prior to mobilization of the recycling train. Clear zone improvements included guardrail installations for box culverts and steep slopes and some culvert extensions. It soon became apparent that this work was added to the project late in the location phase with minimal research. Numerous problems had to be resolved by modifying the plans. Most were due to inadequate right of way, steep slopes where fills would not catch without increasing the embankment quantities 5-fold and incorrect pipe sizes. Solutions were; extra length guard rail posts, additional guardrail length, revised pipe order lists and modification of existing ditches. This work was completed on September 21, 1992.

RECYCLING

Specifications called for 2" deep hot in place recycling of the existing A.C. pavement on both units. Recycling was specified for the travel lanes only with no work on the paved shoulders. R.A. 25 rejuvenating agent was to be added at proportions as directed by the project manager. No seal coat was specified.
This was the 3rd hot-in-place recycling project this summer from this office. In view of problems on the Tangent - Halsey project, the project was reevaluated. More pavement cores were taken and studied. Unit "A" pavement is badly stripped, alligatored and shows signs of delamination between the layers. Unit "B" pavement

was in better condition, but showed some of the same problems to a much lesser degree. Recycling was deleted on unit "A" with a lump sum price agreement item to pay for the contractor's uncoverd mobilization costs.

The specified completion date for this project was August 31, 1992. The contractor informed us early on that his recycling train was tied up in Canada and that he would do the recycling in early fall under liquidated damages. Work in Canada took longer than expected. The recycling train finally arrived on unit "B" on Oct. 20, 1992.

The recycling was done with an "AR-TECH" recycling train. This train differs significantly from the "PYRO-TECH" train used on the 2 previous H.I.R. projects. It has only one grinding unit (PYRO-TECH has 2), but provides more heated stirring of the recycled material and runs the final product through a pugmill. The train operates as follows:
(1) a propane fired infra-red preheater heats the in-place a.c. pavement to a surface temperature of 300 degrees F. (a) the "A" unit supplies more infra-red heat to the pavement and mills out the heated pavement to the specified depth. (3) the "B" unit provides more infra-red heat with fixed offset paddles that stir the mix as they are dragged through it. The trailing end of the "B" unit picks up the milled a.c. and runs it through a pugmill. Rejuvenating agent is added in the pugmill. Application rate is computer controlled and set by the operator. The mix is discharged from the pugmill into a windrow. It is then placed with a conventional "pickup machine" paver. The remainder of the paving operation is conventional with final mat plaeced between 230 and 260 degrees. The mat was compacted with steel wheeled and pneumatic rollers. Compaction acceptance was by roller method spec. Informational nuclear density tests were taken, but results are questionable due to varying specific gravities throughout the roadway.

Recycling began on Oct. 21, 1992. Temperature was 55 degrees and the pavement was surface dry with substantial moisture content from rains that morning and the day before. The manufacturer of the train assured us that this was no problem, as the mix would be heated and stirred until the moisture is eliminated and this process also heats and drys the underlying surface that the mat will be bonded to. Initially this was the case. Recycling went smoothly, albeit somewhat slowly due to moisture and temperature. The completed mat resembled that on the Clearlake - Old Mckenzie Hwy. project. Rejuvenator rates were varied from 0.4 to 0.7 per cent. Application was adjusted to meet varying pavement conditions based on experience of the inspector and manufacturer. The inventor of AR-TECH was on site throughout the recycling operation. Work started in the eastbound lanes, proceeding westward against traffic. As the operation proceeded westward, we encountered a delamination between layers of existing pavement approximately 2 1/2" to 3" below the surface. With the milling heads set at the specified 2" depth, this left 1/2" of unmilled, unbonded material. This material would come loose in large blocks, plugging up the paver augers or floating free in the completed mat. The milling depth was lowered to 2 1/2" to try to chase this delamination layer. It was discovered that the depth of delamination was beyond the capabilities of the machine under these conditions. Additional problems made recycling more difficult. There was some minor stripping of the existing a.c, but not nearly as extensive as on the Tangent-Halsey project. The existing a.c pavement was rutted and had a 1" to 2" crown midway in each lane. Since the recycling operation puts back as much a.c as is milled out, use of all the material leaves us with 2 options: (1) crown the lane of the new mat or (2) pave the new mat on a plane surface and deal with the extra depth at the edges. We compromised and did both. There were some bonding problems at the edges of the recycled mat. They could probably be eliminated with a tack spray bar to treat the edges. This feature is not currently on any of the machines, but could easily be added.

At the end of the workday, Saturday Oct. 24, the contractor asked that we discontinue recycling due to problems arising from the delamination and the crown in the existing pavement. On monday. Oct. 26, Jim Huddleston visited the project and reviewed the situation. Recycling was discontinued with none of the westbound lane recycled and eastbound lanes done up to a point 3,500 ft. short of the west end of the project. A fog seal was added by price agreement to protect the recycled pavement.

CONCLUSIONS

The project underran the project authorization due to large blocks of deleted work. The liquidated damages more than offset the price agreement for uncovered mobilization costs. Deleted work makes cost comparisons questionable. Previous hot in place recycle projects have come in at approximately 65 per cent of the estimated cost of a conventional 2" a.c. overlay.
It is apparent that more research is going to be required in the scoping and location stages for these projects. The 2 cores per mile are not adequate to detect the problems encountered on this project.

The Transportation Ministry of British Columbia has considerable experience with this process. They cut cores with a frequency that picks up all visible changes in the existing mix. This allows for a more precise design of rejuvenator application rates and probably would have picked up the delamination problems on this project. They commonly apply an a.c. overlay or some sort of seal on recycled pavements. A fog seal should be specified for all recycle projects where stripping of the existing a.c. pavement is present.

It appears that this process has good potential to restore pavements at a relatively low cost, but it must be applied before the pavement is too far gone. I believe that it is in O.D.O.T.'s best interest to continue to utilize this process with more research in the location phase. A steady continued commitment will enable more contractors to compete in this field and allow manufacturers to improve the process. Both AR-TECH and PYRO-TECH are working on pilot models with numerous planned improvements.

Mary A. Martin Wright

DURKEE-LIME

PROJECT

HOT-IN-PLACE RECYCLED AC PAVEMENT

Gordon Paving, subcontractor from Burley, Idaho, began recycling operations on May 5, 1993 at "EB" Sta. 1202+91. Gordon Paving utilizes PyroTech and Artec recycling asphalt equipment. The recycle train consisted of Pre-heater unit, #1 Heater-Grinder unit, #2 Heater-Grinder unit, Post Heater unit, and Pickup-Paver unit.

Numerous problems were encountered during H-I-R recycle operations. The following is a list of these problems:

1. Inconsistent grinding depth that was corrected.
2. Moisture in pavement.
3. Variation in existing pavement.
4. Stop & go operations (paver) caused by mechanical breakdowns, too much moisture in mat which lowers mix temperature.
5. Too much adjusting of screed - some problems caused by insufficient amount of mix.
6. (As per contractor) Pneumatic roller leaving groves in pavement causing bad ride.
7. Inconsistent temperature in back of paver.
8. Ravelling problems caused by: Insufficient asphalt in mat? Insufficient rejuvenating agent added? Asphalt pavement heated too much or too little?
9. Lack of bond between existing mat and recycled material.

The worst area of pavement encountered to recycle was between Sta 1312 to Sta 316. The last major work in this area was on the Bubbs Ranch - Weatherby Section in 1970. The existing pavement

Durkee Interchange - Lime Section

was cracked, stripped in the underlying layer, lacked sufficient asphalt, and after recycling operations there was no bond between recycled pavement underlying mat in some areas.

Control strip method of compaction was run on H-I-R mixture. Due to the variation of pavement (three different paving projects, chip seal mats, cold mix patches) encountered the results shown on the compaction reports probably does not truly represent percentage of compaction achieved.

Oregon

DEPARTMENT OF
TRANSPORTATION

Highway Division
Project Manager

FILE CODE:

December 23, 1993

Dave Rogge
Depart of Civil Engineering
Oregon State University
Corvallis, OR 97331

Re: Durkee Interchange - Lime Section
Contract 11,170
Hot-in-Place Recycle

Dear Dave,

Per your request, please find enclosed a copy of the rejuvenating agent spread on subject project. The total quantity of RE-25 used on this project was 40.62 tons, but according to daily spreads the amount of reagent was calculated to be 54.56 tons. This discrepancy was probably due to incorrect meter readings.

The narrative report is not completed at this time. As soon as it is finished, we will forward a copy of the report to you.

Sincerely,

Bill Jacobsen
Assistant Project Manager

AT:sc

cc: Files

1508 East Idaho Ave.
Ontario, OR 97914
(503) 889-8558
FAX (503) 889-8568

Durkee Intchge - Lime Sec. RA-25 Spread.

Date.	Sta	Sta	Lin. Ft.	Sq. Yd	Gallons	Gal/Sq Yd	3.6814x Gal/Yd² %	Remarks.
								◯ Days Total.
5-12-93	EB 1331~	EB 1353~	2200	2,933	(200)	0.0682	0.25%	
5-13-93	EB 1363~	1384+35	2135	2847	308	0.1082	0.40%	
5-13-93	EB 1393+63	EB 1402~	837	1116	25	0.0224	0.08%	
5-13-93				3963	(333)	0.0840	0.31%	Ave.
5-14-93	EB Rt 1402+50	Rt 1407+50	500	667	5.5	0.0083	0.03%	
↓	1407+50	1412+50	500	667	16.5	0.0248	0.09%	
	1412+50	1414+20	170	227	16.5	0.0728	0.27%	
	1414+20	1418+50	430	573	18	0.0314	0.12%	
	1418+50	1432~	1350	1800	27.5	0.0153	0.06%	
5-14-93				3934	(84)	0.0214	0.08%	Ave.
5-18-93	Rt 129+25	Rt 140~	1075	1433	(38)	0.0265	0.10%	Usage from Meter.
5-20-93	145 Rt~	173 Rt~	2800	3733	(242)	0.0648	0.24%	
[illegible]1-93	173 Rt~	Rt 178+50	555	733	(66)	0.0900	0.33%	
[illegible]4-93	139 Rt	147 Rt	800	1067	(34)	0.0319	0.12%	
[illegible]24-93	178+50 Rt	229+50 Rt	5100	6800	(131)	0.0193	0.07%	
[illegible]-25-93	229+50 Rt	283+69.06 Rt	6607	8810	(617)	0.0700	0.26%	
"	284+61.65 Rt	296+50 Rt						
5-26-93	296+50 Rt	298+50 Rt	200	267	(41)	0.1538	0.57%	?
5-27-93	301~ Rt	317+25 Rt	1625	2167	(147)	0.0678	0.25%	
5-27-93	332~ Rt	342+50 Rt	1050	1400	(30)	0.0214	0.08%	
6-4-93	411+50 Rt	415+50 Rt	400	533	(28)	0.0525	0.19%	Exp. to see if mix changes - No effect Noted.
6-10-93	600~ Lt	595+50 Lt	450	600	(55)	0.0900	0.34%	
6-14-93	Lt 595+50	521+65	7145.4	9946.5	(573)	0.0600	0.21%	
6-15-93	Lt 521+65	457+60	6318.8	8425.1	(400)	0.0475	0.17%	
6-16-93	Lt 454+75	420~	3475.0	4633.3	(200)	0.0432	0.16%	
6-17-93	420~ Lt	385+50 Lt			( )			
"	Lt 383+70	379+83.37	8629.7	11,506.27	(525)	0.0456	0.17%	
"	379+08.08	366+40						
6-17-93	363+25	337~						
6-[illegible]-93	337~	330~	700	1829.4	158	0.0864	0.32%	
6-[illegible]-93	324+72.[illegible]	318~	672					
6-[illegible]-93	[illegible]	[illegible]	800	1066.7	265	[illegible]	0.9[illegible]%	
[illegible]-93	310~	[illegible]	700	933.3	105	0.1125	[illegible].41%	
6-18-93	302~	[illegible]	[illegible]	[illegible]	345	[illegible]	[illegible]%	
6-18-93					(873)			

34-3049 (Rev. 2-79)
…GON DEPARTMENT
OF TRANSPORTATION

TABULATION SHEET

SHEET .... OF .... SHEETS

…rkee Intchge - Lime

$3.6814 \text{ gal}/\text{yd}^2$

Date	Sta.	Sta	Lin Ft	Sq. Yd	Gallons	Gal/Sq Yd	%	Remark
6-19-93.	277~ Lt	212~ Lt	6500	8666.7	1725	0.1990	0.73	12'/min. max. spec.
6-21-93	212~ Lt	166+60 Lt	4540	6053.3	1162.5	0.1920	0.71	
6-22-93	166+60 Lt	1457~	7764.1	10,352.2	1900	0.18	0.68	
6-23-93	1457~ Lt to	1377~	7840.0	10,453.4	2210	0.21	0.78	
6-24-93	1377~ Lt to	1311+50 Lt	6481.2	8641.6	1375	0.1591	0.59	End green pavement
6-24-93	1311~ Lt to	1296+50 Lt	1500.0	2000.0	220	0.11	0.41%	End of oi supply

RA-25 8.26 lb/gal Assume A.C. 148#/ft³.
12' Panel 2" Depth.

For 100' Length Total wt/100' = (2/12)(12)(100)(148) = 29,600#.

	% RA-25		
Salem.	1.04 %	2.3 lb/Sq.Yd	0.28 gal/Sq.Yd.

For 100' run. 2" depth 12' panel.

.5%	=	148.7 lb.	=	18.0 gal.
.4%		118.9 lb		14.4 gal.
.3%		89.1 lb		10.8 gal.
.2%		59.3 lb		7.2 gal.
.1%		29.6 lb		3.6 gal.

For #/100'
$29{,}600y = x - xy$
$y = \%$ $x = \#/100'$

For gal./100'
$x/8.26 = \#$ of gal.

.6%	178.7	=	21.6
.7%	208.7	=	25.3
.8%	238.7	=	28.9
.9%	268.8	=	32.5
1.0%	299.0	=	36.2

Appendix B

MIX DESIGN PROCEDURES USED IN THE LABORATORY STUDY

Laboratory Method for

Preparation of Test Specimens of Reclaimed Asphalt Pavement (RAP) Mixtures by Means of California Kneading Compactor

Modified AASHTO DESIGNATION: T 247-80
(ASTM DESIGNATION: D 1561-81a)

1. Preparation of Test Specimens

1.1 *Preparation of Mixture* - Prepare the RAP/virgin mix mixture in accordance with the modified AASHTO T 246 procedures presented below.

1.2 *Size of Specimens* - The size of specimens to be tested with the Hveem apparatus shall be in accordance with the requirements of Method T 246.

2. Procedure

2.1 *Temperatures* - Use the four following specified temperatures in compacting the bituminous mixture:
2.1.1 141 C (285 °F) for heating rejuvenating agents and asphalt cements.
2.1.2 116 C (240 °F) for typical dense-graded RAP mixtures for approximately 2 hours prior to mixing.
2.1.3 163 C (325 °F) for the virgin aggregate.
2.1.4 149 C (325 °F) for the mixed RAP/virgin mix prior to compaction for 45 ± 15 minutes.

2.2A *Mixing 100% RAP Specimens* - Place approximately 1,200 grams of the RAP in a 9" by 13" metal pan. (See Figure B-1) The RAP should be spread evenly throughout the pan to optimize heating. The pan should be covered with aluminum foil and placed in the 116 C (240 °F) oven approximately 2 hours prior to mixing. (See Figure B-2) The rejuvenating agent (for RAP) should be heated to 141 C (285 °F) for mixing. While the RAP is heating, occasionally stir/breakup larger chunks to facilitate absorption of rejuvenating agent by RAP. For 100% RAP specimens, the specific mixing sequence is:

1) Place pre-heated mixing bowl on top of scale. Tare the scale. Remove the RAP from the oven, dump into mixing bowl, record the weight, and re-tare scale. Add design quantity of rejuvenating agent. (See Figure B-3) Mix for approximately 3 minutes. (See Figure B-4)

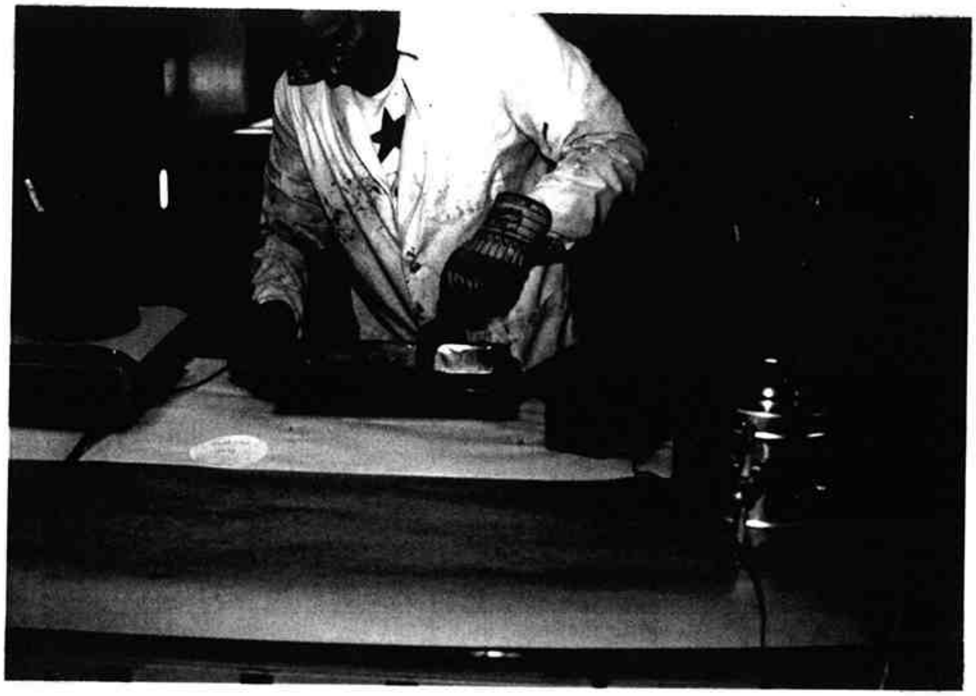

Figure B-1 Spreading the RAP in the pan evenly to optimize heating.

Figure B-2 Covering the RAP with aluminum prior to heating.

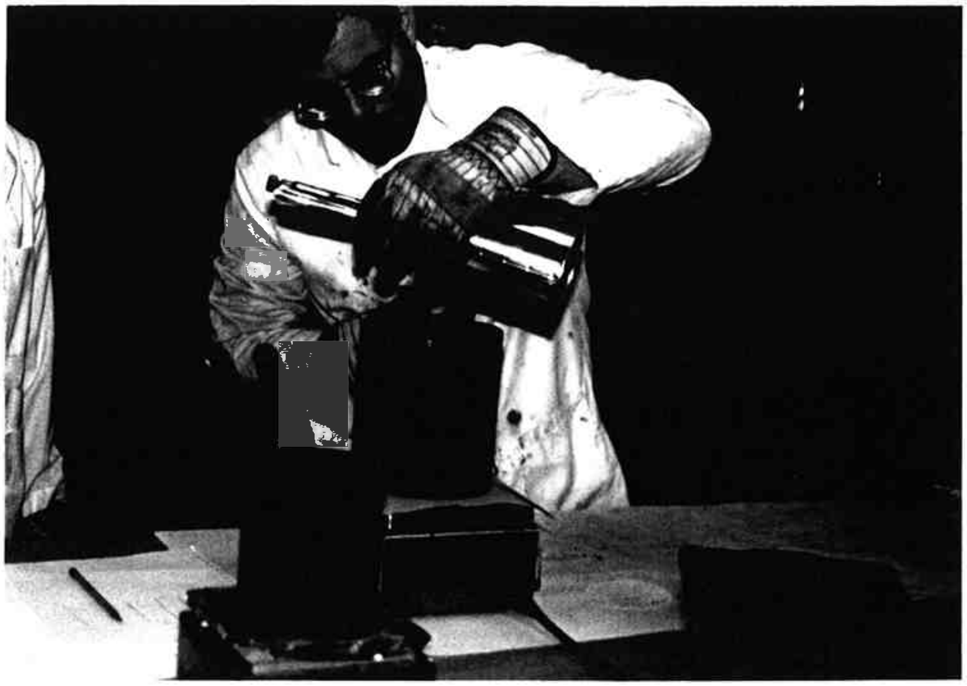

Figure B-3 Adding design quantity of RA.

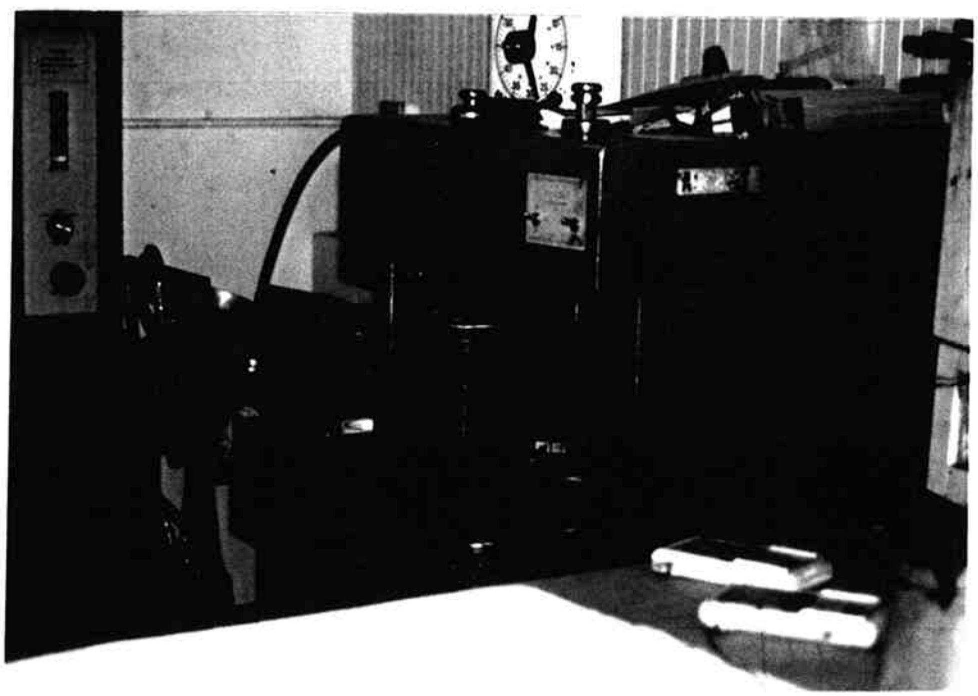

Figure B-4 Mixing the RAP and RA for three minutes.

2) After mixing is completed, place mixture back into 9" by 13" metal pan, cover with aluminum foil, and heat at 149 C (300 °F) for 45 ± 15 minutes.

2.2B *Mixing RAP/Virgin Mix Specimens* - For 80% RAP/20% virgin mix, place approximately 225 grams of virgin aggregate in a 163 C (325 °F) oven for approximately 15 hours prior to mixing. Place approximately 960 grams of the RAP in a 12" by 17" metal pan. The RAP should be spread evenly throughout the pan to optimize heating. The pan should be covered with aluminum foil and placed in the 116 C (240 °F) oven approximately 2 hours prior to mixing. Both rejuvenating agent (for RAP) and asphalt cement (for light coating of virgin aggregate) need to be heated to 141 C (285 °F) for mixing. While RAP is heating, occasionally stir/breakup larger chunks to facilitate absorption of rejuvenating agent by RAP. For mixing RAP/virgin mix specimens, the specific mixing sequence is:

1) Place pre-heated mixing bowl on top of scale. Tare the scale. Remove the virgin aggregate from the oven, dump into mixing bowl, record the weight, and re-tare scale. Add quantity of asphalt cement visually to lightly coat the aggregate. Record quantity of asphalt cement added. Mix for approximately 3 minutes.

2) Place second pre-heated mixing bowl on top of scale. Tare the scale. Remove the RAP from the oven, dump into mixing bowl, record the weight, and re-tare scale. Add design quantity of rejuvenating agent. Mix for approximately 3 minutes.

3) Add virgin mix into mixing bowl with RAP. Mix for approximately 2 minutes.

4) After mixing is completed, place mixture back into 9" by 13" metal pan and heat at 149 C (300 °F) for 45 ± 15 minutes.

NOTE 1 - The mixtures and molds shall be brought to 149 C (300 °F) prior to molding operations.

2.3 *Molding Specimens* - Place the compaction mold in position in the mold holder and insert a paper disk, 102 mm (4 in.) in diameter, to cover the base plate of the mold holder. Place a steel shim under the edge of the mold temporarily in order to have the base plate of the mold holder act as a free-fitting plunger during the compaction operation. Weight out the required amount of bituminous mixture for one specimen at the specified temperature and place in the insulated feeder trough, which shall have been preheated approximately to the compaction temperature for the mixture. Spread the mixture uniformly on the feeder trough to ensure uniformity when transferring to the mold. By means of a paddle of suitable dimensions to fit the cross section of the trough, push one-half of the mixture into the mold. Preheat the round-nose rod. Rod the one-half portion of the mixture 25 times; 15 times around the edge by means of the round-nose rod and the remaining 10 at random over the mixture. (See Figure B-5) Transfer the remainder of the sample to the mold and repeat the rodding procedure. Place the mold and assembly into position on the California kneading compactor. By means of the variable transformer controlling the heater, maintain the compactor foot sufficiently hot to prevent the mixture from adhering to it. Apply approximately 20 tamping blows at a pressure of 1.7 MPa (250 psi). (See Figure B-6) The number of tamping blows will vary, depending upon the type of the mixture, the purpose being to form the mixture into a semi-compacted condition so that it will not be unduly disturbed by the full pressure of 3.4 MPa (500 psi). After semi-compaction has been accomplished remove the shim and release the mold-tightening screw sufficiently to permit free up and down movement of the mold. Increase the compactor foot pressure to 3.4 MPa (500 psi) and apply 150 tamping blows to complete compaction in the California kneading compactor.

2.4 *Visual Evaluation of Asphalt Content* - At the termination of the 150 compacting blows the sample shall be observed for any indication of bleeding. (See Figure B-7) Such evaluation will be useful in estimating the percent voids filled with asphalt.

The visual observation shall be classified according to the amount of surface asphalt present and shall be stated in terms of the following abbreviations:

0....If the surface is sweaty with asphalt.
1....If asphalt has lightly coated the surface to a glossy finish.
2....If asphalt has puddled to the size of a dime.
3....If the puddle is the size of a quarter.

In addition, the use of + or - marks will aid in making a better estimate of the voids filled.

2.5 *Application of Static Load* - After compaction in the California kneading compactor, apply "leveling off" load as follows:

The "leveling off" load shall consist of the application of a static load of 6.9 MPa (1000 psi) in a compression testing machine. (See Figure B-8) Apply the lad by the double plunger method in which metal followers are employed as free-fitting plungers on the top and bottom of the specimen.

Figure B-5 Rodding the mix prior to compaction.

Figure B-6 Compaction with California kneading compactor.

Figure B-7 Visual inspection of compacted specimen for flushing.

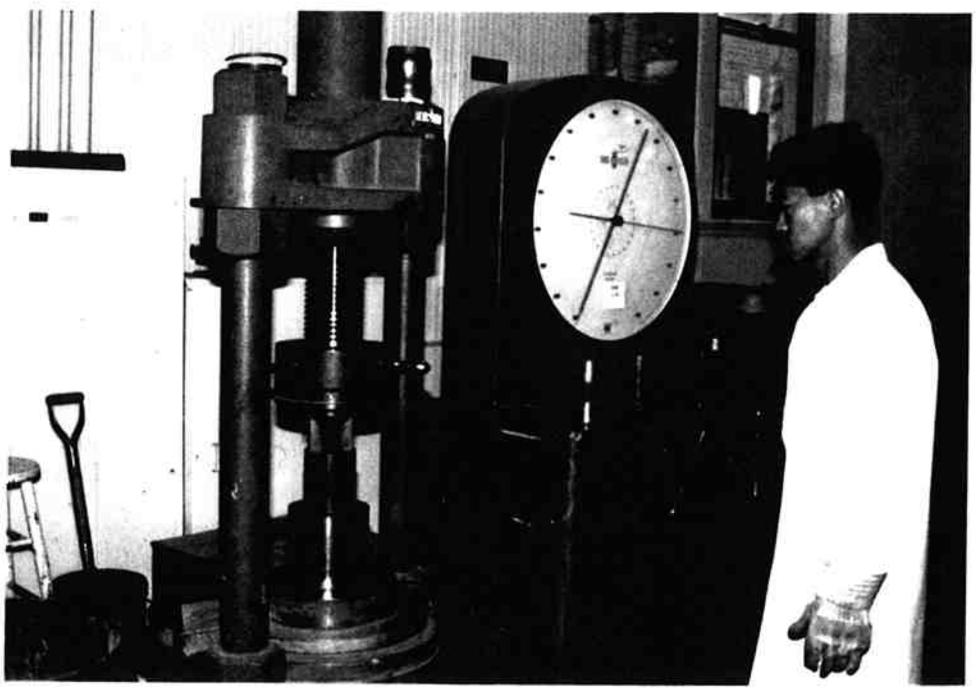

Figure B-8 Applying "leveling off" load to specimen after compaction.

2.6 *Curing to Reduce Variability* - After releasing the "leveling off" load, place specimen (in mold) in 60 C (140 °F) oven in order in reduce variability. After curing is complete, let cool to room temperature before extruding specimen.

3. REPORT

3.1 The report shall include the as mixed quantities of RAP, rejuvenating agent, virgin aggregate, and asphalt cement.

Appendix C

LABORATORY TEST RESULTS

Index of Retrained Resilient Modules
Air Voids and Unit Weight
Hveem Stability
Index of Retrained Strength
Fatigue Life

TEST SPECIMEN FABRICATION DATA

Specimen Fabrication
Bulk Specific Gravity
Rice Specific Gravity
Volume-Air Voids Data

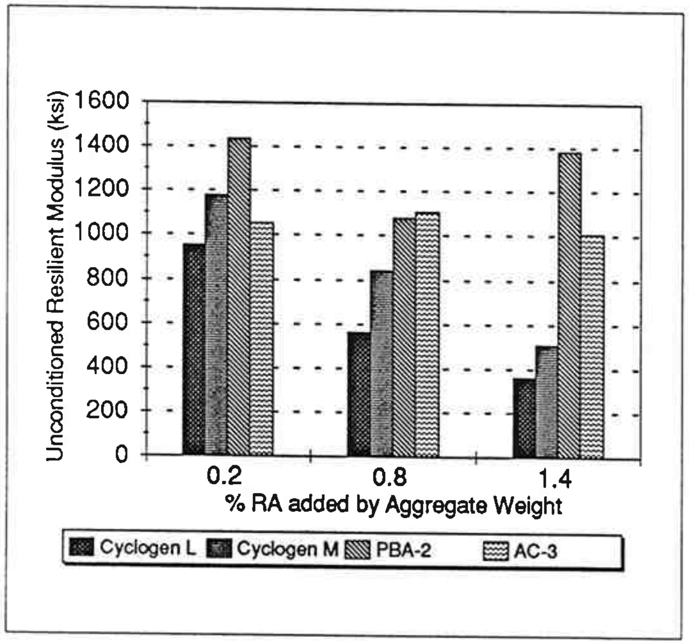

Figure C.1 Unconditioned Resilient Modulus for 100% RAP.

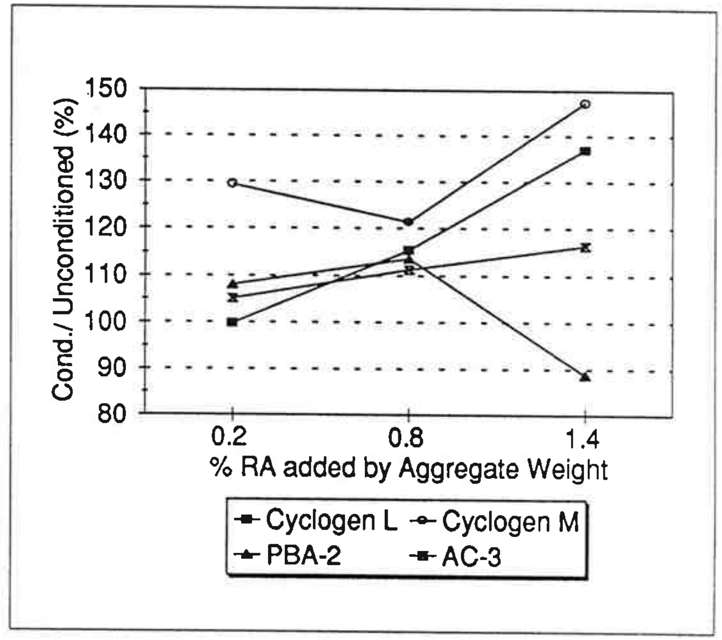

Figure C.2 Index of Retained Resilient Modulus for 100% RAP.

Table C.1 Unconditioned and Freeze/Thaw Data for Index of Retained Resilient Modulus.

RA added	Cyclogen L			Cyclogen M			McCall PBA-2			AC-3		
% of RAP wt.	Unconditioned	Freeze/Thaw	IRMR	Unconditioned	Freeze/Thaw	IRMR	Unconditioned	Freeze/Thaw	IRMR	Unconditioned	Freeze/Thaw	IRMR
0.2	954	951	100	1175	1519	129	1436.5	1552	108	1050.5	1103	105
0.8	566	653	115	841.5	1021	121	1078	1224	114	1104	1227.5	111
1.4	362	496	137	510.5	751.5	147	1381	1224.5	89	1009	1174.5	116

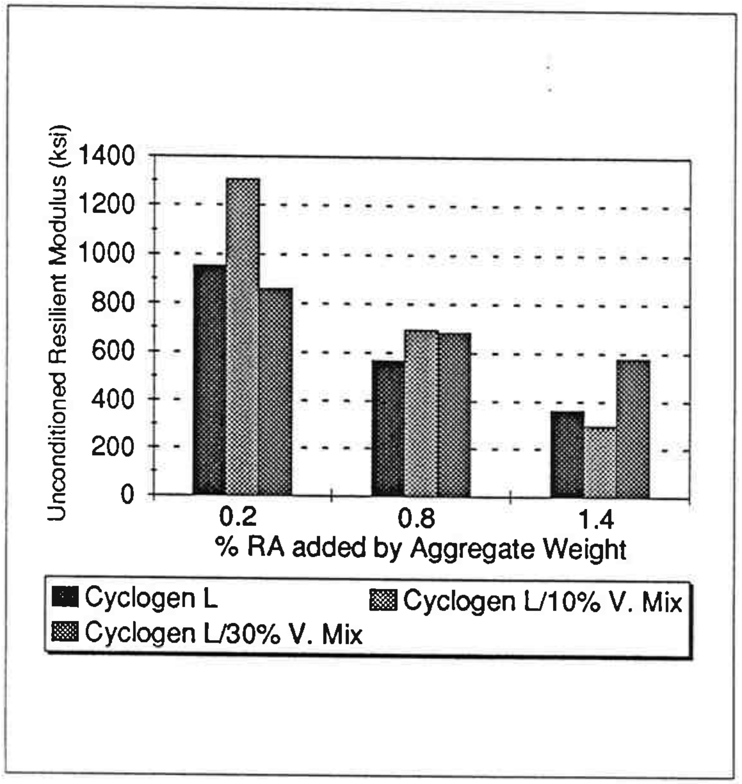

Figure C.3 Unconditioned Resilient Modulus for Cyclogen L RAP.

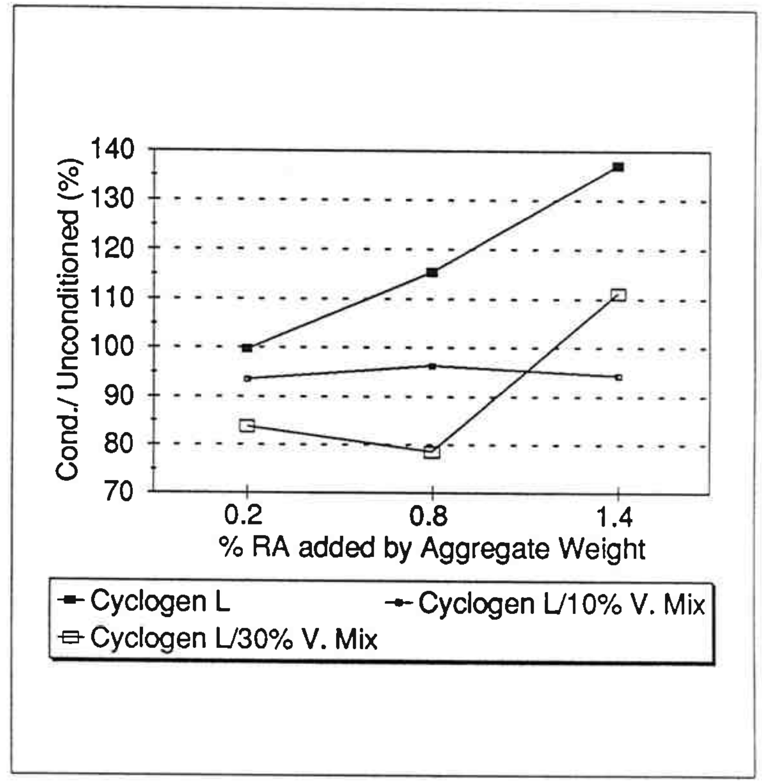

Figure C.4 Index of Retained Resilient Modulus for Cyclogen L RAP.

Table C.2 Unconditioned and Freeze/Thaw Data for Index of Retained Resilient Modulus.

RA added	Cyclogen L			Cyclogen L/10% V. Mix			Cyclogen L/30% V. Mix		
% of RAP wt.	Unconditione	Freeze/Thaw	IRMR	Unconditione	Freeze/Thaw	IRMR	Unconditione	Freeze/Thaw	IRMR
0.2	954	951	100	1305.5	1220.5	93	858.5	718.5	84
0.8	566	653	115	693	667	96	683	536	78
1.4	362	496	137	298	281	94	578	642.5	111

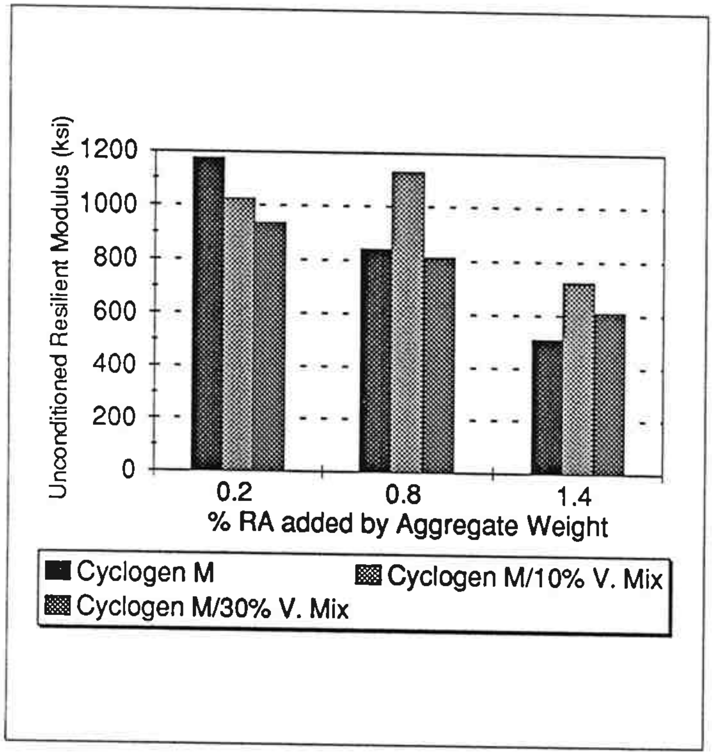

Figure C.5 Unconditioned Resilient Modulus for Cyclogen M RAP.

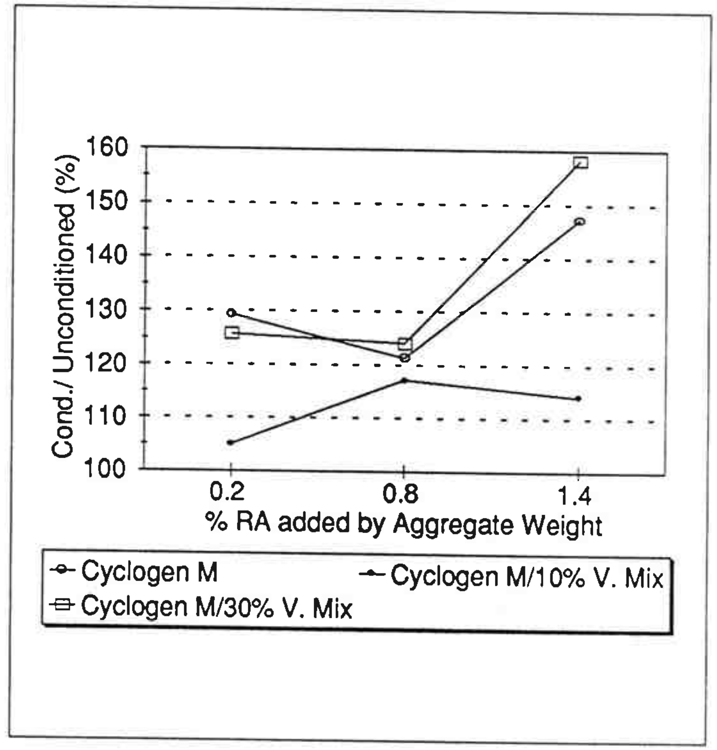

Figure C.6 Index of Retained Resilient Modulus for Cyclogen M RAP.

Table C.3 Unconditioned and Freeze/Thaw Data for Index of Retained Resilient Modulus for Cyclogen M Mixes.

RA added	Cyclogen M			Cyclogen M/10% V. Mix			Cyclogen M/30% V. Mix		
% of RAP wt.	Unconditione	Freeze/Thaw	IRMR	Unconditione	Freeze/Thaw	IRMR	Unconditione	Freeze/Thaw	IRMR
0.2	1175	1519	129	1023	1073.5	105	933	1173	126
0.8	841.5	1021	121	1127	1320.5	117	812.5	1008	124
1.4	510.5	751.5	147	724	826	114	609.5	964	158

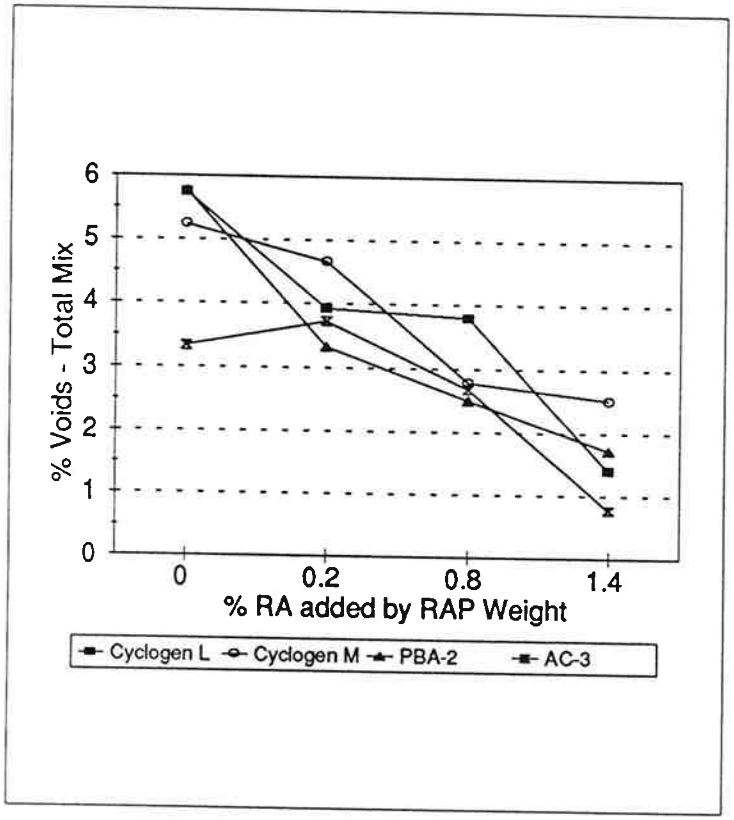

Figure C.7. Percent Air Voids For 100% RAP Mixes.

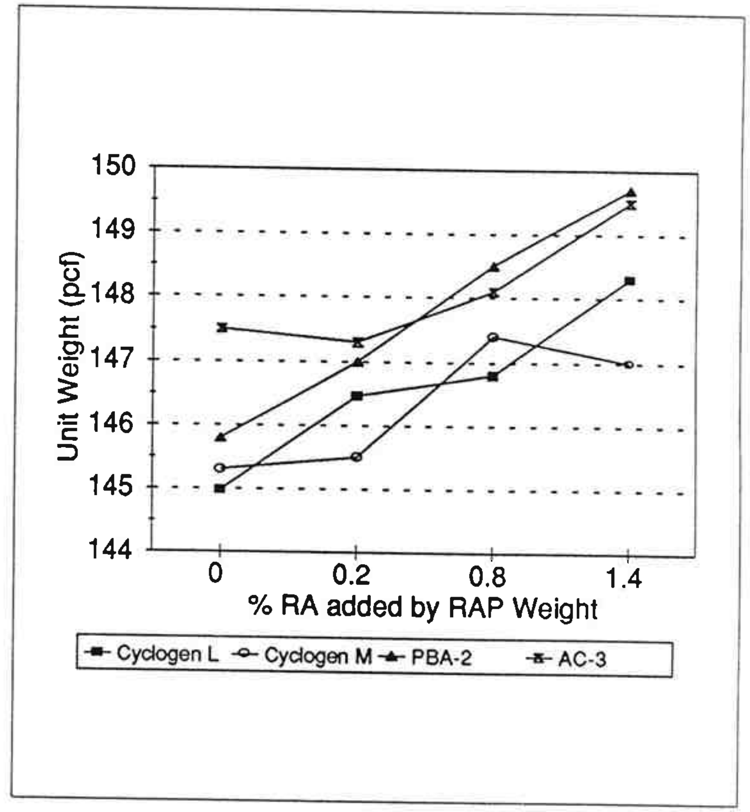

Figure C.8 Unit Weight For 100% RAP Mixes.

Table C.4 Percent Air Voids and Unit Weight Data For 100% RAP Mixes.

% RA added by Aggregate Wt.	% Air Voids				Unit Weight			
	Cyclogen L	Cyclogen M	McCall PBA-2	AC-3	Cyclogen L	Cyclogen M	McCall PBA-2	AC-3
0	5.75	5.23	5.76	3.33	144.98	145.30	145.80	147.50
0.2	4.65	4.65	3.32	3.72	146.47	145.50	147.00	147.30
0.8	3.67	2.78	2.51	2.68	146.80	147.40	148.50	148.10
1.4	1.40	2.52	1.72	0.77	148.30	147.00	149.70	149.50

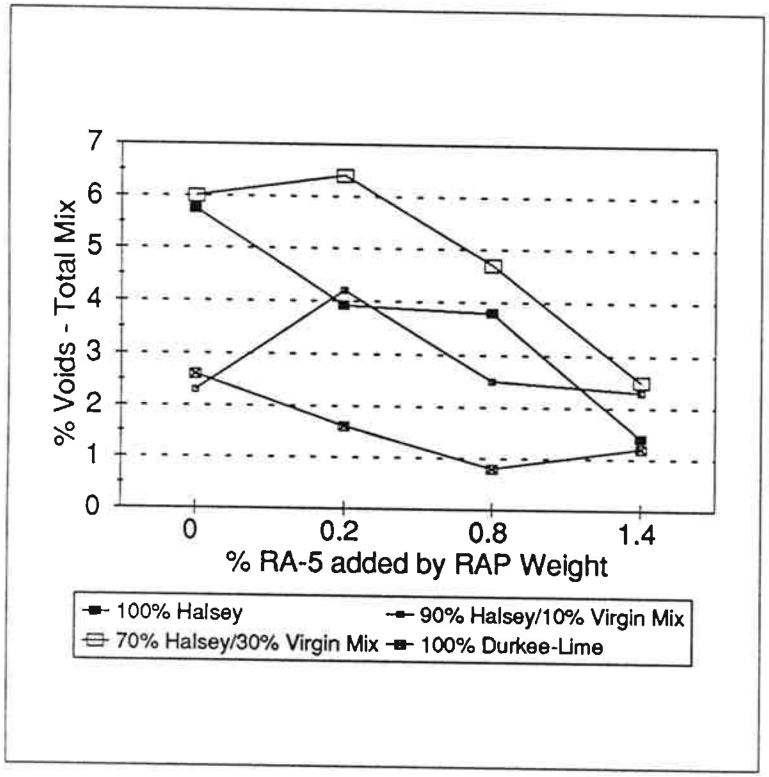

Figure C.9 Percent Air Voids For Cyclogen L RAP Mixes.

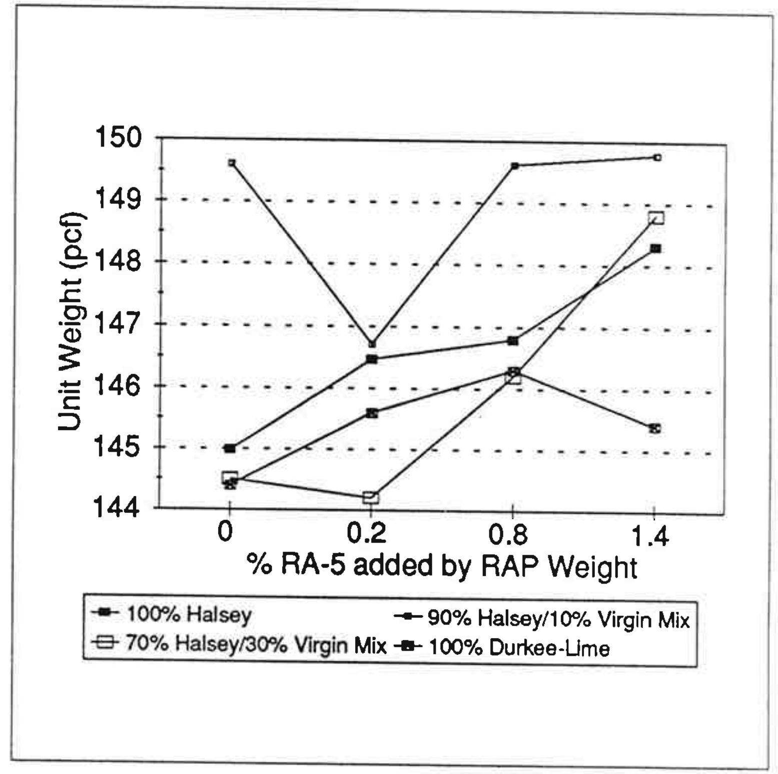

Figure C.10 Unit Weight For Cyclogen L RAP Mixes.

Table C.5 Percent Air Voids and Unit Weight Data for Cyclogen L RAP Mixes.

% RA added by Aggregate Wt.	% Air Voids			Unit Weight		
	Cyclogen L	Cyclogen L 10% Virgin Mix	Cyclogen L 30% Virgin Mix	Cyclogen L	Cyclogen L 10% Virgin Mix	Cyclogen L 30% Virgin Mix
0	5.75	2.30	6.00	144.98	149.60	144.50
0.2	4.65	4.20	6.40	146.47	146.72	144.20
0.8	3.67	2.50	4.70	146.80	149.61	146.20
1.4	1.40	2.30	2.50	148.30	149.78	148.80

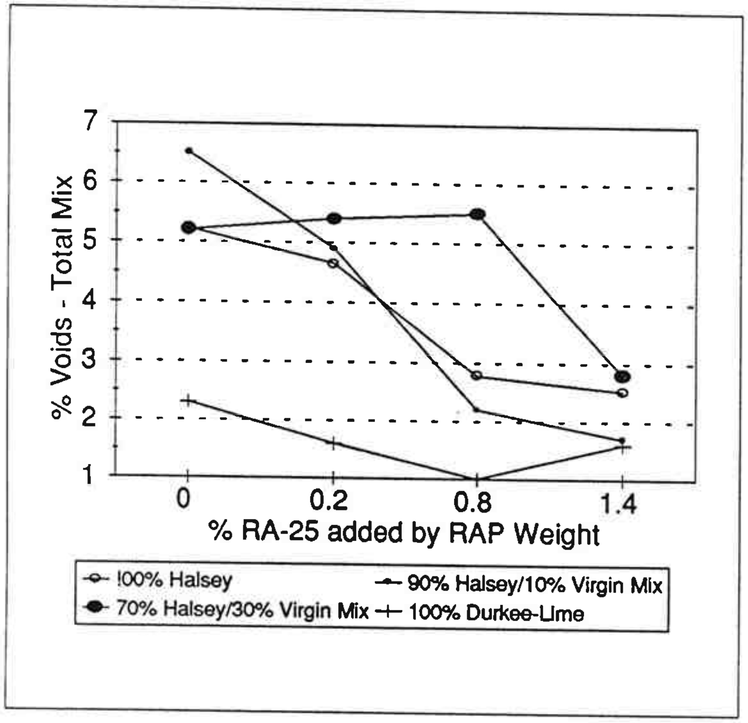

Figure C.11 Percent Air Voids For Cyclogen M RAP Mixes.

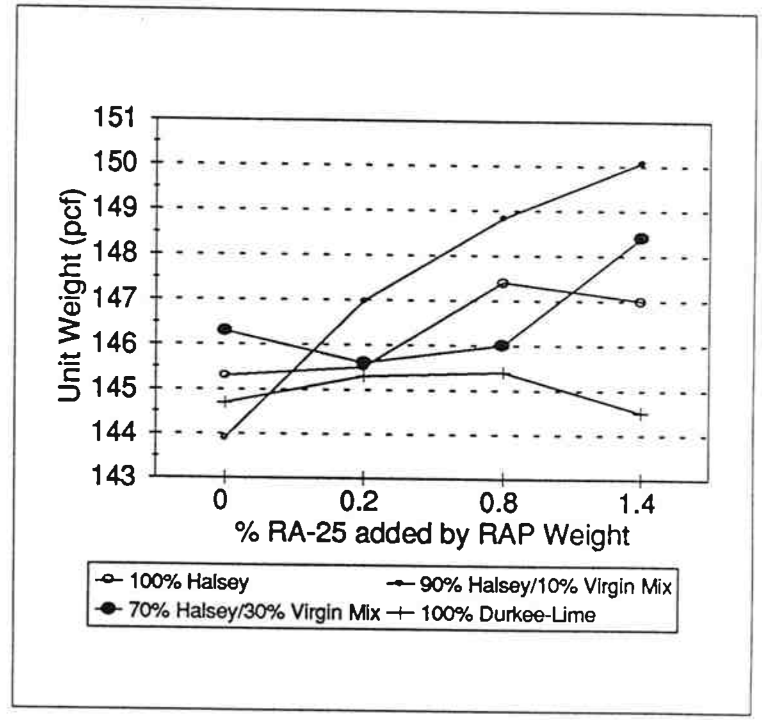

Figure C.12 Unit Weight For Cyclogen M RAP Mixes.

Table C.6 Percent Air Voids and Unit Weight Data For Cyclogen M RAP Mixes.

% RA added by Aggregate Wt.	% Air Voids			Unit Weight		
	Cyclogen M	Cyclogen M 10% Virgin Mix	Cyclogen M 30% Virgin Mix	Cyclogen M	Cyclogen M 10% Virgin Mix	Cyclogen M 30% Virgin Mix
0	5.2	2.3	5.0	145.3	143.9	146.3
0.2	4.6	4.9	5.4	145.5	147.0	145.6
0.8	2.8	2.2	5.5	147.4	148.8	146.0
1.4	2.5	1.7	2.8	147.0	150.1	148.4

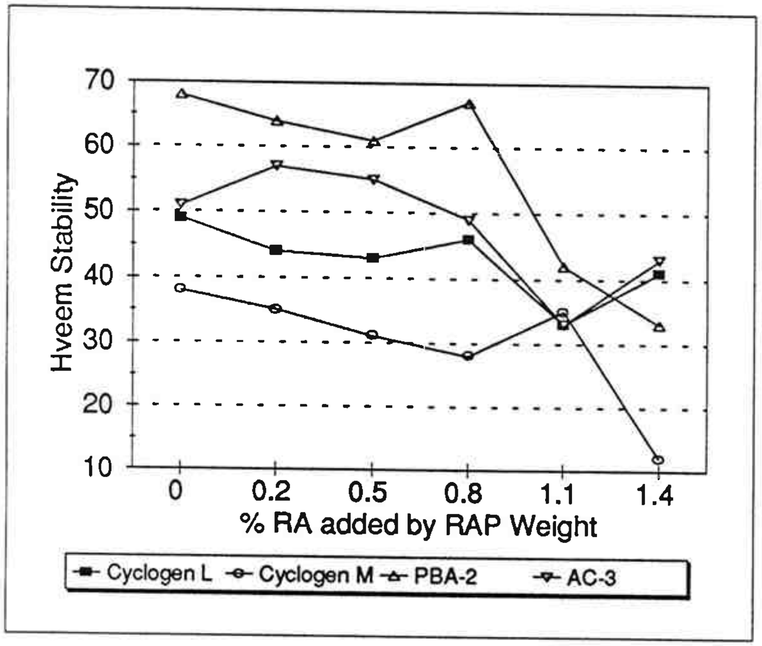

Figure C.13 First Hveem Stability Numbers for 100% RAP Mixes.

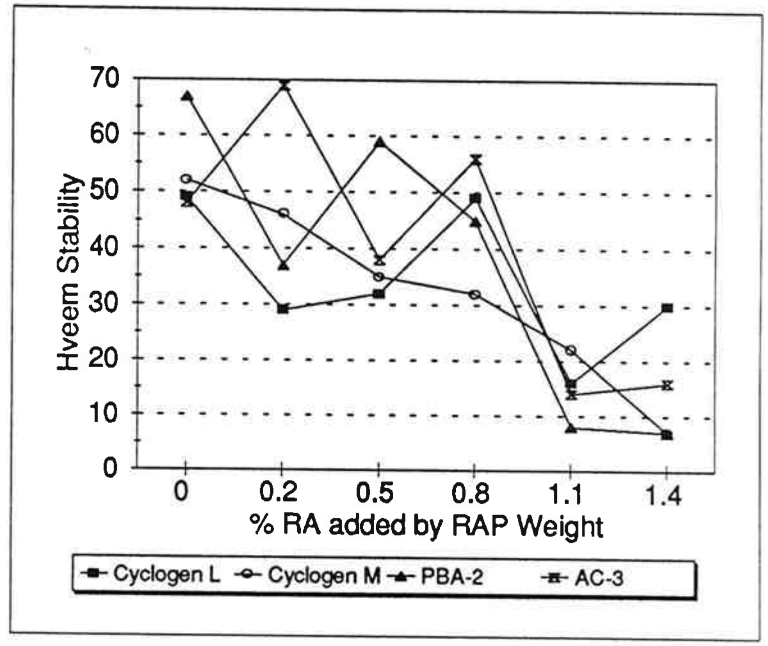

Figure C.14 Second Hveem Stability numbers for 100% RAP Mixes.

Table C.7 Hveem Stability Numbers for 100% RAP Mixes.
(First Compaction/Second Compaction)

% RA added by Aggregate Wt.	Cyclogen L	Cyclogen M	McCall PBA-2	AC-3
0	49/50	38/52	68/67	51/48
0.2	44/29	35/46	64/37	57/69
0.5	43/32	31/35	61/59	59/38
0.8	46/49	28/28	67/45	49/56
1.1	33/13	35/22	42/8	33/14
1.4	41/30	12/7	33/7	43/16

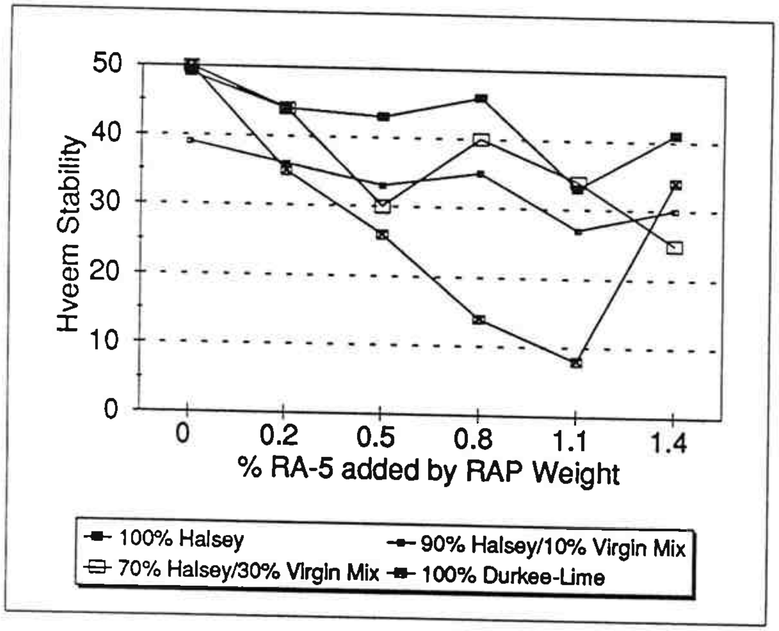

Figure C.15 First Hveem Stability numbers for Cyclogen L RAP Mixes.

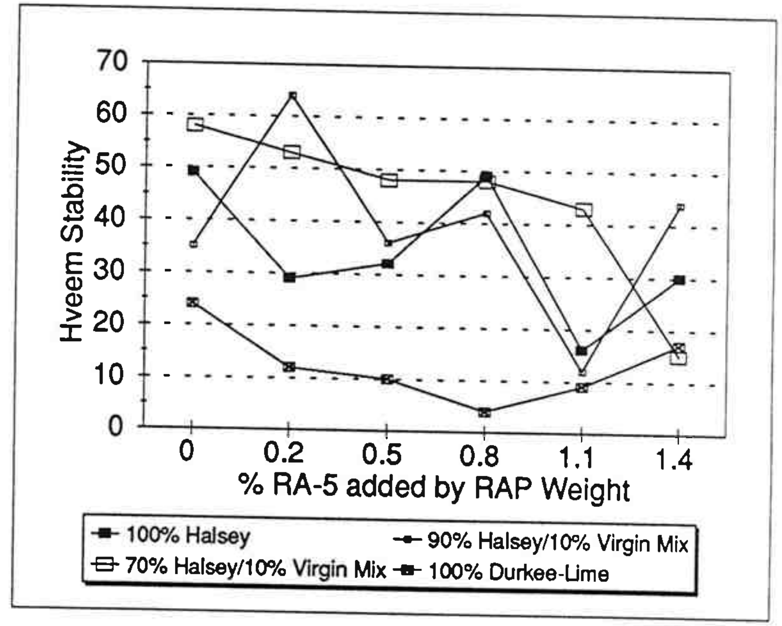

Figure C.16 Second Hveem Stability numbers for Cyclogen L RAP Mixes.

Table C.8 Hveem Stability Numbers for Cyclogen L RAP Mixes. (First Compaction/Second Compaction)

% RA added by Aggregate Wt.	Cyclogen L	Cyclogen L 10% Virgin Mix	Cyclogen L 30% Virgin Mix
0	49/50	39/31	
0.2	44/29	36/64	44/53
0.5	43/32	33/32	30/48
0.8	46/49	35/42	40/48
1.1	33/13	27/10	34/43
1.4	41/30	30/44	25/12

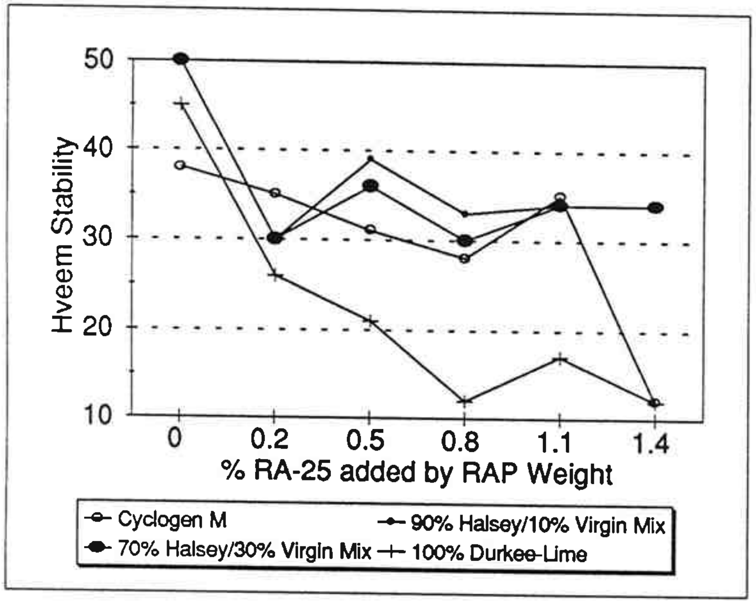

Figure C.17 First Hveem Stability numbers for Cyclogen M RAP Mixes.

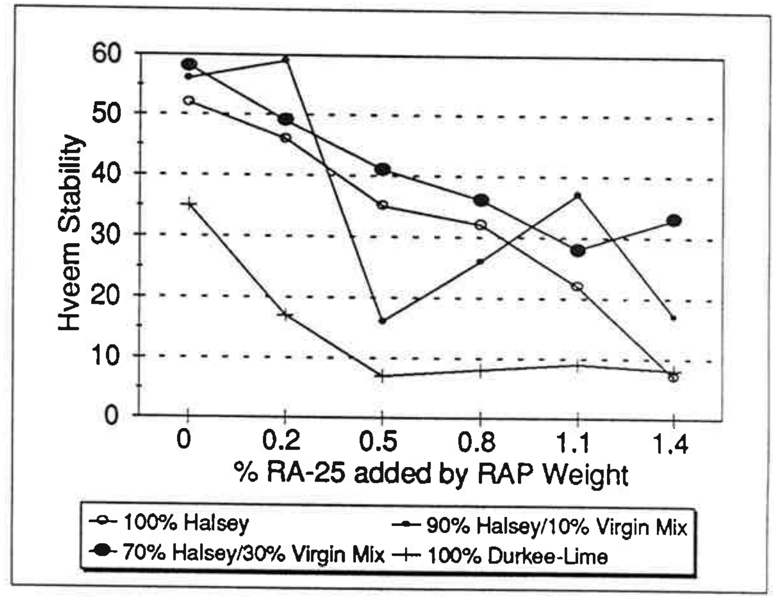

Figure C.18 Second Hveem Stability numbers for Cyclogen M RAP Mixes.

Table C.9 Hveem Stability Numbers for Cyclogen M RAP Mixes. (First Compaction/Second Compaction)

% RA added by Aggregate Wt.	Cyclogen M	Cyclogen M 10% Virgin Mix	Cyclogen M 30% Virgin Mix
0	38/52	46/56	50/58
0.2	35/46	50/59	30/49
0.5	31/35	17/13	39/41
0.8	28/28	37/22	33/36
1.1	35/22	13/37	34/28
1.4	12/7	22/14	34/33

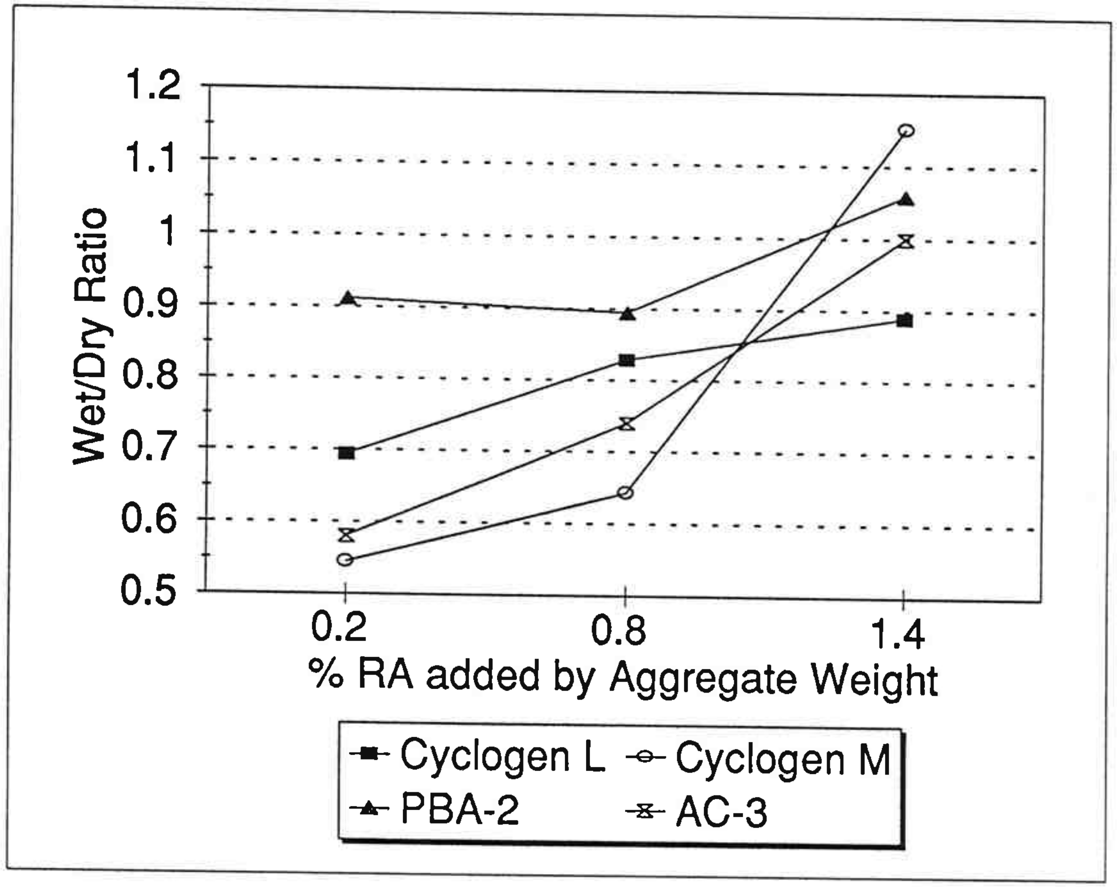

Figure C.19 Index of Retained Strength (IRS) For 100% RAP Specimens.

Table C.10 Data For Results Of Unconfined Compressive Strength Tests For IRS.

RA added	Cyclogen L			Cyclogen M			McCall PBA-2			AC-3		
% of RAP wt.	Dry	Wet	Ratio	Dry	Wet	Ratio	Dry	Wet	Ratio	Dry	Wet	Ratio
0.2	1496	1038	69	1623	883	54	1257	1146	91	1281	748	58
0.8	1440	1194	83	1536	987	64	1361	1218	89	1210	891	74
1.4	1182	1050	89	1003	1154	115	1218	1289	106	875	875	100

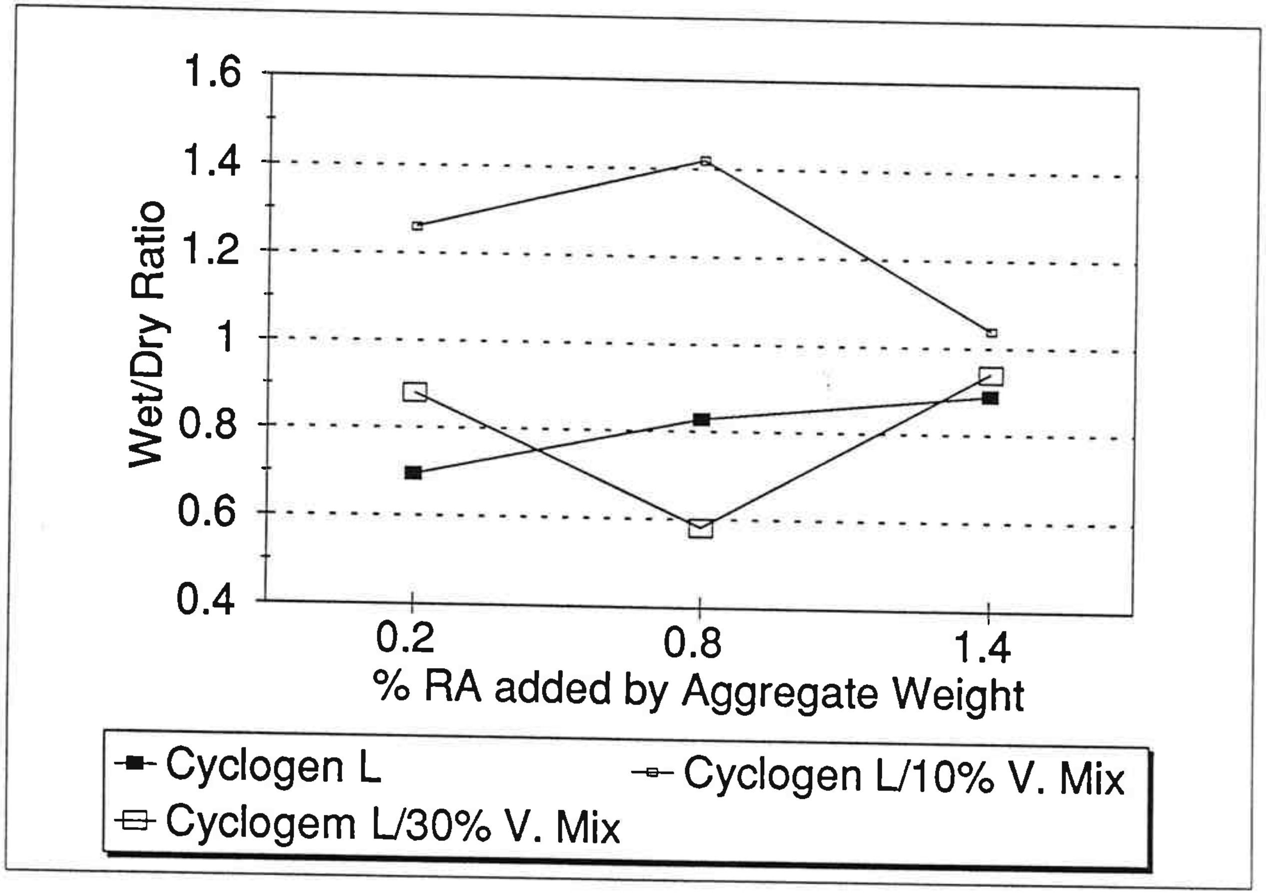

Figure C.20 Index Of Retained Strength (IRS) For Cyclogen L Specimens.

Table C.11 Data For Results Of Unconfined Compressive Strength Tests For IRS.

RA added % of RAP wt.	Cyclogen L			Cyclogen L/10% V. Mix			Cyclogen L/30% V. Mix		
	Dry	Wet	Ratio	Dry	Wet	Ratio	Dry	Wet	Ratio
0.2	1496	1038	69	853	1082	127	680	597	88
0.8	1440	1194	83	844	1134	134	861	501	58
1.4	1182	1050	89	1027	1066	104	653	613	94

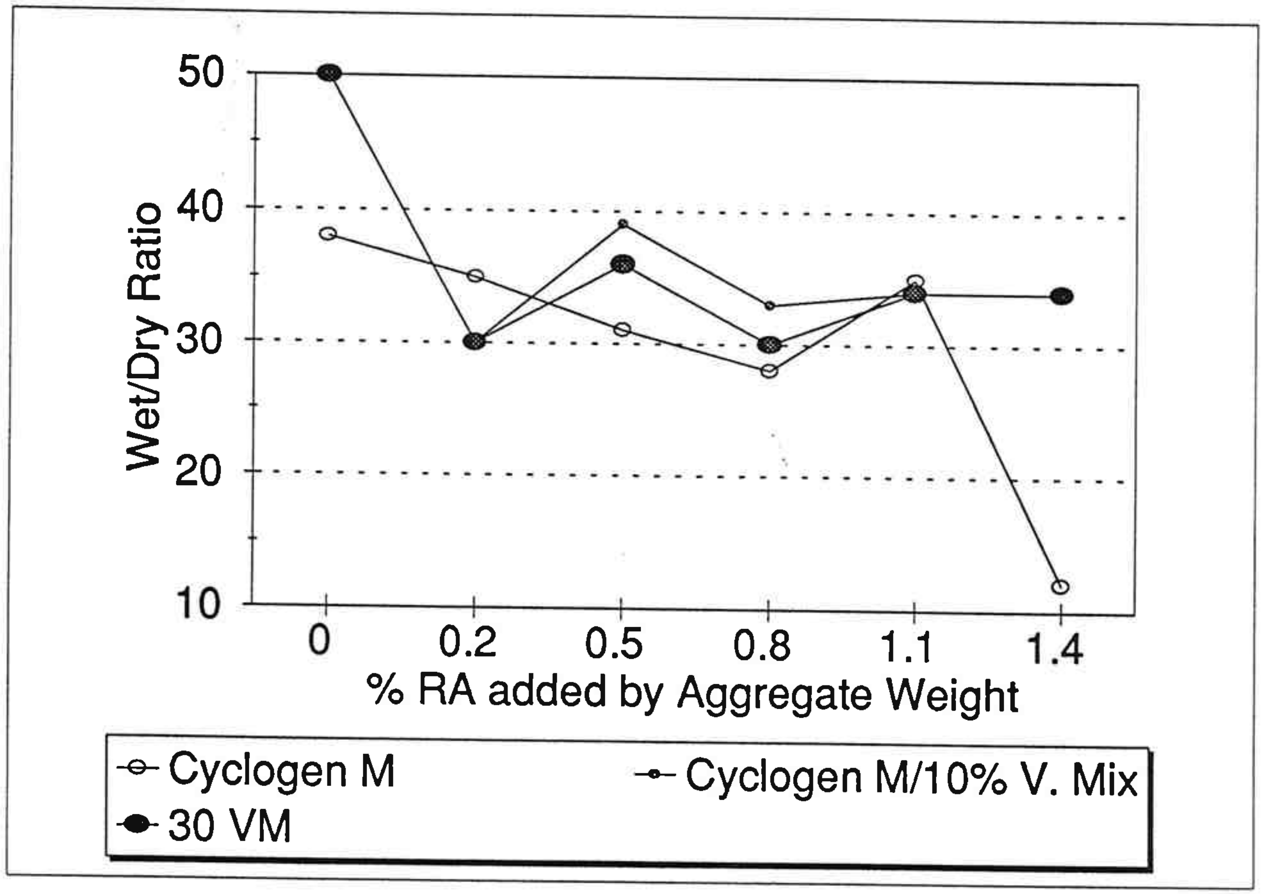

Figure C.21 Index Of Retained Strength (IRS) For Cyclogen M Specimens.

Table C.12 Data For Results Of Unconfined Compressive Strength Tests For IRS.

RA added	Cyclogen M			Cyclogen M/10% V. Mix			Cyclogen M/30% V. Mix		
% of RAP wt.	Dry	Wet	Ratio	Dry	Wet	Ratio	Dry	Wet	Ratio
0.2	1623	883	54	987	836	85	875	458	52
0.8	1536	987	64	1122	804	72	715	538	75
1.4	1003	1154	115	899	1027	114	804	565	70

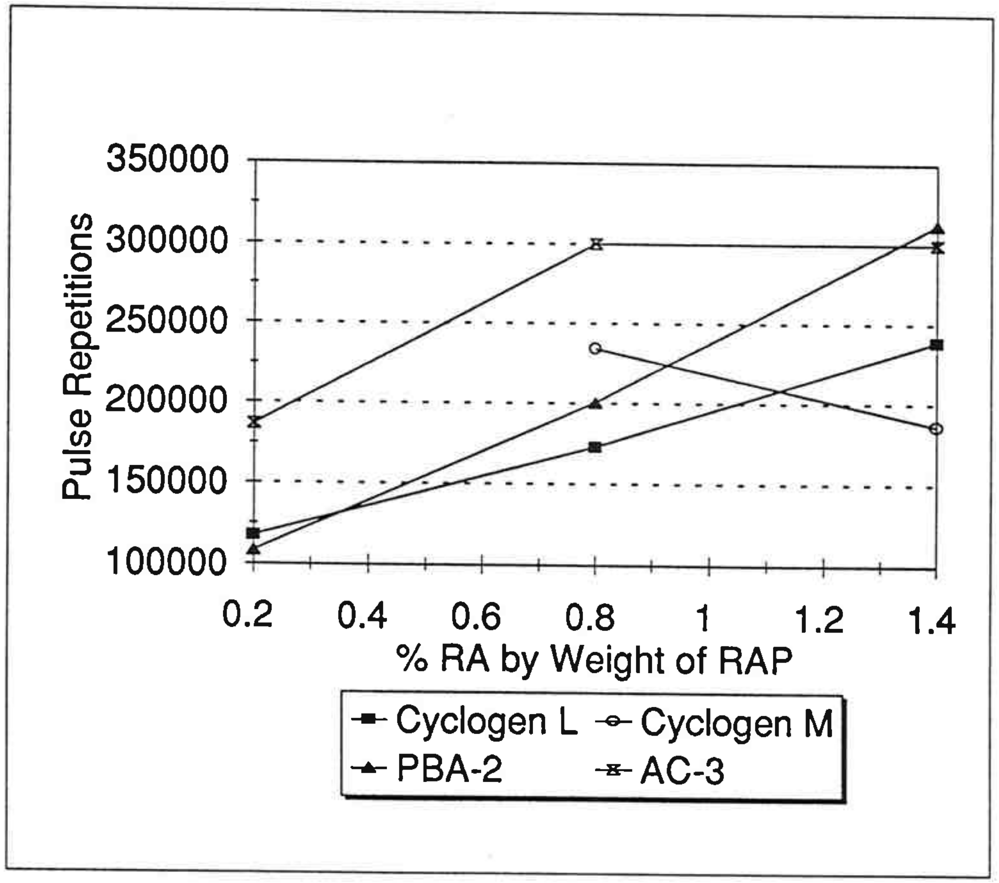

Table C.22 Fatigue Life For 100% RAP Specimens.

Table C.13 Data Of Results For Fatigue Life Tests.

RA added % of RAP wt.	Cyclogen L	Cyclogen M	McCall PBA-2	AC-3
0.2	117551		108452	186675
0.8	172986	234260	200362	300000+
1.4	239232	186097	312382	300000+

ODOT Recycling Study - 1993

Aggregate: Halsey RAP
Asphalt: Cyclogen L
Mix Date: 7/23/93

BSG Date 7/26/93
Gmm Date 8/20/93

Bulk Specific Gravity - Volume Air Voids Data

0.0 % RA added (control Specimen)

Gmm: 2.465

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
C-1	1180.7	0	0.00	2.529	2.541	2.541	2.537	1178.5	676.5	1181.9	2.33	145.5	5.4	Fatigue
C-2	1166.8	0	0.00	2.512	2.518	2.521	2.517	1164.7	666.8	1168.8	2.32	144.8	5.9	Hveem
C-3	1169.6	0	0.00	2.485	2.51	2.476	2.49	1162.1	669.4	1170.7	2.32	144.7	6.0	Modulus
										Averages	2.32	145.0	5.7	

0.2 % RA added

Gmm: 2.443

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1176.3	2.4	0.20	2.503	2.5	2.52	2.508	1176.7	682.2	1181.7	2.36	147.0	3.6	Hveem
0.2-2	1172.1	2.5	0.21	2.478	2.495	2.488	2.487	1171.7	676.8	1176.1	2.35	146.4	3.9	Modulus
0.2-3	1171.9	2.4	0.20	2.508	2.518	2.526	2.517	1173	677.7	1179.6	2.34	145.8	4.3	Fatigue
0.2-4	1187.1	2.5	0.21	2.52	2.52	2.51	2.517	1186	683.6	1188.4	2.35	146.6	3.8	Fatigue
										Averages	2.35	146.5	3.92	

0.5 % RA added

Gmm: 2.439

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.5	1177	5.9	0.50	2.538	2.545	2.528	2.537	1186	683.6	1188.4	2.35	146.6	3.7	Hveem

0.8 % RA added

Gmm: 2.445

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1186.5	10	0.84	2.478	2.481	2.503	2.487	1190.5	690.1	1192.5	2.37	147.9	3.1	Fatigue
0.8-2	1166.6	9.3	0.80	2.489	2.492	2.54	2.507	1172	676.7	1176.8	2.34	146.2	4.2	Modulus
0.8-3	1163.3	9.5	0.82	2.48	2.501	2.481	2.487	1169.3	673.2	1172.4	2.34	146.2	4.2	Fatigue
0.8-4	1200.5	9.4	0.78	2.567	2.563	2.568	2.566	1210.4	698.3	1212.6	2.35	146.9	3.7	Hveem
										Averages	2.35	146.8	3.79	

Aggregate: Halsey RAP
Asphalt: Cyclogen L
Mix Date: 7/23/93

BSG Date: 7/26/93
Gmm Date:

1.1 % RA added

Gmm: 2.424

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.1	1184.8	13.6	1.15	2.503	2.504	2.504	2.504	1171.1	685.6	1171.7	2.41	150.3	0.6	Hveem

1.4 % RA added

Gmm: 2.426

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1176.8	17.3	1.47	2.468	2.486	2.485	2.480	1180.2	682.1	1181	2.37	147.6	2.5	Fatigue
1.4-2	1193.1	16.3	1.37	2.566	2.569	2.57	2.568	1201	690.1	1204.9	2.33	145.6	3.8	Hveem
1.4-3	1166.6	17	1.46	2.402	2.398	2.398	2.399	1171.1	685.7	1171.7	2.41	150.4	0.7	Modulus
1.4-4	1176.1	17.8	1.51	2.464	2.458	2.455	2.459	1184.9	691.9	1185.5	2.40	149.8	1.1	Fatigue
										Averages	2.38	148.3	1.4	

Hveem Stability Test Specimens
Prior to Compaction

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C-2	2.512	2.518	2.521	2.517	1164.7	666.8	1168.8	2.32	5.9	22	3.96	49
0.2-1	2.503	2.5	2.52	2.508	1176.7	682.2	1181.7	2.36	3.6	27	3.87	44
0.5	2.538	2.545	2.528	2.537	1186	683.6	1188.4	2.35	3.7	29	3.82	43
0.8-4	2.567	2.563	2.568	2.566	1210.4	698.3	1212.6	2.35	3.7	26	3.72	46
1.1	2.503	2.504	2.504	2.504	1171.1	685.6	1171.7	2.41	0.6	40	4.06	33
1.4-4	2.464	2.458	2.455	2.459	1184.9	691.9	1185.5	2.40	1.1	33	3.57	41

After Compaction (second BSG)

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C-2	2.414	2.421	2.428	2.421	1164.5	678.1	1167.6	2.38	3.5	18	4.8	49
0.2-1	2.376	2.39	2.346	2.371	1175.5	691.3	1176	2.43	0.7	30	5.61	29*
0.5	2.377	2.351	2.375	2.368	1183.3	694.5	1184.1	2.42	0.9	29	5.16	32*
0.8-4	2.455	2.445	2.475	2.458	1207.9	706.1	1208.7	2.40	1.7	21	4.09	49
1.1	2.318	2.331	2.319	2.323	1183.5	695.6	1184	2.42	0.0	67	5.92	13*
1.4-4	2.429	2.423	2.443	2.432	1199.5	699.7	1200	2.40	1.2	42	4.35	30

COMPRESSIVE STRENGTH OF BITUMINOUS MIXTURES
OSHD Test Method 307C-86

1. Bulk Specific Gravity Data:

Aggregate: Halsey RAP
Asphalt: Cyclogen L
Mix Date: 7/29/93

BSG Date: 8/2/93
Gmm Date: 8/20/93

Bulk Specific Gravity - Volume Air Voids Data

0.2 % RA added

Gmm: 2.443

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1797	3.5	0.19	3.845	3.857	3.847	3.850	1788.3	1020.3	1796.1	2.31	143.8	5.0	Wet
0.2-2	1794	3.7	0.21	3.851	3.855	3.86	3.855	1797.5	1027.2	1805.4	2.31	144.1	4.8	Dry
										Averages	2.31	144.0	4.9	

0.8 % RA added

Gmm: 2.445

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1810.7	14.4	0.80	3.861	3.852	3.852	3.855	1805.3	1032.7	1810.1	2.32	144.9	4.3	Wet
0.8-2	1785.7	14.2	0.80	3.769	3.762	3.775	3.769	1779.7	1021.3	1783	2.34	145.8	3.7	Dry
										Averages	2.33	145.4	4.0	

1.4 % RA added

Gmm: 2.426

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1767.8	25.1	1.42	3.788	3.789	3.802	3.793	1781.1	1016.8	1784.4	2.32	144.8	4.4	Wet
1.4-2	1765.8	25.8	1.46	3.751	3.766	3.76	3.759	1771.9	1013.6	1774.6	2.33	145.3	4.0	Dry
											2.32	145.0	4.2	

2. Compressive Strength Results:

Specimen	Load dry cure (lbs.)	Load wet cure (lbs.)	Strength dry cure (PSI)	Strength wet cure (PSI)	Wet/Dry Ratio
0.2	18800	13050	1496	1038	0.69
0.8	18100	15000	1440	1194	0.83
1.4	14850	13200	1182	1050	0.89

ODOT Recycling Study - 1993

Aggregate: Halsey RAP
Asphalt: Cyclogen M
Mix Date: 7/30/93

BSG Date 8/2/93
Gmm Date 8/20/93

Bulk Specific Gravity - Volume Air Voids Data

0.0% RA added (Control Specimen)

Gmm: 2.457

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
C-1	1797	3.5	0.19	2.525	2.54	2.518	2.528	1191.1	692.1	1196.8	2.36	147.3	3.9	Hveem
C-2	1794	3.7	0.21	2.545	2.533	2.543	2.540	1173.4	677.5	1182.3	2.32	145.0	5.4	Fatigue
C-3	1794	3.7	0.21	2.63	2.633	2.62	2.628	1200.9	690.6	1212.5	2.30	143.6	6.3	Modulus
										Averages	2.33	145.3		

0.2 % RA added

Gmm: 2.445

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1199.6	2.3	0.19	2.58	2.595	2.578	2.584	1194.2	683	1199.1	2.31	144.4	5.4	Fatigue
0.2-2	1206	2.4	0.20	2.586	2.576	2.578	2.580	1204.6	699.5	1212.1	2.35	146.6	3.9	Modulus
0.2-3	1200	2.8	0.23	2.58	2.579	2.586	2.582	1200.5	687.70	1205.3	2.32	144.7	5.1	Fatigue
0.2-4	1196.7	2.5	0.21	2.503	2.501	2.508	2.504	1186.5	686.1	1192.7	2.34	146.1	4.2	Hveem
										Averages	2.33	145.5	4.6	

0.5 % RA added

Gmm: 2.45

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.5	1197.7	6.3	0.53	2.508	2.512	2.509	2.510	1201.6	701.9	1203.9	2.39	149.4	2.3	Hveem

0.8 % RA added

Gmm: 2.429

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1201.8	9.4	0.78	2.601	2.591	2.596	2.596	1194.7	694.2	1201.4	2.36	147.0	3.0	Modulus
0.8-2	1201.3	9.7	0.81	2.575	2.584	2.58	2.580	1199.5	693.4	1204.8	2.35	146.4	3.4	Fatigue
0.8-3	1201.8	9.5	0.79	2.562	2.57	2.573	2.568	1206.1	701.1	1210.5	2.37	147.7	2.5	Fatigue
0.8-4	1203.3	9.7	0.81	2.507	2.501	2.511	2.506	1187.8	689.5	1189.1	2.38	148.4	2.1	Hveem
											2.37	147.4	2.8	

Aggregate: Halsey RAP
Asphalt: Cyclogen M
Mix Date: 7/30/93

BSG Date: 8/2/93
Gmm Date: 8/20/93

1.1 % RA added

Gmm: 2.442

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.1	1200.6	13	1.08	2.628	2.631	2.643	2.634	1212.7	699.2	1226.7	2.30	143.5	5.9	Hveem

1.4 % RA added

Gmm: 2.417

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1196.8	16.8	1.40	2.561	2.566	2.553	2.560	1191.8	683.9	1197	2.32	144.9	3.9	Modulus
1.4-2	1193.9	18	1.51	2.485	2.503	2.499	2.496	1194.8	693.4	1195.4	2.38	148.5	1.5	Hveem
1.4-3	1194.5	16.6	1.39	2.551	2.54	2.545	2.545	1194.3	689.2	1196.4	2.35	146.9	2.6	Fatigue
1.4-4	1196.2	16.6	1.39	2.545	2.547	2.538	2.543	1205.9	697.9	1207.4	2.37	147.7	2.1	Fatigue
										Averages	2.35	147.0	2.5	

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Press (psi)	Displace.	Stability number
C-1	2.525	2.54	2.518	2.528	1191.1	692.1	1196.8	2.36	3.9	35	3.81	38
0.2-3	2.58	2.579	2.586	2.582	1200.5	687.70	1205.3	2.32	5.1	43	3.4	35
0.5	2.508	2.512	2.509	2.510	1201.6	701.9	1203.9	2.39	2.3	43	4.04	31
0.8-4	2.507	2.501	2.511	2.506	1187.8	689.5	1189.1	2.38	2.1	49	4.18	27
1.1	2.628	2.631	2.643	2.634	1212.7	699.2	1226.7	2.30	5.9	39	3.97	34
1.4-2	2.485	2.503	2.499	2.496	1194.8	693.4	1195.4	2.38	1.5	107	4.43	12

After Compaction (second BSG)

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Press (psi)	Displace.	Stability number
C-1	2.390	2.393	2.400	2.394	1183.5	697.2	1184.4	2.43	1.1	18	4.31	52
0.2-3	2.410	2.412	2.418	2.413	1204.1	710.1	1204.5	2.44	0.4	34	2.83	46
0.5	2.412	2.413	2.415	2.413	1204.5	707.2	1205.0	2.42	1.2	41	3.61	35
0.8-4	2.339	2.385	2.340	2.355	1170.4	685.3	1171.3	2.41	0.9	40	4.26	32
1.1	2.320	2.312	2.298	2.310	1167.4	689.6	1168.2	2.44	0.1	38	5.99	26
1.4-2	2.343	2.336	2.361	2.347	1178.7	690.6	1179.2	2.41	0.2	111	5.89	9

COMPRESSIVE STRENGTH OF BITUMINOUS MIXTURES
OSHD Test Method 307C-86

1. Bulk Specific Gravity Data:

Aggregate:	Halsey RAP	BSG Date:	8/2/93
Asphalt:	Cyclogen M	Gmm Date:	8/20/93
Mix Date:	7/29/93		

Bulk Specific Gravity - Volume Air Voids Data

0.2 % RA added Gmm: 2.445

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1774.2	3.7	0.21	3.878	3.869	3.892	3.880	1774.2	996.6	1778.7	2.27	141.6	6.1	Dry
0.2-2	1757.7	3.5	0.20	3.798	3.812	3.813	3.808	1758.9	990.3	1762.4	2.28	142.2	5.7	Wet
										Averages	2.27	141.9	5.9	

0.8% RA added Gmm: 2.429

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1759.7	14.6	0.83	3.824	3.818	3.823	3.822	1775.6	1009.5	1781	2.30	143.6	4.8	Dry
0.8-2	1789.9	14.3	0.80	3.775	3.786	3.766	3.776	1776.4	1016	1780.4	2.32	145.0	3.9	Wet
										Averages	2.31	144.3	4.3	

1.4 % RA added Gmm: 2.417

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1795	25.5	1.42	3.73	3.74	3.748	3.739	1786.5	1028.4	1781	2.37	148.1	1.8	Dry
1.4-2	1759.7	25.6	1.45	3.934	3.902	3.907	3.914	1812	1033.3	1780.4	2.43	151.3	-0.3	Wet
											2.40	149.7	0.7	

2. Compressive Strength Results:

Specimen	Load dry cure (lbs.)	Load wet cure (lbs.)	Strength dry cure (PSI)	Strength wet cure (PSI)	Wet/Dry Ratio
0.2	20400	11100	1623	883	0.54
0.8	19300	12400	1536	987	0.64
1.4	12600	14500	1003	1154	1.15

ODOT Recycling Study - 1993

Aggregate: Halsey RAP
Asphalt: PBA-2
Mix Date: 8/23/93

BSG Date 8/24/93
Gmm Date:

Bulk Specific Gravity - Volume Air Voids Data

0.0 % RA added (Control Specimen)

Gmm: 2.479

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
C-1	1199.3	0	0	2.619	2.621	2.611	2.617	1195.4	696.4	1209.1	2.33	145.5	5.9	
C-2	1194.8	0	0	2.572	2.565	2.569	2.569	1190.3	692.6	1201.1	2.34	146.1	5.6	Hveem
										Averages	2.34	145.8	5.8	

0.2 % RA added

Gmm: 2.436

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1200.6	2.4	0.20	2.541	2.55	2.548	2.546	1200.5	693.9	1204.4	2.35	146.7	3.5	Hveem
0.2-2	1191.7	2.7	0.23	2.63	2.542	2.536	2.569	1189.6	688.9	1194.7	2.35	146.8	3.5	Fatigue
0.2-3	1199.7	2.7	0.23	2.492	2.482	2.495	2.490	1195.3	693.4	1196.1	2.38	148.4	2.4	Modulus
0.2-4	1197.3	2.5	0.21	2.561	2.563	2.562	2.562	1195	693.4	1204.3	2.34	146.0	4.0	Fatigue
										Averages	2.36	147.0	3.3	

0.5 % RA added

Gmm: 2.448

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.5	1200.4	5.9	0.49	2.555	2.561	2.561	2.559	1198.4	694.7	1204.3	2.35	146.7	3.9	Hveem

0.8 % RA added

Gmm: 2.441

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1199.2	10	0.83	2.495	2.489	2.502	2.495	1190.0	690.8	1191.2	2.38	148.4	2.6	Modulus
0.8-2	1179.4	9.6	0.81	2.451	2.457	2.461	2.456	1177.6	684.6	1174.9	2.40	149.9	1.6	Fatigue
0.8-3	1194.1	9.7	0.81	2.43	2.443	2.438	2.437	1195.8	696.1	1197.9	2.38	148.7	2.4	Fatigue
0.8-4	1198.8	9.8	0.82	2.502	2.51	2.511	2.508	1204.8	695	1206.3	2.36	147.0	3.5	Hveem
										Averages	2.38	148.5	2.5	

Aggregate: Halsey RAP
Asphalt: PBA-2
Mix Date: 8/23/93

BSG Date: 8/24/93
Gmm Date:

1.1 % RA added

Gmm: N.A.

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.1	1202.1	13.1	1.09	2.558	2.533	2.548	2.546	1204.8	695	1206.3	2.36	147.0	N.A.	Hveem

1.4 % RA added

Gmm: 2.412

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1190.4	16.9	1.42	2.443	2.448	2.446	2.446	1187.3	693.6	1187.9	2.40	149.9	1.6	Fatigue
1.4-2	1202.7	16.7	1.39	2.486	2.488	2.482	2.485	1191.5	694	1193	2.39	149.0	2.2	Modulus
1.4-3	1195.7	16.8	1.41	2.471	2.47	2.469	2.470	1197.4	699.8	1197.8	2.40	150.0	1.5	Hveem
1.4-4	1192.2	16.8	1.41	2.47	2.459	2.462	2.464	1193.9	697.3	1194.4	2.40	149.9	1.6	Fatigue
										Averages	2.40	149.7	1.7	

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C-2	2.572	2.565	2.569	2.569	1190.3	692.6	1201.1	2.34	5.6	11	3.72	68
0.2-1	2.541	2.55	2.548	2.546	1200.5	693.9	1204.4	2.35	5.1	14	3.40	64
0.5	2.555	2.561	2.561	2.559	1198.4	694.7	1204.3	2.35	3.9	15	3.72	60
0.8-4	2.502	2.51	2.511	2.508	1204.8	695	1206.3	2.36	3.5	11	3.80	67
1.1	2.558	2.533	2.548	2.546	1204.8	695	1206.3	2.36	NA	33	3.45	42
1.4-3	2.471	2.47	2.469	2.470	1197.4	699.8	1197.8	2.40	0.3	55	4.09	25

After Compaction (second BSG)

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	0 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C-2	2.487	2.469	2.484	2.480	1190.3	697.7	1194.4	2.40	3.3	12	4.34	62
0.2-1	2.541	2.55	2.548	2.546	1198.8	706.8	1199.6	2.43	0.1	42	4.00	32
0.5	2.555	2.561	2.561	2.559	1198.1	705.3	1198.8	2.43	0.8	18	3.90	55
0.8-4	2.412	2.399	2.388	2.400	1195.9	705.9	1196.4	2.44	0.1	31	4.21	38
1.1	2.348	2.34	2.352	2.347	1194.9	703	1195.4	2.43	NA	148	4.89	7
1.4-3	2.345	2.36	2.4	2.368	1202.9	705.4	1203.4	2.42	0.0	178	4.68	6

COMPRESSIVE STRENGTH OF BITUMINOUS MIXTURES
OSHD Test Method 307C-86

1. Bulk Specific Gravity Data:

Aggregate:	Halsey RAP	BSG Date:	8/2/93
Asphalt:	McCall PBA-2	Gmm Date:	8/20/93
Mix Date:	7/29/93		

Bulk Specific Gravity - Volume Air Voids Data

0.2 % RA added

Gmm: 2.445

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1797.8	3.6	0.20	3.84	3.836	3.845	3.840	1779.6	1023.2	1792.8	2.31	144.3	5.4	Dry
0.2-2	1794.8	3.7	0.21	3.774	3.778	3.776	3.776	1760.8	1018.3	1774.3	2.33	145.3	4.7	Wet
										Averages	2.32	144.8	5.1	

0.8% RA added

Gmm: 2.429

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1798.1	14.4	0.80	3.828	3.835	3.825	3.829	1787.4	1028.1	1796	2.33	145.2	4.8	Dry
0.8-2	1801.6	14.6	0.81	3.871	3.876	3.893	3.880	1806.9	1029.8	1812.7	2.31	144.0	5.6	Wet
										Averages	2.32	144.6	5.2	

1.4 % RA added

Gmm: 2.417

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1797.3	25.3	1.41	3.868	3.871	3.871	3.870	1788.8	1016	1794.8	2.30	143.3	6.1	Dry
1.4-2	1720.2	25.5	1.48	3.789	3.795	3.797	3.794	1778	1020.6	1782.2	2.33	145.7	4.5	Wet
											2.32	144.5	5.3	

2. Compressive Strength Results:

Specimen	Load dry cure (lbs.)	Load wet cure (lbs.)	Strength dry cure (PSI)	Strength wet cure (PSI)	Wet/Dry Ratio
0.2	15800	14400	1257	1146	0.91
0.8	17100	15300	1361	1218	0.89
1.4	15300	16200	1218	1289	1.06

ODOT Recycling Study - 1993

Aggregate: Halsey RAP
Asphalt: AC-3
Mix Date: 9/01/93

BSG Date: 9/03/93
Gmm Date: 9/27/93

Bulk Specific Gravity - Volume Air Voids Data

0.0 % RA added (control specimen)

Gmm: 2.4458

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
C-1		0	0	2.535	2.535	2.552	2.541	1204.4	701.5	1210.9	2.36	147.5	3.3	Hveem

0.2 % RA added

Gmm: 2.4516

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1204.4	2.4	0.20	2.546	2.56	2.545	2.550	1204.2	702.2	1213.3	2.36	147.0	3.9	Hveem
0.2-2	1201.4	2.4	0.20	2.516	2.525	2.532	2.524	1199.3	700.3	1203.9	2.38	148.6	2.9	Fatigue
0.2-3	1200.7	2.6	0.22	2.583	2.58	2.59	2.584	1202.2	698.3	1213.6	2.33	145.6	4.8	Modulus
0.2-4	1196.9	2.4	0.20	2.517	2.532	2.513	2.521	1195.7	696.7	1201	2.37	148.0	3.3	Fatigue
										Averages	2.37	147.3	3.7	

0.5 % RA added

Gmm: 2.4479

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.5	1209.3	5.9	0.49	2.542	2.514	2.532	2.529	1211.9	710.3	1216.4	2.39	149.4	2.2	Hveem

0.8 % RA added

Gmm: 2.4396

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1201.6	9.6	0.80	2.575	2.578	2.576	2.576	1205.2	698.9	1212	2.35	146.6	3.7	Hveem
0.8-2	1196.4	9.4	0.79	2.522	2.538	2.53	2.530	1200.8	699.6	1204.6	2.38	148.4	2.5	Modulus
0.8-3	1209.3	9.5	0.79	2.514	2.525	2.497	2.512	1199.7	698.5	1203.5	2.38	148.2	2.6	Fatigue
0.8-4	1200.7	9.5	0.79	2.488	2.498	2.482	2.489	1200.8	701.9	1203.4	2.39	149.4	1.9	Fatigue
										Averages	2.37	148.1	2.7	

Aggregate: Halsey RAP
Asphalt: AC-3
Mix Date: 9/01/93

BSG Date: 9/03/93
Gmm Date: 9/27/93

1.1 % RA added

Gmm: 2.4125

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.1	1202.1	13.1	1.09	2.541	2.531	2.535	2.536	1207.6	702.1	1210.4	2.38	148.2	1.5	Hveem

1.4 % RA added

Gmm: 2.4144

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1201.8	17	1.41	2.516	2.504	2.481	2.500	1204.4	702.1	1205.6	2.39	149.3	0.9	Fatigue
1.4-2	1206.3	16.9	1.40	2.551	2.536	2.54	2.542	1218.7	710.5	1220.5	2.39	149.1	1.0	Hveem
1.4-3	1195.2	16.8	1.41	2.476	2.464	2.472	2.471	1199	702.5	1200.2	2.41	150.3	0.2	Modulus
1.4-4	1199.3	16.9	1.41	2.512	2.498	2.488	2.499	1206.8	704.2	1208.7	2.39	149.3	0.9	Fatigue
											2.40	149.5	0.8	

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Press (psi)	Displace.	Stability number
C-1	2.535	2.535	2.552	2.541	1204.4	701.5	1210.9	2.36	3.3	23	3.46	51
0.2-1	2.546	2.560	2.545	2.550	1204.2	702.2	1213.3	2.36	3.9	16	4.03	57
0.5	2.542	2.514	2.532	2.529	1211.9	710.3	1216.4	2.39	2.2	19	3.67	55
0.8-1	2.575	2.578	2.576	2.576	1205.2	698.9	1212	2.35	3.7	23	3.79	49
1.1	2.541	2.531	2.535	2.536	1207.6	702.1	1210.4	2.38	1.5	45	3.62	32
1.4-2	2.551	2.536	2.540	2.542	1218.7	710.5	1220.5	2.39	3.8	31	3.49	43

After Compaction (second BSG)

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Press (psi)	Displace.	Stability number
C-1	2.425	2.408	2.415	2.416	1204.7	710.4	1205.9	2.43	0.6	24	3.84	47
0.2-1	2.440	2.428	2.424	2.431	1205.8	709.4	1206.8	2.42	1.1	14	2.78	69
0.5	2.415	2.430	2.408	2.418	1210.7	715.8	1211.5	2.44	0.2	32	4.18	38
0.8-1	2.457	2.461	2.460	2.459	1206.3	707	1207.3	2.41	1.2	17	3.95	56
1.1	2.403	2.410	2.386	2.400	1207.2	708.9	1208.2	2.42	-0.2	98	4.04	14
1.4-2	2.431	2.410	2.407	2.416	1218.1	716.1	1218.8	2.42	-0.4	92	3.89	16

COMPRESSIVE STRENGTH OF BITUMINOUS MIXTURES
OSHD Test Method 307C-86

1. Bulk Specific Gravity Data:

Aggregate: Halsey RAP
Asphalt: AC-3
Mix Date: 9/02/93

BSG Date: 9/03/93
Gmm Date: 9/27/93

Bulk Specific Gravity - Volume Air Voids Data

0.2 % RA added

Gmm: 2.4516

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1795.4	3.5	0.19	3.885	3.879	3.892	3.885	1798.8	1018.7	1804.7	2.29	142.8	6.7	Dry
0.2-2	1797.9	3.7	0.21	3.945	3.92	3.906	3.924	1801.2	1020.5	1809.4	2.28	142.5	6.9	Wet
										Averages	2.29	142.6	6.8	

0.8% RA added

Gmm: 2.4396

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1790.4	14.4	0.80	3.865	3.86	3.89	3.872	1802.6	1023.9	1809.7	2.29	143.1	6.0	Dry
0.8-2	1791.6	14.7	0.82	3.862	3.827	3.872	3.854	1807	1032.3	1813.6	2.31	144.3	5.2	Wet
										Averages	2.30	143.7	5.6	

1.4 % RA added

Gmm: 2.4144

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave) (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1799.2	25.1	1.40	3.896	3.879	3.883	3.886	1824.2	1049.3	1834.4	2.32	145.0	3.8	Dry
1.4-2	1799.3	25.3	1.41	3.772	3.778	3.802	3.784	1821.7	1050.3	1823.6	2.36	147.0	2.4	Wet
											2.34	146.0	3.1	

2. Compressive Strength Results:

Specimen	Load dry cure (lbs.)	Load wet cure (lbs.)	Strength dry cure (PSI)	Strength wet cure (PSI)	Wet/Dry Ratio
0.2	16100	9400	1281	748	0.58
0.8	15200	11200	1210	891	0.74
1.4	11000	11000	875	875	1.00

ODOT Recycling Study - 1993

Aggregate: Halsey RAP/10% Virgin agg. BSG Date: 11/27/93
Asphalt: Cyclogen L/ PBA-2 Gmm Date: 01/06/94
Mix Date: 11/26/93

Bulk Specific Gravity - Volume Air Voids Data

0.0 % RA added (control specimen)

Gmm: 2.454

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
C-1	1076.9	0	123.5	2.4	10.5	1.9	0.00	2.497	2.478	2.501	2.492	1200.1	703.3	1204	2.40	149.6	2.3	Hveem

0.2 % RA added

Gmm: 2.455

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1076.4	2.2	120.9	2.2	10.2	1.8	0.20	2.579	2.604	2.587	2.590	1193.5	696	1207	2.34	145.7	4.9	Hveem
0.2-2	1072.5	2.3	122.6	2.2	10.4	1.8	0.21	2.532	2.538	2.545	2.538	1194.5	698.9	1200.7	2.38	148.5	3.0	IRRM
0.2-3	1071.4	2.3	123.8	2.7	10.5	2.2	0.21	2.648	2.622	2.648	2.639	1199.4	694.5	1211.5	2.32	144.8	5.5	Fatigue
0.2-4	1059	2.3	123.6	2.3	10.6	1.9	0.22	2.424	2.431	2.425	2.427	1184	695.3	1195	2.37	147.9	3.5	Fatigue
														Averages	2.35	146.72	4.2	

0.5 % RA added

Gmm: 2.461

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.5	1055.2	5.4	117.2	2.3	10.1	2.0	0.51	2.481	2.468	2.472	2.474	1174.7	685.7	1178.1	2.39	148.9	3.1	Hveem

0.8 % RA added

Gmm: 2.458

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.6-1	1072.5	8.6	121.5	2.4	10.3	2.0	0.80	2.506	2.51	2.508	2.508	1200.5	701.7	1202.6	2.40	149.6	2.5	Hveem
0.8-2	1071.9	8.9	120.4	2.7	10.2	2.2	0.83	2.484	2.482	2.486	2.484	1195.5	702.5	1198.5	2.41	150.4	1.9	Fatigue
0.8-3	1056.7	8.4	119.8	2.5	10.3	2.1	0.79	2.421	2.437	2.438	2.432	1181.7	694.1	1183.3	2.42	150.7	1.7	Fatigue
0.8-4	1049.7	8.3	123	2.3	10.6	1.9	0.79	2.503	2.505	2.501	2.503	1174	682.6	1178.4	2.37	147.8	3.7	IRRM
														Averages	2.40	149.61	2.5	

Aggregate: Halsey RAP/10% Virgin agg.
Asphalt: Cyclogen L/ PBA-2
Mix Date: 11/26/93

BSG Date: 11/27/93
Gmm Date: 01/06/94

1.1 % RA added

Gmm: 2.443

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.1	1073.2	11.9	123.3	2.4	10.4	1.9	1.11	2.492	2.475	2.48	2.482	1199.5	702.5	1200.4	2.41	150.3	1.4	Hveem

1.4 % RA added

Gmm: 2.462

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1056.8	15.1	120.1	2.6	10.3	2.2	1.43	2.502	2.503	2.518	2.508	1182.1	688.1	1184.6	2.38	148.6	3.3	Hveem
1.4-2	1070.8	15.3	119.6	2.1	10.1	1.8	1.43	2.44	2.44	2.441	2.440	1190.5	699.7	1191.4	2.42	151.1	1.7	Fatigue
1.4-3	1067.4	15.2	119	2.2	10.1	1.8	1.42	2.43	2.44	2.435	2.435	1188.1	698.9	1188.9	2.42	151.3	1.5	Fatigue
1.4-4	1064.2	15.1	121.5	2.3	10.3	1.9	1.42	2.558	2.552	2.553	2.554	1188.6	692.9	1193.4	2.37	148.2	3.5	IRRM
															2.40	149.78	2.3	

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C-1	2.497	2.478	2.501	2.492	1200.1	703.3	1204	2.40	2.3	30	4.18	39
0.2-1	2.579	2.604	2.587	2.590	1193.5	696	1207	2.34	4.9	37	3.84	36
0.5	2.481	2.468	2.472	2.474	1174.7	685.7	1178.1	2.39	3.1	35	4.69	33
0.8-1	2.506	2.51	2.508	2.508	1200.5	701.7	1202.6	2.40	2.5	35	4.23	35
1.1	2.492	2.475	2.48	2.482	1199.5	702.5	1200.4	2.41	1.4	47	4.48	27
1.4-1	2.502	2.503	2.518	2.508	1182.1	688.1	1184.6	2.38	3.3	37	5.08	30

After Compaction (second BSG)

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C-1	2.365	2.375	2.37	2.370	1195.2	708	1196.3	2.45	0.3	30	5.02	31*
0.2-1	2.48	2.482	2.478	2.480	1192.2	702.1	1196.3	2.41	1.7	9	5.37	64
0.5	2.34	2.34	2.345	2.342	1174.3	696.3	1175	2.45	0.3	24	6.06	32*
0.8-1	2.407	2.408	2.41	2.408	1200.2	710.5	1201.1	2.45	0.5	23	5.07	42
1.1	2.355	2.365	2.36	2.360	1198.1	708.2	1198.7	2.44	0.0	87	5.8	10*
1.4-1	2.412	2.408	2.417	2.412	1182.5	696.3	1183.2	2.43	1.4	19	5.7	44

COMPRESSIVE STRENGTH OF BITUMINOUS MIXTURES
OSHD Test Method 307C-86

1. Bulk Specific Gravity Data:

Aggregate: Halsey RAP/10% Virgin agg. BSG Date: 11/27/93
Asphalt: Cyclogen L/ PBA-2 Gmm Date: 01/06/94
Mix Date: 9/02/93

Bulk Specific Gravity - Volume Air Voids Data

0.2 % RA added

Gmm: 2.478

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1599	3.6	180.6	3.5	10.3	1.9	0.23	3.951	3.954	3.963	3.956	1775.2	1037.2	1817.7	2.27	141.9	8.2	Dry
0.2-2	1603.8	3.8	184.9	3.8	10.5	2.1	0.24	3.825	3.83	3.83	3.828	1782.2	1035.4	1804.6	2.32	144.6	6.5	Wet
														Averages	2.30	143.3	7.4	

0.8% RA added

Gmm: 2.458

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1612.2	13	182.6	3.4	10.3	1.9	0.81	3.952	3.975	3.962	3.963	1803.2	1042.9	1833.4	2.28	142.3	7.2	Dry
0.8-2	1610.2	12.9	178.6	3.4	10.1	1.9	0.80	3.876	3.873	3.875	3.875	1803	1042.2	1815.1	2.33	145.6	5.1	Wet
														Averages	2.31	144.0	6.1	

1.4 % RA added

Gmm: 2.462

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1604.6	22.6	185.8	3.2	10.4	1.7	1.41	3.926	3.927	3.922	3.925	1803.9	1035.6	1822.3	2.29	143.1	6.9	Dry
1.4-2	1591.4	23.4	182.8	3.4	10.3	1.9	1.47	3.903	3.896	3.909	3.903	1812.5	1038.7	1823.6	2.31	144.1	6.2	Wet
															2.30	143.6	6.5	

2. Compressive Strength Results:

Specimen	Load dry cure (lbs.)	Load wet cure (lbs.)	Strength dry cure (PSI)	Strength wet cure (PSI)	Wet/Dry Ratio
0.2	10800	13600	859	1082	1.26
0.8	10600	15000	844	1194	1.42
1.4	12900	13400	1027	1066	1.04

ODOT Recycling Study - 1993

Aggregate: Halsey RAP/10% Virgin agg.
Asphalt: Cyclogen M/ PBA-2
Mix Date: 11/28/93

BSG Date: 11/29/93
Gmm Date: 01/06/94

Bulk Specific Gravity - Volume Air Voids Data

0.0 % RA added (control specimen)

Gmm: 2.465

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
C-1	1078.8	0	120.5	2.4	10.2	2.0	0.00	2.65	2.635	2.641	2.642	1188.9	691.5	1207.1	2.31	143.9	6.5	Hveem

0.2 % RA added

Gmm: 2.478

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1074.1	2.3	119.4	2.4	10.2	2.0	0.21	2.500	2.495	2.499	2.498	1191.6	697.4	1195.1	2.39	149.4	3.4	Fatigue
0.2-2	1069	2.1	124.1	2.4	10.6	1.9	0.20	2.606	2.598	2.600	2.601	1190.2	694	1202.5	2.34	146.1	5.5	Hveem
0.2-3	1083.1	2.2	124	2.4	10.4	1.9	0.20	2.605	2.615	2.615	2.612	1208	704.5	1218.7	2.35	146.6	5.2	IRRM
0.2-4	1078.1	2.1	120.2	2.4	10.2	2.0	0.19	2.581	2.579	2.584	2.581	1200.7	699.8	1213.5	2.34	145.9	5.7	Fatigue
														Averages	2.36	146.97	4.9	

0.5 % RA added

Gmm: 2.444

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.5	1076.1	5.6	121.3	2.3	10.3	1.9	0.52	2.491	2.468	2.472	2.477	1199.3	704.8	1200.2	2.42	151.1	0.9	Hveem

0.8 % RA added

Gmm: 2.44

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1074.7	8.6	120.3	2.3	10.2	1.9	0.80	2.482	2.471	2.479	2.477	1198.8	701.6	1199.8	2.41	150.2	1.4	IRRM
0.8-2	1076	8.8	119.1	2.3	10.1	1.9	0.82	2.504	2.496	2.501	2.500	1188.1	692.1	1190.4	2.38	148.8	2.3	Hveem
0.8-3	1072.8	8.8	119.9	2.6	10.2	2.2	0.82	2.476	2.478	2.48	2.478	1197.8	700.1	1199.8	2.40	149.6	1.8	Fatigue
0.8-4	1057.6	8.7	127.8	2.4	10.9	1.9	0.82	2.567	2.565	2.564	2.565	1187.7	689.7	1194.5	2.35	146.8	3.6	Fatigue
														Averages	2.39	148.83	2.2	

Aggregate: Halsey RAP/10% Virgin agg.
Asphalt: Cyclogen M/PBA-2
Mix Date: 11/26/93

BSG Date: 11/27/93
Gmm Date: 01/06/94

1.1 % RA added

Gmm: 2.445

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.1	1063.5	12	122.6	2.5	10.4	2.0	1.13	2.584	2.576	2.589	2.583	1192	687.8	1196.7	2.34	146.2	4.2	Hveem

1.4 % RA added

Gmm: 2.447

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1071	15.2	120.9	2.5	10.2	2.1	1.42	2.485	2.5	2.497	2.494	1201.8	703.5	1202.6	2.41	150.3	1.6	Hveem
1.4-2	1074.9	15	119.1	2.4	10.0	2.0	1.40	2.486	2.471	2.485	2.481	1202.7	703.3	1203.1	2.41	150.2	1.7	IRRM
1.4-3	1071.8	15.4	120.5	2.4	10.2	2.0	1.44	2.465	2.474	2.47	2.470	1197.5	701.4	1198.1	2.41	150.4	1.5	Fatigue
1.4-4	1073.2	15.3	123.9	2.6	10.4	2.1	1.43	2.518	2.531	2.525	2.525	1208.9	705.3	1210.3	2.39	149.4	2.2	Fatigue
														Averages	2.40	150.06	1.7	

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Press (psi)	Displace.	Stability number
C-1	2.650	2.635	2.641	2.642	1188.9	691.5	1207.1	2.31	6.5	27	3.99	46*
0.2-2	2.606	2.598	2.600	2.601	1190.2	694.0	1202.5	2.34	5.5	23	3.93	50*
0.5	2.491	2.468	2.472	2.477	1199.3	704.8	1200.2	2.42	0.9	71	4.98	17
0.8-2	2.504	2.496	2.501	2.500	1188.1	692.1	1190.4	2.38	2.3	32	4.38	37
1.1	2.584	2.576	2.589	2.583	1192.0	687.8	1196.7	2.34	4.2	90	5.02	13
1.4-1	2.485	2.500	2.497	2.494	1201.8	703.5	1202.6	2.41	1.6	57	4.59	22

After Compaction (second BSG)

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Press (psi)	Displace.	Stability number
C-1	2.485	2.484	2.490	2.486	1187.7	694.5	1191.3	2.39	3.0	15	4.50	56
0.2-2	2.498	2.498	2.496	2.497	1188.9	695.9	1191.8	2.40	3.3	13	4.62	59
0.5	2.300	2.322	2.303	2.308	1185.2	700.4	1186.4	2.44	0.2	71	5.42	13*
0.8-2	2.350	2.350	2.380	2.360	1184.9	699.5	1185.7	2.44	0.1	37	6.19	22*
1.1	2.433	2.415	2.410	2.419	1190.5	699.2	1192.0	2.42	1.2	27	5.16	37
1.4-1	2.365	2.368	2.352	2.362	1197.1	707.9	1197.6	2.44	0.1	64	5.57	14*

COMPRESSIVE STRENGTH OF BITUMINOUS MIXTURES
OSHD Test Method 307C-86

1. Bulk Specific Gravity Data:

Aggregate: Halsey RAP/10% Virgin agg.
Asphalt: Cyclogen M/PBA-2
Mix Date: 11/26/93

BSG Date: 11/27/93
Gmm Date: 01/06/94

Bulk Specific Gravity - Volume Air Voids Data

0.2 % RA added

Gmm: 2.478

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1603.8	3.2	184	3.5	10.4	1.9	0.20	3.98	3.971	3.962	3.971	1794.3	1044.8	1833.9	2.27	141.9	8.2	Dry
0.2-2	1596.4	3.3	184.3	3.4	10.5	1.8	0.21	3.926	3.922	3.912	3.920	1788.3	1036.4	1819.8	2.28	142.4	7.9	Wet
														Averages	2.28	142.2	8.1	

0.8% RA added

Gmm: 2.44

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1582.7	13.1	179.2	3.2	10.3	1.8	0.83	3.807	3.807	3.811	3.808	1775.3	1029.3	1792.6	2.33	145.1	4.7	Dry
0.8-2	1605.4	13.2	181.5	3.4	10.3	1.9	0.82	3.966	3.983	3.975	3.975	1800.5	1041.8	1833.3	2.27	141.9	7.0	Wet
														Averages	2.30	143.5	5.9	

1.4 % RA added

Gmm: 2.447

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1596.4	22.5	185.2	3.5	10.4	1.9	1.41	3.926	3.927	3.922	3.925	1803.9	1035.6	1822.3	2.29	143.1	6.3	Dry
1.4-2	1609.4	22.5	182	5.3	10.3	2.9	1.40	3.903	3.896	3.909	3.903	1812.5	1038.7	1823.6	2.31	144.1	5.6	Wet
															2.30	143.6	6.0	

2. Compressive Strength Results:

Specimen	Load dry cure (lbs.)	Load wet cure (lbs.)	Strength dry cure (PSI)	Strength wet cure (PSI)	Wet/Dry Ratio
0.2	12400	10500	987	836	0.85
0.8	14100	10100	1122	804	0.72
1.4	11300	12900	899	1027	1.14

ODOT Recycling Study - 1993

Aggregate: Halsey RAP/30% Virgin agg.
Asphalt: Cyclogen L/ PBA-2
Mix Date: 12/24/93

BSG Date: 12/24/93
Gmm Date: 01/06/94

Bulk Specific Gravity - Volume Air Voids Data

0.0 % RA added (control specimen)

Gmm: 2.462

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
C-1	834	0	356.5	11.9	30.6	3.3	0.00	2.63	2.624	2.632	2.629	1188.1	687	1202	2.31	144.0	6.3	
C-1	833.4	0	358.4	11.9	30.8	3.3	0.00	2.592	2.587	2.588	2.589	1193.8	687.9	1201.7	2.32	145.0	5.6	Hveem
														Averages	2.32	144.5	6.0	

0.2 % RA added

Gmm: 2.469

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	836.1	1.7	356.9	11.6	30.5	3.3	0.20	2.608	2.603	2.602	2.604	1194.2	688	1204.8	2.31	144.2	6.4	Hveem
0.2-2	837.2	1.7	357.8	12.1	30.6	3.4	0.20	2.606	2.604	2.608	2.606	1202.6	691.5	1211.1	2.31	144.4	6.3	Fatigue
0.2-3	835.8	1.6	361.6	11.9	30.8	3.3	0.19	2.722	2.721	2.723	2.722	1205	695.9	1224	2.28	142.4	7.6	Fatigue
0.2-4	840.8	1.9	366.4	11.7	31.0	3.2	0.23	2.645	2.637	2.623	2.635	1216.1	704.5	1225.3	2.34	145.7	5.4	IRRM
														Averages	2.32	144.2	6.4	

0.5 % RA added

Gmm: 2.474

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.5	836.4	4.3	357.8	11.8	30.5	3.3	0.51	2.652	2.651	2.653	2.652	1202.4	690.1	1213	2.30	143.5	7.1	Hveem

0.8 % RA added

Gmm: 2.46

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	839	6.6	366.5	11.8	30.9	3.2	0.79	2.625	2.612	2.617	2.618	1219.6	706.8	1226.2	2.35	146.5	4.5	IRRM
0.8-2	834	6.7	364.4	12.1	30.9	3.3	0.80	2.59	2.602	2.588	2.593	1201.9	693.4	1207.6	2.34	145.9	5.0	Hveem
0.8-3	836.2	6.5	357.7	12.1	30.5	3.4	0.78	2.555	2.551	2.564	2.557	1204.2	698.7	1206.9	2.37	147.9	3.7	Fatigue
0.8-4	835.9	6.6	366.4	11.7	31.0	3.2	0.79	2.659	2.652	2.648	2.653	1219.9	702.3	1228.3	2.32	144.7	5.7	Fatigue
														Averages	2.35	146.2	4.7	

Aggregate: Halsey RAP/30% Virgin agg. BSG Date: 12/24/93
Asphalt: Cyclogen L/ PBA-2 Gmm Date: 01/06/94
Mix Date: 12/24/93

1.1 % RA added

Gmm: 2.456

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.1	834.8	9.1	362.1	11.7	30.7	3.2	1.09	2.61	2.609	2.615	2.611	1212.3	698	1217.5	2.33	145.6	5.0	Hveem

1.4 % RA added

Gmm: 2.445

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	828.5	11.7	358.5	11.7	30.6	3.3	1.41	2.48	2.471	2.469	2.473	1205.5	706.7	1206.3	2.41	150.6	1.3	IRRM
1.4-2	835.8	11.8	357	12.2	30.3	3.4	1.41	2.586	2.591	2.595	2.591	1203.4	694.4	1206.3	2.35	146.7	3.9	Fatigue
1.4-3	837.1	11.7	360.3	12	30.5	3.3	1.40	2.518	2.514	2.508	2.513	1214.5	712.2	1215.8	2.41	150.5	1.4	Hveem
1.4-4	836.5	11.8	368.5	12.2	31.0	3.3	1.41	2.595	2.594	2.596	2.595	1222.8	708.7	1226	2.36	147.5	3.3	Fatigue
															2.40	148.8	2.5	

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
0.2-1	2.608	2.603	2.602	2.604	1194.2	688	1204.8	2.31	6.4	30	3.41	44
0.5	2.652	2.651	2.653	2.652	1202.4	690.1	1213	2.30	7.1	48	3.86	30
0.8-2	2.59	2.602	2.588	2.593	1201.9	693.4	1207.6	2.34	5.0	31	3.93	40
1.1	2.61	2.609	2.615	2.611	1212.3	698	1217.5	2.33	5.0	41	3.7	34
1.4-3	2.518	2.514	2.508	2.513	1214.5	712.2	1215.8	2.41	1.4	61	3.77	25

After Compaction (second BSG)

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
0.2-1	2.478	2.477	2.478	2.478	1191.7	699.7	1196.1	2.40	2.8	17	4.5	53
0.5	2.54	2.546	2.547	2.544	1201.2	699.9	1205.1	2.38	3.9	21	4.37	48
0.8-2	2.496	2.498	2.496	2.497	1202.2	704.2	1204.2	2.40	2.3	19	4.71	48
1.1	2.515	2.512	2.527	2.518	1212	709.4	1213.8	2.40	2.2	25	4.38	43
1.4-3	2.392	2.389	2.381	2.387	1210.3	716.4	1210.9	2.45	0.0	76	5.52	12*

COMPRESSIVE STRENGTH OF BITUMINOUS MIXTURES
OSHD Test Method 307C-86

1. Bulk Specific Gravity Data:

Aggregate: Halsey RAP/30% Virgin agg. BSG Date: 11/27/93
Asphalt: Cyclogen L/ PBA-2 Gmm Date: 01/06/94
Mix Date: 11/23/93

Bulk Specific Gravity - Volume Air Voids Data

0.2 % RA added

Gmm: 2.469

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1261.3	2.4	551	17.1	31.0	3.1	0.19	4.009	4.018	3.994	4.007	1798.3	1023.7	1815.3	2.27	141.8	8.0	Dry
0.2-2	1259	2.6	536	17	30.5	3.2	0.21	4.13	4.132	4.13	4.131	1829.8	1039.1	1853.5	2.25	140.2	9.0	Wet
														Averages	2.26	141.0	8.5	

0.8% RA added

Gmm: 2.474

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1254	10.2	542.7	17	30.7	3.1	0.81	4.082	4.072	4.059	4.071	1824.7	1049.1	1856.1	2.26	141.1	8.6	Dry
0.8-2	1252.8	10.9	541.7	16.9	30.7	3.1	0.87	4.08	4.082	4.091	4.084	1840.5	1052.5	1863.7	2.27	141.6	8.3	Wet
0.8-3	1257.2	10.2	544.2	17	30.7	3.1	0.81	4.082	4.072	4.059	4.071	1824.7	1049.1	1856.1	2.26	141.1	8.6	Dry
0.8-4	1247.7	10.1	547.1	17.7	31.0	3.2	0.81	4.08	4.082	4.091	4.084	1840.5	1052.5	1863.7	2.27	141.6	8.3	Wet
														Averages	2.26	141.3	8.4	

1.4 % RA added

Gmm: 2.445

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 add grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1257.2	18.1	552.8	17	30.9	3.1	1.44	4.01	3.998	3.999	4.002	1832.5	1044.3	1847	2.28	142.5	6.6	Dry
1.4-2	1257.9	17.5	550.4	16.9	30.8	3.1	1.39	4.038	4.015	4.02	4.024	1832.3	1043.8	1848	2.28	142.2	6.8	Wet
															2.28	142.3	6.7	

2. Compressive Strength Results:

Specimen	Load dry cure (lbs.)	Load wet cure (lbs.)	Strength dry cure (PSI)	Strength wet cure (PSI)	Wet/Dry Ratio
0.2	8540	7500	680	597	0.88
0.8	10820	6300	861	501	0.58
1.4	8200	7700	653	613	0.94

ODOT Recycling Study - 1993

Aggregate: Halsey RAP/30% Virgin agg. BSG Date: 10/20/93
Asphalt: Cyclogen M/ PBA-2 Gmm Date: 01/06/94
Mix Date: 10/16/93

Bulk Specific Gravity - Volume Air Voids Data

0.0 % RA added (control specimen)

Gmm: 2.462

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
C-1	838.9	0	359.6	11.1	30.6	3.1	0.00	2.641	2.636	2.651	2.643	1198.1	691.9	1210.4	2.31	144.2	6.1	
C-2	838	0	361.5	10.8	30.8	3.0	0.00	2.55	2.553	2.538	2.547	1208.3	705.1	1217.4	2.36	147.2	4.2	
														Averages	2.33	145.7	5.2	

0.2 % RA added

Gmm: 2.469

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	838.8	1.6	364.3	10.7	30.9	2.9	0.19	2.61	2.619	2.605	2.611	1211.9	704.4	1222.8	2.34	145.9	5.3	IRRM
0.2-2	838.2	10.8	364.3	10.8	30.6	3.0	1.29	2.595	2.587	2.609	2.597	1207.6	701.4	1216.6	2.34	146.3	5.1	Lost
0.2-3	840.6	10.9	362.2	10.9	30.5	3.0	1.30	2.645	2.65	2.643	2.646	1215.3	703.2	1228.1	2.32	144.5	6.2	Fatigue
0.2-4	838	10.9	358.3	10.9	30.3	3.0	1.30	2.627	2.635	2.648	2.637	1201.1	699.9	1211.8	2.35	146.4	5.0	Fatigue
														Averages	2.34	145.8	5.4	

0.5 % RA added

Gmm: 2.478

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.5	835.7	4.4	367	10.6	31.0	2.9	0.53	2.568	2.576	2.571	2.572	1217.5	708.4	1222.5	2.37	147.8	4.4	Lost

0.8 % RA added

Gmm: 2.479

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	835.9	6.8	362.1	10.7	30.7	3.0	0.81	2.63	2.625	2.635	2.630	1209.2	701.7	1216.6	2.35	146.5	5.3	Lost
0.8-2	836.7	7.4	362.1	10.7	30.6	3.0	0.88	2.583	2.579	2.595	2.586	1209	701.9	1217.6	2.34	146.3	5.4	Fatigue
0.8-3	836.4	6.8	367.9	10.6	31.0	2.9	0.81	2.612	2.627	2.61	2.616	1217	703.5	1224.8	2.33	145.7	5.8	Fatigue
0.8-4	838	6.7	368.7	10.8	31.0	2.9	0.80	2.62	2.625	2.625	2.623	1215.6	704.5	1222.3	2.35	146.5	5.3	IRRM
														Averages	2.34	146.2	5.5	

Aggregate: Halsey RAP/30% Virgin agg.
Asphalt: Cyclogen M/ PBA-2
Mix Date: 10/16/93

BSG Date: 10/20/93
Gmm Date: 01/06/94

1.1 % RA added

Gmm: 2.452

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.1	837.1	9.6	364.7	10.8	30.7	3.0	1.15	2.577	2.572	2.576	2.575	1216.3	707.6	1221.3	2.37	147.7	3.4	Lost

1.4 % RA added

Gmm: 2.449

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	836.2	12.2	361.7	10.9	30.5	3.0	1.46	2.537	2.552	2.55	2.546	1219.9	713.7	1222.4	2.40	149.6	2.1	Fatigue
1.4-2	837.4	12.8	366.6	10.8	30.7	2.9	1.53	2.555	2.565	2.56	2.560	1214.7	707.4	1218.1	2.38	148.4	2.9	Lost
1.4-3	834.9	11.5	365.1	10.8	30.8	3.0	1.38	2.575	2.572	2.579	2.575	1214	704.3	1217.5	2.37	147.6	3.4	Fatigue
1.4-4	837.6	11.8	367.5	10.8	30.8	2.9	1.41	2.536	2.556	2.558	2.550	1225.6	712.2	1227.7	2.38	148.4	2.9	IRRM
															2.38	148.5	2.8	

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1*	836.5	1.7	357.8	11.6	30.6	3.2	0.20	2.595	2.575	2.592	2.587	1197.2	690.2	1206.2	2.32	144.8	5.3	Hveem
0.5-1*	836.9	4.4	356.2	11.7	30.4	3.3	0.53	2.67	2.648	2.648	2.655	1207.6	696.9	1218.8	2.31	144.4	5.5	Hveem
0.8-1*	834.9	6.8	358	11.9	30.5	3.3	0.81	2.675	2.681	2.676	2.677	1210	699.7	1220.2	2.32	145.1	5.1	Hveem
1.1-1*	837.4	9.5	358.2	12.2	30.4	3.4	1.13	2.527	2.536	2.525	2.529	1200.8	699	1203.2	2.38	148.6	2.8	Hveem
1.4-1*	835.1	11.7	358.2	12	30.4	3.4	1.40	2.546	2.528	2.54	2.538	1209.9	701.9	1211.9	2.37	148.0	3.1	Hveem

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C*	2.496	2.552	2.527	2.525	1178.8	678	1182.2	2.34	5.0	22	3.72	50
0.2*	2.595	2.575	2.592	2.587	1197.2	690.2	1206.2	2.32	6.0	44	4.10	30
0.5*	2.67	2.648	2.648	2.655	1207.6	696.9	1218.8	2.31	6.6	35	4.02	39*
0.8*	2.675	2.681	2.676	2.677	1210	699.7	1220.2	2.32	6.2	41	4.45	33*
1.1*	2.527	2.536	2.525	2.529	1200.8	699	1203.2	2.38	2.9	35	4.41	34
1.4*	2.546	2.528	2.54	2.538	1209.9	701.9	1211.9	2.37	3.1	38	4.05	34

After Compaction (second BSG)

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C*	2.496	2.5	2.492	2.496	1193.4	699	1200	2.38	3.2	15	4.13	58
0.2*	2.495	2.489	2.495	2.493	1195.2	702.3	1199.8	2.40	2.7	20	4.4	49
0.5*	2.556	2.555	2.555	2.555	1208.1	705.4	1212.1	2.38	3.8	26	4.51	41
0.8*	2.57	2.58	2.57	2.573	1208.9	706.5	1213.6	2.38	3.8	31	4.59	36
1.1*	2.42	2.425	2.41	2.418	1200.6	709.6	1202	2.44	0.6	39	5.16	28
1.4*	2.45	2.465	2.448	2.454	1209.4	712.1	1210.5	2.43	0.9	35	4.62	33

COMPRESSIVE STRENGTH OF BITUMINOUS MIXTURES
OSHD Test Method 307C-86

1. Bulk Specific Gravity Data:

Aggregate: Halsey RAP/30% Virgin agg.
Asphalt: Cyclogen M/ PBA-2
Mix Date: 10/23/93

BSG Date: 11/27/93
Gmm Date: 01/06/94

Bulk Specific Gravity - Volume Air Voids Data

0.2 % RA added

Gmm: 2.469

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1250.3	2.7	551.8	17.5	31.2	3.2	0.22	4.009	4.018	3.994	4.007	1798.3	1023.7	1815.3	2.27	141.8	8.0	Dry
0.2-2	1255.7	2.7	554.5	16.2	31.2	2.9	0.22	4.13	4.132	4.13	4.131	1829.8	1039.1	1853.5	2.25	140.2	9.0	Wet
														Averages	2.26	141.0	8.5	

0.8% RA added

Gmm: 2.479

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1255.6	10.3	551.9	17.3	31.0	3.1	0.82	4.082	4.072	4.059	4.071	1824.7	1049.1	1856.1	2.26	141.1	8.8	Dry
0.8-2	1252.3	10.3	563.3	17	31.5	3.0	0.82	4.08	4.082	4.091	4.084	1840.5	1052.5	1863.7	2.27	141.6	8.5	Wet
														Averages	2.26	141.3	8.6	

1.4 % RA added

Gmm: 2.449

Specimen	RAP Wt. grams	RA added grams	V. Agg. grams	PBA-2 added grams	Agg./RAP %	PBA-2 %	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1251.7	17.7	557.4	17	31.2	3.0	1.41	4.01	3.998	3.999	4.002	1832.5	1044.3	1847	2.28	142.5	6.8	Dry
1.4-2	1254.4	17.6	551.3	17.1	30.9	3.1	1.40	4.038	4.015	4.02	4.024	1832.3	1043.8	1848	2.28	142.2	7.0	Wet
															2.28	142.3	6.9	

2. Compressive Strength Results:

Specimen	Load dry cure (lbs.)	Load wet cure (lbs.)	Strength dry cure (PSI)	Strength wet cure (PSI)	Wet/Dry Ratio
0.2	11000	5760	875	458	0.52
0.8	8980	6760	715	538	0.75
1.4	10100	7100	804	565	0.70

ODOT Recycling Study - 1993

Aggregate: Durkee-Lime
Asphalt: Cyclogen L
Mix Date: 1/28/94

Bulk Specific Gravity - Volume Air Voids Data

0.0 % RA added (control specimen)

Gmm: 2.377

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
C-1	1202.5	0	0.00	2.607	2.613	2.602	2.607	1210.4	689.3	1212.3	2.31	144.4	2.6	Hveem

0.2 % RA added

Gmm: 2.37

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1206	2.4	0.20	2.525	2.520	2.527	2.524	1177.6	672.7	1178.8	2.33	145.2	1.8	Fatigue
0.2-2	1204.1	2.6	0.22	2.545	2.545	2.531	2.540	1187.9	679	1188.8	2.33	145.4	1.7	Hveem
0.2-3	1208.3	2.4	0.20	2.521	2.502	2.505	2.509	1181.4	677	1182.5	2.34	145.8	1.4	IRRM
0.2-4	1193.4	2.4	0.20	2.524	2.534	2.519	2.526	1185.5	679.3	1186.4	2.34	145.9	1.4	Fatigue
										Averages	2.33	145.6	1.6	

0.5 % RA added

Gmm: 2.361

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.5	1220.2	6.1	0.50	2.527	2.531	2.521	2.526	1182.5	676.4	1183.6	2.33	145.5	1.3	Hveem

0.8 % RA added

Gmm: 2.363

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1193.7	9.5	0.80	2.524	2.501	2.514	2.513	1186.4	682.3	1187.2	2.35	146.6	0.6	IRRM
0.8-2	1206.4	9.6	0.80	2.482	2.49	2.497	2.490	1184.4	680.6	1185.0	2.35	146.5	0.6	Hveem
0.8-3	1168.3	9.4	0.80	2.486	2.482	2.476	2.481	1177.0	675.7	1177.9	2.34	146.2	0.8	Fatigue
0.8-4	1195.2	9.8	0.82	2.477	2.478	2.491	2.482	1169.1	669.9	1169.9	2.34	145.9	1.0	Fatigue
										Averages	2.34	146.3	0.8	

Aggregate: Durkee-Lime
Asphalt: Cyclogen L
Mix Date: 1/21/94

1.1 % RA added

Gmm: 2.373

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.1	1211.8	13.1	1.08	2.535	2.538	2.54	2.538	1189.9	680.5	1190.6	2.33	145.6	1.7	Hveem

1.4 % RA added

Gmm: 2.359

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1206.8	16.7	1.38	2.529	2.516	2.535	2.527	1186.8	678.5	1187.6	2.33	145.5	1.2	Hveem
1.4-2	1210.1	16.7	1.38	2.500	2.501	2.473	2.491	1181.1	675.8	1181.9	2.33	145.6	1.1	IRRM
1.4-3	1201.7	16.7	1.39	2.507	2.525	2.523	2.518	1190.2	681.0	1191.1	2.33	145.6	1.1	Fatigue
1.4-4	1197.2	16.8	1.40	2.550	2.542	2.534	2.542	1193.0	680.6	1194.0	2.32	145.0	1.5	Fatigue
										Averages	2.33	145.4	1.2	

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C-1	2.607	2.613	2.602	2.607	1210.4	689.3	1212.3	2.31	2.6	35	3.16	42
0.2-2	2.545	2.545	2.531	2.540	1187.9	679.0	1188.8	2.33	1.7	59	3.64	26
0.5	2.527	2.531	2.521	2.526	1182.5	676.4	1183.6	2.33	1.3	73	3.76	21
0.8-2	2.482	2.490	2.497	2.490	1184.4	680.6	1185.0	2.35	0.6	110	4.15	12
1.1	2.535	2.538	2.540	2.538	1189.9	680.5	1190.6	2.33	1.7	89	3.66	17
1.4-1	2.529	2.516	2.535	2.527	1186.8	678.5	1187.6	2.33	1.2	118	3.76	12

After Compaction (second BSG)

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C-1	2.508	2.505	2.510	2.508	1208.8	696.9	1209.2	2.36	0.7	47	3.03	35
0.2-2	2.428	2.432	2.423	2.428	1181.3	681.1	1182.2	2.36	0.5	82	4.11	17
0.5	2.403	2.388	2.401	2.397	1175.8	677.3	1177.4	2.35	0.4	146	4.13	8
0.8-2	2.355	2.350	2.366	2.357	1162.9	669.6	1164.2	2.35	0.5	100	5.74	10
1.1	2.410	2.412	2.413	2.412	1179.5	677.6	1180.8	2.34	1.2	145	4.03	9
1.4-1	2.410	2.401	2.415	2.409	1176.9	676.0	1178.1	2.34	0.6	132	4.98	8

ODOT Recycling Study - 1993

Aggregate: Durkee-Lime
Asphalt: Cyclogen M
Mix Date: 1/28/94

Bulk Specific Gravity - Volume Air Voids Data

0.0 % RA added (control specimen)

Gmm: 2.374

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (In.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
C-1	1202.5	0	0.00	2.551	2.564	2.55	2.555	1198.9	683	1200.1	2.32	144.7	2.3	Hveem

0.2 % RA added

Gmm: 2.366

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.2-1	1206	2.4	0.20	2.579	2.535	2.556	2.557	1198.8	686.4	1200	2.33	145.6	1.3	IRRM
0.2-2	1204.1	2.6	0.22	2.593	2.603	2.592	2.596	1199.7	682.1	1201.8	2.31	144.0	2.4	Fatigue
0.2-3	1208.3	2.4	0.20	2.545	2.560	2.559	2.555	1203.3	690.3	1204.5	2.34	146.0	1.1	Fatigue
0.2-4	1193.4	2.4	0.20	2.538	2.535	2.536	2.536	1191	681.1	1192.1	2.33	145.4	1.5	Hveem
										Averages	2.33	145.3	1.6	

0.5 % RA added

Gmm: 2.369

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.5	1220.2	6.1	0.50	2.538	2.559	2.55	2.549	1210.6	695.0	1211.4	2.34	146.3	1.0	Hveem

0.8 % RA added

Gmm: 2.353

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
0.8-1	1193.7	9.5	0.80	2.523	2.515	2.51	2.516	1186.9	679.4	1187.9	2.33	145.6	0.8	IRRM
0.8-2	1206.4	9.6	0.80	2.543	2.546	2.562	2.550	1199.1	686	1200.2	2.33	145.5	0.9	Hveem
0.8-3	1168.3	9.4	0.80	2.475	2.483	2.495	2.484	1164.0	663.6	1165.0	2.32	144.9	1.3	Fatigue
0.8-4	1195.2	9.8	0.82	2.564	2.53	2.522	2.539	1194.4	683.6	1195.7	2.33	145.5	0.9	Fatigue
										Averages	2.33	145.4	1.0	

Aggregate: **Durkee-Lime**
Asphalt: **Cyclogen M**
Mix Date: 1/21/94

1.1 % RA added

Gmm: 2.354

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.1	1211.8	13.1	1.08	2.55	2.589	2.572	2.570	1215.8	694.4	1216.7	2.33	145.3	1.1	Hveem

1.4 % RA added

Gmm: 2.354

Specimen	RAP Wt. grams	RA added grams	RA %	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	Thick (ave (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Unit Wt. (pcf)	Air Voids %	Notes
1.4-1	1206.8	16.7	1.38	2.573	2.593	2.606	2.591	1207.5	686.8	1208.6	2.31	144.4	1.7	Fatigue
1.4-2	1210.1	16.7	1.38	2.568	2.578	2.553	2.566	1209.3	690	1210.5	2.32	145.0	1.3	IRRM
1.4-3	1201.7	16.7	1.39	2.577	2.58	2.572	2.576	1205.9	686.4	1207.2	2.32	144.5	1.6	Hveem
1.4-4	1197.2	16.8	1.40	2.555	2.54	2.554	2.550	1196	679.4	1197.1	2.31	144.2	1.9	Fatigue
										Averages	2.32	144.5	1.6	

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C-1	2.551	2.564	2.55	2.555	1188.9	691.5	1207.1	2.31	2.9	27	3.1	50
0.2-4	2.538	2.535	2.536	2.536	1191	681.1	1192.1	2.33	1.5	46	3.17	35
0.5	2.538	2.559	2.55	2.549	1210.6	695.0	1211.4	2.34	1.0	64	3.35	26
0.8-2	2.543	2.546	2.562	2.550	1199.1	686	1200.2	2.33	0.9	114	3.42	14
1.1	2.55	2.589	2.572	2.570	1215.8	694.4	1216.7	2.33	1.1	158	3.64	8
1.4-1	2.573	2.593	2.606	2.591	1207.5	686.8	1208.6	2.31	1.7	48	3.13	34

After Compaction (second BSG)

Bulk Specific Gravity - Volume Air Voids Data

Specimen	Thick 1 (in.)	Thick 2 (in.)	Thick 3 (in.)	ave.Thick (in.)	Air Wt. grams	H2O Wt. grams	SSD Wt. grams	Gmb	Air Voids %	Horiz. Pre (psi)	Displace.	Stability number
C-1	2.448	2.451	2.455	2.451	1195.8	691.8	1196.3	2.37	0.2	67	3.44	24
0.2-4	2.395	2.385	2.390	2.390	1184.7	683.7	1185.8	2.36	0.3	118	3.74	12
0.5	2.430	2.455	2.440	2.442	1200.6	694.0	1201.6	2.37	0.2	138	3.95	10
0.8-2	2.420	2.422	2.418	2.420	1188.3	681.7	1190.2	2.34	0.7	220	4.04	4
1.1	2.439	2.445	2.435	2.440	1186.0	680.6	1187.6	2.34	0.6	131	4.56	9
1.4-1	2.492	2.500	2.495	2.496	1200.5	688.0	1201.8	2.34	0.7	106	3.01	17