THE USE OF PERFORMANCE GRADED ASPHALT CEMENT IN RECYCLED HOT MIX

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ABSTRACT

Recycled asphalt pavement (RAP) has been used in the hot mix industry with good success since the early 1970s. The recent introduction of SHRP performance graded asphalt cement (PGAC) specifications did not examine the issue of recycling. The Ministry of Transportation of Ontario (MTO) developed a recycling strategy where a particular PGAC would be used, depending on the location and the percentage of RAP being used. This is an interim stage until further research and field verification can be done.

In 1998 the Region of Ottawa-Carleton (RMOC) tendered a hot mix paving contract calling for three lifts of hot mix using PG 58-34. Beaver Road Builders, the successful bidder, obtained the permission of RMOC to use 20% RAP in the base lifts. The only requirement was that the finished asphalt cement in the road had to conform to the contract requirements of PG 58-34. McAsphalt Engineering Services analyzed the RAP and developed the required virgin PGAC to give a final PGAC of PG 58-34 in the road.

This paper describes the pre-engineering work in the laboratory, the field preparation for construction and the laboratory testing on the field samples. Also discussed are recommendations to ensure successful use of RAP mixes utilizing PGAC.

RÉSUMÉ

Les revêtements bitumineux de recyclage (RBR) ont été utilisés dans l'industrie des enrobés à chaud avec un bon succès depuis le début des années 1970. Lors de l'introduction récente des spécifications des bitumes SHRP classés selon la performance (bitume PG) on n'a pas examiné la question du recyclage. Le Ministère des Transports de l'Ontario (MTO) a développé une stratégie de recyclage où un bitume PG particulier serait utilisé, selon la localisation et le pourcentage de RBR utilisé. C'est une étape intérimaire jusqu'à ce que l'on puisse faire davantage de recherche et de vérification sur le chantier.

En 1998, la région d'Ottawa-Carleton (RMOC) a fait un appel d'offres d'un contrat d'enrobé à chaud demandant trois couches d'enrobés avec bitume PG 58-34. Les Constructeurs de Routes Beaver, le soumissionnaire gagnant, a obtenu la permission de RMOC d'utiliser 20% de RBR dans les couches de base. La seule exigence était que le bitume sur la route se conforme aux exigences du PG 58-34. Les Services d'Ingénierie McAsphalt ont analysé le RBR et ont développé le bitume PG original requis pour donner un bitume final PG 58-34 sur la route.

Cet exposé décrit le travail d'ingénierie d'avant projet en laboratoire, la préparation du chantier pour la construction et les essais de laboratoire sur les échantillons du chantier. On discute aussi des recommandations pour assurer une fructueuse utilisation du RBR avec les bitumes PG.

1. INTRODUCTION

The use of recycled asphalt pavement (RAP) has been a mainstay of the hot mix industry for the last twenty-five years. Over the years the use of RAP has increased in both base and some surface mixes in the northern part of the Province of Ontario, and in base mixes in the rest of the Province. In the last two years, with the introduction of performance graded asphalt cements (PGAC), the use of RAP material has been reduced to a maximum of 20% in the hot mix. RAP is still being used as part of the granular material and as shouldering material but use in hot mix has decreased to almost nil. For this reason the RAP stockpiles are growing again. For example, in 1998, as part of their resurfacing program, the Regional Municipality of Ottawa-Carleton had over 200,000 metric tonnes of hot mix removed by grinding but only 80,000 tonnes were utilized in recycled mixes.

Another reason for the decline in the use of RAP in hot mix was that during the original Strategic Highway Research Program (SHRP) the researchers, when investigating the new specifications for asphalt cement, only dealt with the use of asphalt cement in virgin hot mix and did not take into account the use of PGAC in recycled hot mix. Because PGAC takes into account how the pavement will perform at both the high and low service temperatures, the use of RAP combined with these new PGACs has not been studied in great detail. Since there was very little information available in the industry, the hot mix contractors have tended to stay away from using high recycle mixes (>20%).

2. BACKGROUND

The Regional Municipality of Ottawa-Carleton (RMOC) tendered a road reconstruction project (RMOC 98-46 – Conroy Road) which involves the reconstruction of a two-lane road into a four-lane divided road. The pavement portion called for the placement of two 50-mm lifts of base mix (HL8) with one lift of surface course mix (HL1). The PGAC to be used on the project for all lifts was required to meet the AASHTO MP1 specification for PG 58-34. Beaver Road Builders Limited of Gloucester was awarded the contract and as part of their ongoing commitment to new asphalt technology decided to approach RMOC about the possibility of using a RAP HL8 mix in the base lift instead of the virgin mix. The Region gave permission for its use as long as the RAP mix conformed to the contract requirements. The main requirement was that the asphalt cement used in the mix placed on the road must conform to a PG 58-34. Beaver Road Builders Limited retained the services of McAsphalt Engineering Services to determine the virgin PG grade of asphalt cement required and to monitor the production during construction.

Samples of the RAP material that was to be used in the mix as well as the design values for asphalt content were forwarded to McAsphalt's laboratory in Scarborough. A pre-engineering study on the RAP material was implemented and a virgin PGAC determined to satisfy the RMOC contract requirements.

3. LABORATORY STUDY

The contractor decided to use a recycle percentage of 20 % and the total asphalt content in the base mix was 5.0%. The laboratory analyzed samples of RAP to determine what grade of virgin asphalt cement would be required to bring the finished mix laid on the road to a PG 58-34. In order to determine this the RAP material would have to be tested to determine the SHRP properties of the RAP asphalt cement (AC). Once the physical properties of the RAP AC were obtained, new blends (using the proper proportions of

RAP AC and virgin AC) were required using virgin PGAC that was specially formulated to meet the desired properties. For this to be accomplished, a number of trial blends were required before the proper virgin PGAC was obtained.

3.1 RAP Material

In order for a project of this type to succeed all the ingredients must be of consistent quality with a minimal amount of fluctuation in the properties. The stockpile management of the aggregates as well as of the RAP material will be discussed later in the paper.

Representative samples of the RAP material were obtained and analyzed in the laboratory. The asphalt cement was recovered from the RAP material using the Abson method of recovery (LS 284). A large amount of the recovered AC was needed for both the blending work and the determination of the SHRP properties of the RAP AC. The SHRP data on the asphalt cement extracted from the RAP material are shown in Table 1.

TABLE 1: SHRP Results on Recovered AC from RAP Material

Tests on Recovered AC	**Results**	**Specification**
Penetration @ 25°C, 100g, 5 sec	15	
DSR @ 76°C, G*/Sin δ, 10 rad/sec. kPa @ 82°C	5.453 2.639	
BBR on PAV Residue		
Stiffness @ -12°C, S, 60 sec, MPa @ -18°C	195.0 371.0	300 max
Slope @ -12°C, m, 60 sec @ -18°C	0.341 0.263	0.300 min
PG Range	**83.5-25.2**	

AC = Asphalt Cement; RAP = Recycled Asphalt Pavement; DSR = Dynamic Shear Rheometer; BBR = Bending Beam Rheometer; PAV = Pressure Aging Vessel; PG = Performance Grade

Based on the SHRP testing of the RAP AC this material would have a temperature range of 83.5-25.2. This indicates that the original asphalt cement used in the RAP material was most likely an 85/100 penetration asphalt cement which typically grades as a PG 58-22. In order to move the low temperature from a -22°C grade (-25.2°) to a -34°C grade a relatively soft virgin asphalt cement was required. This virgin asphalt cement must still maintain a high temperature performance grading of 58°C but have a low enough temperature on the cold end of the performance grading to give a –34°C finished grade. Based on our experience, a PGAC grade meeting –40°C was needed.

3.2 Blending Work

The RAP material to be utilized in the project had an average residual asphalt cement content of 4.55 %. According to Beaver Road Builders, the new base hot mix would contain 20 % recycled material and be designed with a total of 5.0 % asphalt cement including the contribution of the RAP asphalt cement. Based on these assumptions the ratio of the percentage of virgin AC to RAP AC is 81.8 to 18.2. In order to simply the blending process we assumed the ratio was 80/20. Each blend was prepared by blending the RAP AC with the virgin AC in the ratio of 1:4 and then this blend was tested according to the AASHTO MP1 protocols. The virgin asphalt cement used in each blend was also tested to the SHRP protocols.

3.3 Trial One

In order to establish a benchmark, a blend was put together using a PGAC that was available in the laboratory. The RAP/virgin PGAC blend was then tested to the SHRP protocols (Table 2). This quick blend gave us a better starting point to determine the proper virgin PGAC needed.

As Table 2 shows, the blended asphalt cement graded as a PG 58-28 (63.3-32.7) and missed meeting the required low temperature by 1.3°C. The blend had a strong top temperature, which indicated that the virgin PGAC could be made with a lower temperature on the bottom end without losing the 58°C temperature on the top. With this in mind a second trial batch was produced.

TABLE 2: SHRP Results on First Blend of Recovered Asphalt Cement with a Virgin Performance Graded Asphalt Cement (Trial 1)

Trial	**1**	**Spec**
Tests on Unaged Material		
Brookfield Viscosity @ 135°C mPa.s @ 165°C	0.475 0.145	3.0 max
Flash Point, COC, °C	230+	230 min
G*/Sin δ @ 58°C, 10 rad/sec, kPa @ 64°C	1.848 0.919	1.0 min
Tests on RTFO Residue		
% Loss, Weight	0.659	1.0 max
G*/Sin δ @ 58°C, 10 rad/sec, kPa @ 64°C	4.770 2.302	2.2 max
Tests on PAV (after RTFO) (Run @ 100°C), Residue		
G* x Sin δ @ 16°C, 10 rad/sec, kPa @ 19°C	2948 2062	5000 max
Creep Stiffness @ -24°C, s, 60 sec, MPa @ -18°C	192.5 94.7	300 max
Slope @ -24°C, m, 60 sec @ -18°C	0.289 0.341	0.300 min
PG Range	**63.3-32.7**	

COC = Cleveland Open Cup; RTFO = Rolling Thin Film Oven; PAV = Pressure Aging Vessel; PG = Performance Grade

3.4 Trial Two

The virgin PGAC was modified to give better low temperature properties, as there was sufficient room on the high temperature side to allow for this. The new PGAC was added to the RAP AC in the proper proportions and mixed. Then both the blended mixture (Blend #2) and the virgin PGAC were tested to the SHRP procedures with the test results as shown in Table 3. The test results obtained on Blend #2 show that the results came very close to meeting the PG 58-34 values needed. The virgin blend of PGAC had to be further modified to give better low temperature properties. A third trial was then initiated.

TABLE 3: SHRP Results of Virgin (Modified) Performance Graded Asphalt Cement (PGAC) and Blend of Recovered Asphalt Cement with the Modified PGAC (Trial 2)

Trial	Blend #2	Virgin #2	Spec
Tests on Unaged Material			
Brookfield Viscosity @ 135°C, mPa.s @ 165°C	0.425 0.135	0.312 0.110	3.0 max
Flash Point, COC, °C	230+	230+	230 min
G*/Sin δ @ 52°C, 10 rad/sec, kPa @ 58°C @ 64°C	 1.542 0.807	1.307 0.661	1.0 min
Tests on RTFO Residue			
% Loss, Weight	0.661	0.545	1.0 max
G*/Sin δ @ 52°C, 10 rad/sec, kPa @ 58°C @ 64°C	 4.507 2.228	3.684 1.787	2.2 min
Tests on PAV (after RTFO) (Run @ 100°C/90°C), Residue			
G* x Sin δ @ 10°C, 10 rad/sec, kPa @ 16°C @ 19°C	 2634 1863	2319	5000 max
Creep Stiffness @ -36°C, s, 60 sec, MPa @ -30°C @ -24°C @ -18°C	 168.5 77.9	470.5 206.5	300 max
Slope @ -36°C, m, 60 sec @ -30°C @ -24°C @ -18°C	 0.295 0.338	0.245 0.309	0.300 min
PG Range	**62.0-33.3**	**54.4-40.8**	

COC = Cleveland Open Cup; RTFO = Rolling Thin Film Oven; PAV = Pressure Aging Vessel; PG = Performance Grade

3.5 Trial Three

The virgin PGAC was reformulated using polymer to give better low temperature properties while still maintaining the high temperature needed to give the RAP mixture the required high temperature properties. The RAP AC and the newly formulated virgin PGAC were blended in the proper ratio and both the blend (#3) and the virgin PGAC (#3) were tested to the SHRP protocols. The laboratory results on these two samples are as shown in Table 4. As the results indicate the blend containing the virgin PGAC blend #3 gave results that satisfy the specification requirements that the asphalt cement shall conform to PG 58-34. The results on the temperature spread (60.0 – 35.0) indicate that the virgin asphalt cement had sufficient range in both high and low temperature to allow for any fluctuations which might occur in the RAP properties throughout the project. These fluctuations are a major factor that has to be carefully monitored to ensure that the recovered PGAC material taken from the road meets the SHRP requirements.

TABLE 4: SHRP Results on Virgin Polymer-Modified Performance-Graded Asphalt (PGAC) and on the Blend of the Virgin Polymer-Modified PGAC with Recovered Asphalt Cement (Trial 3)

Trial	**Blend #3**	**Virgin #3**	**Spec**
Tests on Unaged Material			
Brookfield Viscosity @ 135°C, mPa.s @ 165°C	0.368 0.120	0.275 0.095	3.0 max
Flash Point, COC, °C	230+	230+	230 min
G*/Sin δ @ 52°C, 10 rad/sec, kPa @ 58°C @ 64°C	 1.236 0.662	1.037 0.548	1.0 min
Tests on RTFO Residue			
% Loss, Weight	0.615	0.531	1.0 max
G*/Sin δ @ 52°C, 10 rad/sec, kPa @ 58°C @ 64°C	 3.468 1.712	2.921 1.495	2.2 min
Tests on PAV (after RTFO) (Run @ 100°C/90°C), Residue			
G* x Sin δ @ 10°C, 10 rad/sec, kPa @ 16°C @ 19°C	 1195	1302	5000 max
Creep Stiffness @ -36°C, s, 60 sec, MPa @ -30°C @ -24°C @ -18°C	 223.0 108.0	283.0 142.0	300 max
Slope @ -36°C, m, 60 sec @ -30°C @ -24°C @ -18°C	 0.271 0.306	0.293 0.312	0.300 min
PG Range	**60.0-35.0**	**52.3-43.8**	

COC = Cleveland Open Cup; RTFO = Rolling Thin Film Oven; PAV = Pressure Aging Vessel; PG = Performance Grade

4. LABORATORY STUDY RECOMMENDATIONS

Based on the laboratory work we recommended the use of the Trial #3 blend of the virgin PGAC. What had to be remembered was that this study was based on a stockpile sample of RAP material which was supposed to be representative of the RAP material to be used in the mix. The blending was based on the assumption that the hot mix design would have 5.0 % asphalt cement content and that the average percent asphalt cement in the RAP material was 4.55 %. As this project was the first of this type it was recommended that a large number of random representative samples be taken during production and be tested to the SHRP protocols. This would give the players involved a high level of comfort that the process of pre-engineering is viable and that this type of recycling can be done effectively and in a cost effective manner.

5. FIELD CONSTRUCTION

5.1 Stockpile Management

In order to decrease the possibility of large fluctuations in the SHRP test results on the asphalt samples taken from the road good RAP stockpile management is required. Because the RAP material has a large influence on the final product, good control has to be maintained to ensure that the RAP material is not only consistent in asphalt content and gradation but is also isolated to avoid any contamination. Beaver Road Builders maintains a large area for stockpiling RAP material removed from various constructions projects (Photo 1). Each stockpile only contains RAP material from one construction project. The stockpiles are also separated by mix type (i.e.; surface, base, HDBC, HL1 etc.). In order to accurately control these piles excellent quality control is done to accurately monitor what is in each stockpile. As

PHOTOGRAPH 1: Area Containing Various Stockpiles of Recycled Asphalt Pavement (RAP) Material from Different Construction Projects

extra protection against contamination, Beaver has a policy that if the asphalt grinding unit breaks through the asphalt layer into the granular material below that particular truckload of RAP material is rerouted to a separate stockpile especially for contaminated RAP. The stockpile in the foreground of photograph #1 is the RAP material being used in the HL8 base mix for this project on Conroy Road.

5.2 Mix Design

The mix design was developed by Beaver Road Builders in their CCIL certified Type `A' asphalt laboratory. The mix comprised the following ingredients and had the following Marshall mix properties:

Ingredients:	HL8 Stone	25.0 %
	HL3 Stone	12.5 %
	Sand	42.0 %
	Mineral Filler	0.5 %
	RAP	20.0 %
	PGAC	5.0 %
Marshall Mix Properties:		
	Marshall Stability (N @ 60°C)	15208
	Flow Index (@ 3.5% Air Voids)	9.6
	% Air Voids in Mixture	3.9
	% Voids in Mineral Aggregate	14.8
	Bulk Relative Density (Mg/m^3)	2.423
	Maximum Relative Density (Mg/m^3)	2.521

The mix was produced in an 8000 lb Barber Greene batch plant (Photo 2), which had been modified to include RAP capability, mineral filler silo, liquid anti-strip addition and a fibre silo (used in special mixes such as SMA).

PHOTOGRAPH 2: Beaver Road Builders 8000 lb Barber Greene Batch Plant

6. FIELD TESTING

6.1 Day One

The initial construction of the first lift of HL8 RAP hot mix started on October 26, 1998. Two samples of the recycle mix were taken at random intervals and sent to McAsphalt's laboratory for analysis of the recovered asphalt cement. A sample of the virgin PGAC (MacPlus) was also obtained from the contractor's asphalt storage tank and tested to the AASHTO MP1 protocols. The test results obtained by the laboratory on the recovered asphalt cement from the hot mix samples as well as the test results on the virgin PGAC (MacPlus) are shown in Tables 5 and 6.

TABLE 5: SHRP Test Results on Field Samples from first Lift of HL8 RAP Hot Mix (October 26 1998)

Sample #	1	2	Spec
Date Sampled	Oct 26/98	Oct 26/98	
Lot #	1	1	
Sublot #	1	2	
Station	51+185	51+401	
Tests on Recovered PGAC			
DSR, G*/Sin δ, 10 rad/sec, kPa @ 52°C @ 58°C @ 64°C	3.664 1.804	7.257 3.441 1.681	2.2 min
Tests on PAV Residue			
DSR, G* x Sin δ, 10 rad/sec, kPa @ 16°C	1464	2253	5000 max
Stiffness, S, 60 sec, MPa @ -24°C @ -30°C	90.3 194.5	108.5 208.0	300 max
Slope, m, 60 sec @ -24°C @ -30°C	0.312 0.278	0.306 0.264	0.300 min
PG Range	**PG 56.3 – 36.1**	**PG 61.7 – 34.9**	

RAP = Recycled Asphalt Pavement; PGAC = Performance Graded Asphalt Cement; DSR = Dynamic Shear Rheometer; PAV = Pressure Aging Vessel; PG = Performance Grade

The test results shown in Table 5 on the initial two samples of recovered PGAC indicate that there is some variability in the RAP material. Sample #1 fails to meet the upper temperature requirement of 58°C, but meets all the other requirements for PG 58-34. Sample #2 on the other hand conforms to both the high and low temperature specification requirements. These results show that even though the same virgin PGAC was used, there can be variability within the RAP material that can affect the final results of the hot mix in the road.

The use of RAP in PGAC mixes is going to show some variability in physical properties of the recovered PGAC due to a number of factors. There normally are some differences in the percentage of asphalt cement in the RAP material and there could also be some slight variability in the SHRP physical properties of the RAP asphalt cement itself. If the AC content in the RAP is lower than expected the ratio of virgin PGAC to RAP AC will increase. This increased ratio will cause a shift in the blended asphalt cement and could possibly cause the high temperature value to be lower than expected. Sample #1 in Table 5 shows this type of variability.

TABLE 6: SHRP Test Results on the Polymer-Modified Performance-Graded Asphalt Cement (MacPlus) sampled on October 25 1998

	Result	Spec
Date	Oct 25/98	
Tests on Unaged Material		
Brookfield, 135°C, mPa.s	0.287	3.0 max
Flash Point, COC, °C	230+	230 min
DSR, G*/Sin δ, 10 rad/sec, kPa @ 46°C @ 52°C	1.931 0.969	1.0 min
Tests on RTFO Residue		
% Loss Weight	0.476	1.0 max
DSR, G*/Sin δ, 10 rad/sec, kPa @ 52°C @ 58°C	2.835 1.424	2.2 min
Tests on PAV (after RTFO) (Run @ 90°C) Residue		
DSR, G* x Sin δ, 10 rad/sec, kPa @ 7°C @ 10°C	1019 777	5000 max
Stiffness, S, 60 sec, MPa @ -30°C @ -36°C	130.5 245.0	300 max
Slope, m, 60 sec @ -30°C @ -36°C	0.319 0.270	0.300 min
PG Range	**PG 51.7 – 42.3**	

COC = Cleveland Open Cup; DSR = Dynamic Shear Rheometer; RTFO = Rolling Thin Film Oven; PAV = Pressure Aging Vessel; PG = Performance Grade

6.2 Day Two

The second day of production was on October 29, 1998. Because of the variability shown in the results of the first day's production, the virgin PGAC (MacPlus) was adjusted slightly with the addition of more polymer to increase the high temperature value while maintaining the low temperature value. The test results on the new batch of MacPlus are as shown in Table 7. The tests show that the new batch of virgin PGAC has improved high temperature values with a modest rise in low temperature properties.

During the second day of production three samples of the HL8 RAP hot mix were taken and sent to McAsphalt's laboratory for testing to the SHRP protocols. The asphalt cement was recovered from the hot mix samples using the Abson recovery method and then the recovered PGAC was tested to the AASHTO MP1 protocols. The test results obtained on the three samples are shown in Table 8.

The three samples conformed to all the RMOC specification requirements of PG 58-34 in the road. All three samples showed good low temperature properties that were well below the specification requirements of at least -34°C. The three samples, although they met the high temperature requirement of 58°C, were very close to the minimum requirement of 58°C. These results show that the RAP material used in the production on this day was much more consistent and most likely had better low temperature properties than the earlier RAP material used in the first day's production. In addition, the plant was operating much more efficiently as the personnel were more familiar with the virgin PGAC, with which they had never worked before.

TABLE 7: SHRP Test Results on the Virgin (extra) Polymer-Modified Performance-Graded Asphalt Cement (MacPlus) sampled on October 29, 1998

	Result	Spec
Date	Oct 29/98	
Tests on Unaged Material		
Brookfield, 135°C, mPa.s	0.287	3.0 max
Flash Point, COC, °C	230+	230 min
DSR, G*/Sin δ, 10 rad/sec, kPa @ 52°C @ 58°C	1.223 0.659	1.0 min
Tests on RTFO Residue		
% Loss Weight	0.529	1.0 max
DSR, G*/Sin δ, 10 rad/sec, kPa @ 52°C @ 58°C	2.985 1.490	2.2 min
Tests on PAV (after RTFO) (Run @ 90°C) Residue		
DSR, G* x Sin δ, 10 rad/sec, kPa @ 10°C	1061	5000 max
Stiffness, S, 60 sec, MPa @ -30°C @ -36°C	134.5 273.5	300 max
Slope, m, 60 sec @ -30°C @ -36°C	0.307 0.276	0.300 min
PG Range	**PG 54.0 – 41.4**	

COC = Cleveland Open Cup; DSR = Dynamic Shear Rheometer; RTFO = Rolling Thin Film Oven; PAV = Pressure Aging Vessel; PG = Performance Grade

TABLE 8: SHRP Test Results on Field Samples of HL8 RAP Hot Mix placed October 29, 1998

Sample #	3	4	5	Spec
Date	Oct 29/98	Oct 29/98	Oct 29/98	
Lot #	4	5	5	
Sublot #	3	1	2	
Station	51+626	51+785	51+866	
Tests on Recovered PGAC				
DSR, G*/Sin δ, 10 rad/sec, kPa @ 52°C @ 58°C @ 64°C	 2.312 1.156	4.532 2.201	 2.291 1.164	2.2 min
Tests on PAV Residue				
DSR, G* x Sin δ, 10 rad/sec kPa @ 16°C	1471	1747	1416	5000 max
Stiffness, S, 60 sec, MPa @ -30°C @ -36°C	90.3 167.3	107.0 199.0	102.5 189.0	300 max
Slope, m, 60 sec @ -30°C @ -36°C	0.322 0.282	0.314 0.252	0.318 0.270	0.300 min
PG Range	**PG 58.4-37.3**	**PG 58.0-35.3**	**PG 58.4-36.3**	

RAP = Recycled Asphalt Pavement; COC = Cleveland Open Cup; DSR = Dynamic Shear Rheometer; RTFO = Rolling Thin Film Oven; PAV = Pressure Aging Vessel; PG = Performance Grade

6.3 Day Three

The third day's production occurred on November 10, 1998. The HL8 RAP placed on this day was on the second lift of base material. During this day's production two samples of the hot mix were taken and tested to the AASHTO MP1 protocols. The results obtained by the laboratory are as shown in Table 9.

TABLE 9: SHRP Test Results – Field Samples of the HL8 RAP Hot Mix placed as Second Lift of Base Material on November 10,1998

Sample #	6	7	Spec
Date Sampled	Nov 10/98	Nov 10/98	
Lift #	2	2	
Lot #	1	1	
Sublot #	2	3	
Station	40+045	20+118	
Tests on Recovered PGAC			
DSR, G*/Sin δ, 10 rad/sec, kPa @ 52°C @ 58°C @ 64°C	 2.484 1.238	5.847 2.647 1.276	2.2 min
Tests on PAV Residue			
DSR, G* x Sin δ, 10 rad/sec, kPa @ 16°C	2132	1724	5000 max
Stiffness, S, 60 sec, MPa @ -24°C @ -30°C	153.0 317.0	151.0 339.0	300 max
Slope, m, 60 sec @ -24°C @ -30°C	0.294 0.256	0.294 0.252	0.300 min
PG Range	**PG 59.1 – 33.1**	**PG 59.6 – 33.1**	

RAP = Recycled Asphalt Material; COC = Cleveland Open Cup; DSR = Dynamic Shear Rheometer; RTFO = Rolling Thin Film Oven; PAV = Pressure Aging Vessel; PG = Performance Grade

The test results for both samples are very similar which would indicate that the RAP material was quite consistent and the plant production controls were also very constant during the production of the hot mix. The results of the testing also showed that the material in the road failed to meet the low temperature requirement of -34°C. The virgin PGAC used during this days' production was from the same batch of PGAC that was used on the second day of paving (Table 10). There are very slight differences in the test results between the batch sample tested October 29th and the results of the batch sample tested on November 6. No modifications were made to the tank of virgin PGAC. The minor differences in the test results are most likely testing variability.

Since the virgin PGAC is the same material as used earlier the cause for the failure to meet specification would most likely be in the physical properties of the RAP material. As the high temperature numbers are slightly higher than the previous day's production (Sample #3, 4 and 5), it would appear that this RAP material did not have low temperature properties that were as good as that of the earlier RAP material. The most likely cause of the failure is that the asphalt content in the RAP material has increased slightly. This increase in asphalt content would lower the ratio between the virgin PGAC and the RAP AC. The lowering of the ratio would cause a shift in the temperature properties of the recovered PGAC blend. The low temperature properties would become higher and the high temperature values will also increase. The test results in Table 9 show this occurrence.

TABLE 10: SHRP Test Results on Virgin (extra) Polymer-Modified Performance-Graded Asphalt Cement (MacPlus) sampled November 6 1998

	Result	Spec
Date	Nov 6/98	
Tests on Unaged Material		
Brookfield, 135°C, mPa.s	0.300	3.0 max
Flash Point, COC, °C	230+	230 min
DSR, G*/Sin δ, 10 rad/sec, kPa @ 52°C @ 58°C	1.141 0.615	1.0 min
Tests on RTFO Residue		
% Loss Weight	0.560	1.0 max
DSR, G*/Sin δ, 10 rad/sec, kPa @ 52°C @ 58°C	2.770 1.393	2.2 min
Tests on PAV (after RTFO) (Run @ 90°C) Residue		
DSR, G* x Sin δ, 10 rad/sec, kPa @ 10°C	1046	5000 max
Stiffness, S, 60 sec, MPa @ -30°C @ -36°C	130.0 296.0	300 max
Slope, m, 60 sec @ -30°C @ -36°C	0.313 0.263	0.300 min
PG Range	**PG 53.3 – 41.6**	

COC = Cleveland Open Cup; DSR = Dynamic Shear Rheometer; RTFO = Rolling Thin Film Oven; PAV = Pressure Aging Vessel; PG = Performance Grade

7. CONSTRUCTION PRACTICE

The mixing and laydown of these types of recycled asphalt pavements was very similar to that of the original RAP mixes. More care had to be taken in monitoring the temperatures of the mix at the asphalt plant and the temperature of the virgin PGAC in the storage tanks. The contractor had to work very closely with the PGAC supplier to ensure that the proper temperatures were maintained and that any special handling characteristics of the new PGAC were communicated to the contractor. In general the mix temperatures, the wet and dry mixing cycles and transportation were all very similar to that of the old conventional recycled mixes using penetration graded asphalt cement.

The laying of the PGAC recycled mixes was no different than before. The temperatures may have been slightly hotter due to the nature of the virgin PGAC, but nothing out of the ordinary. Photograph #3 shows the laydown of the second lift of HL8 recycle mix on Conroy Road. That the mix is slightly hotter is shown by the smoke. The air temperature when this photograph was taken was approximately 10°C. The pavement mat was very uniform and showed no evidence of segregation.

Since this mix contained some polymer modified asphalt cement, there was a slight delay before the compaction rollers could start their process. The breakdown roller was generally a vibratory steel which had the capability to spray a soap solution on the drums to prevent any pick-up of hot mix on the drums. The intermediate roller was a rubber tired compactor. As Photograph #4 shows, the rubber tired roller is outfitted with a heating system to keep the rubber tires hot in order to prevent pick-up on the tires,. These heating systems can be propane fired hot air systems and infrared heat systems. A number of the compaction equipment manufacturers are now building their rollers with these heating systems.

PHOTOGRAPH 3: Standard Asphalt Spreader Laying Performance-Graded Asphalt Cement Recycled Hot Mix

This project is still ongoing and the two base lifts will be completed this year. At the time of the writing of this paper a proposal has been made and accepted by the Region of Ottawa-Carleton to allow the use of RAP material in the surface mix. The surface mix is a modified HL3 mix utilizing high quality coarse aggregates. The RAP material to be used in this surface mix will be HL1 material incorporating traprock aggregate, which has been milled from a high volume highway. The same specification requirements as required for the base lifts will apply to the surface mix.

8. CONCLUSIONS

The following conclusions can be drawn from this recycling project:

1/ Based on the results obtained on this project the concept of using Performance Graded Asphalt Cement (PGAC) for recycling is a viable option.

2/ Extensive pre-engineering work is required to establish and develop the virgin PGAC required for the finished recycled hot mix to meet the contract requirements.

3/ The use of good stockpile management on the RAP material is essential to ensure that the new hot mix conforms to specification requirements.

4/ There will be variability in the test results on the recovered asphalt cement due to fluctuations in the RAP material. A specification should be established to take into account this variability.

PHOTOGRAPH 4: Compaction Equipment Rolling Hot Mat. Note Heating Vent and Skirts on Rubber Tired Roller to Aid in Preventing Pick-up.

9. RECOMMENDATONS

The following recommendations are made regarding the use of PGAC in the recycling process:

1/ Samples of the RAP material should be analyzed frequently to monitor the variability of the performance properties of the RAP asphalt cement. This can be done on a continuing basis as the RAP is stockpiled. The contractor and his PGAC supplier will have to work together closely before and during the recycling project.

2/ Further study should be done on the feasibility of using higher RAP contents with different virgin PGAC to determine the economics of using these different grades.

3/ A test/tests should be established to give the agency/owner a comfort level that will assure them that they are getting what they requested. This test/tests would be a replacement for the recovered penetration test, which has been used in all recycle mixes in the past.

10. REFERENCES

1. American Association of State Highway and Transportation Officials. "AASHTO Provisional Standards – June 1998 Edition".

2. Asphalt Institute. "Performance Graded Asphalt Binder Specification and Testing" Superpave Series No 1 (SP-1).

3. MTO. "Method of Test for Recovery of Asphalt from Solution by Abson or Rotavapor", Test Method LS 284, Ontario Ministry of Transportation.