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PAVEMENT AND MATERIALS TECHNOLOGY REVIEW - PHASE II

City of Hamilton

Submitted to:

Mr. Gary Moore, P.Eng., Director
Capital Planning and Implementation Division
Public Works Department
City of Hamilton
320-77 James Street North
Hamilton, Ontario
L8R 2K3

REPORT

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by the City of Hamilton (the City) to complete Phase II of the Pavement and Materials Technology Review (PMTR). Phase II complemented the findings of Phase I and expanded on multiple areas. The primary focus of Phase II was the development of specific recommendations for upgrading and improving the current City's Materials and Construction Specifications. In addition to working on the current Standard Specifications the work in Phase II also included developing specifications for the use of Warm Mix Asphalt (WMA) in the City.

Prior to providing recommendations for revisions to the Standard Specifications it was necessary to understand the state of the practice in the City in terms of pavement design, material testing, construction, Quality Control (QC) and Quality Assurance (QA). Information in these areas was collected through discussions with technical City staff members, site visits to selected 2007, 2008 and 2009 pavement, 2010 and 2011 City project data analysis, and limited material testing. This information has been interpreted to assess the aspects in which the current Standard Specifications are leading to successful projects and to identify challenges that are currently being experienced in the City. The collected information and the interpretation of it are presented in this report. The recommended revisions to the Standard Specifications based on the findings in the collected data are included and discussed in this report. Number of City of Hamilton Special Provisions were developed to address the observed deficiencies in paving. For simplicity wherever possible, the numbering of the Special Provisions and OPSS standards were corresponding.

1.1 Review of Phase I

Phase I of the PMTR was provided to the City in November 2009. Phase I included:

- Discussions with the City's technical staff at regarding current construction quality and state of the practice in the City;
- Visual condition surveys to identify typical distresses and possible causes;
- Review of current City maintenance, rehabilitation and construction specifications from the Quality Control (QC) and Quality Assurance (QA) point of view;
- Site visits to review paving techniques and methods, QC/QA procedures, construction supervision and general quality of constructed pavements;
- Review of selected contract and QC/QA documents, procedures and practices;
- Review of material testing results from contractors/suppliers of granular and asphalt materials on City projects;
- Review of QA testing results submitted to the City by other consultants and the associated follow up or consequence;
- Recommendations for improvements in construction quality;
- City staff education on QC/QA aspects of paving specification; and
- Assistance to the City in implementation of the recommendations.

In Phase I it was identified that although the City was a leader in terms of implementing innovative technologies, weaknesses existed in the quality of construction which impacted the performance of pavements. Condition inspections of pavements ranging from less than one (1) year in age to more than five (5) years in age showed evidence of premature distresses and underperforming pavements on a number of the roads. A preliminary review of the City's Materials and Construction Specifications indicated the following as being some of the areas for revisions:

- Reference to QC or QA, currently limited;
- Compaction requirements;
- Referenced OPSS standards that were no longer current;
- Reference to asphalt cement penetration grade no longer available in Ontario;
- Generic pavement structural designs that did not consider traffic volumes or soil type;
- Requirements in the specifications which were not being met in the projects files, particularly related to required testing results being provided to the City; and
- Improvements to construction drawings.

Site visits were made to construction sites by representatives of Golder. Some deficiencies were noted and included: inconsistent quality; poorly prepared granular bases; poor paving joints; lack of temperature control of materials; minimal tack coating on vertical faces of curbs, manholes and catch basins; compaction issues; and asphalt segregation.

The Phase I report provided several recommendations to improve construction quality within the City.

2.0 PHASE II PROJECT METHODOLOGY

The tasks involved in the completion of Phase II of the PMTR are the following:

1. Meeting with technical City staff members;
2. Analysis of state of the practice in the City using 2010 and 2011 mix designs; QA results; HMA compaction; and soil compaction;
3. Site visits to selected 2007, 2008 and 2009 poorly performing pavements and analysis of their available QA results;
4. Evaluation of the use of limestone aggregate from local sources for various traffic level pavements. This included Polished Stone Value (PSV) testing;
5. Review of City's current Materials and Construction Specifications;
6. Recommendations for revisions to City's current Materials and Construction Specifications based on analysis of the state of the practice in the City;
7. Development of recommendations and specifications for the use of Warm Mix Asphalt (WMA); and

8. Training for technical City staff members regarding revised specifications and new WMA specifications.

Items 3, 4 and 7 were requested by the City as an addition to the original scope of Phase II.

3.0 CITY OF HAMILTON TECHNICAL STAFF SURVEY

The involvement of the City's technical staff was an important aspect in Phase II. A meeting was held with eight (8) City staff members and two (2) Golder representatives on December 19, 2011. Prior to the December 19, 2011 meeting, Golder representatives and the City identified 12 topics that impact the performance of pavements in the City and successful implementation of revised specifications. The 12 topics are noted below and were the basis of the discussion on December 19, 2011.

1. Paving specifications;
9. Granular materials;
10. Aggregates;
11. Asphalt cement;
12. Asphalt mixes;
13. Warm Mix Asphalt;
14. Pavement rehabilitation;
15. Pavement preservation;
16. Pavement evaluation and design;
17. Staff training;
18. Workshop for Contractors and Consultants; and
19. Implementations and report.

Within each of the 12 topics noted above, various aspects were discussed. City staff members shared current practices and concerns related to each topic during the meeting. The discussion with the City staff members during this meeting was very important in the success of Phase II. These City representatives are very familiar with the current practices and specifications in the City and therefore provided instrumental insight into ongoing success and challenges. Complete notes from the meeting are included in Appendix A.

The key points suggestions for each of the 12 topics are summarized below:

1. Paving Specifications – General Discussion
   - Only Superpave mixes will be covered in this report.
   - The mixes and construction will be generally based on OPSS 1151 and 310 and City of Hamilton Special Provisions.
   - Special provisions will be developed when modifications to OPSS are required or special mix design or construction requirements are needed.

- The report will include what mixes should be used for what particular conditions and locations.
- A special provision prohibiting the use of Engine Oil Residue (EOR) will be developed.

2. Granular Materials

- There is lack of documentation of the results of granular materials physical properties testing. The only records are for compaction testing.
- Granular materials should meet the requirements of OPSS 1010 and constriction should be in accordance with OPSS 314.
- Physical prosperities testing results must be submitted for each type of granular material, minimum on an annual basis.
- Performance history of granular materials from particular sources should be reviewed and accepted.
- Any granular materials deteriorating in stockpiles should not be used in pavement layers.
- If compaction of granular layers is an issue, the physical properties of the materials and the methods of compaction should be checked.

3. Aggregates

- Should meet the requirements of OPSS 1001 and 1003 and City of Hamilton Special Provisions.
- Aggregate properties must be included in any asphalt mix design.
- Different amounts of RAP can be allowed in asphalt mixes for different road/street categories.
- RAP quality can be very variable. We have to know what we are putting in our asphalt mixes.
- Consider certified RAP stockpiles to reduce the impact of inconsistency.
- Besides the OPSS specified properties Polished Stone Value (PSV) should be taken into consideration. PSV testing has been carried out and this was discussed, as well as the impact of having low PSV results. Discussion regarding the effectiveness in terms of performance and cost of using trap rock initially in surface mixes or using limestone and micro surfacing in the future. The City could not recall issues in the last 10 years related to polishing of the aggregate in the surface mix. Ludomir noted that he has seen this occur in mixes in York Region and Toronto.
  - Results of testing in Ireland: 41 and 45
  - Lafarge Dundas – 41
  - Dufferin Milton – 45

4. Asphalt Cement

- Asphalt cement should meet the requirements of OPSS.MUNI 1101 and City of Hamilton Special Provisions.
- Bumping the asphalt cement grade should follow the OPSS procedure. A grade bumping table will be included in the report. It will also be covered in the training.
- Polymer modification of asphalt cement is the recommended way of bumping the grade.
- A comment regarding using polymer modified PG 70 – 28 will be included in the specification.

5. Asphalt Mixes

- Superpave mixes should meet the OPSS.MUNI 1151 requirements. Construction should be to OPSS 310. Any modifications to the OPSS requirements will be covered in special provisions.
- The City of Toronto has similar composite pavements and uses their typical surface mix.

- The report will clarify what mix types should be used on what road categories and take into account required pavement life and anticipated traffic loading. Training will be provided.
- Mix type and cost shall be verified against the required pavement performance.
- The required thickness of asphalt layer will have an impact on what mix types should be used. For thin lifts (< 40 mm) Superpave 9.5 mix can be considered.
- Effective control of the amount of RAP added to asphalt mixes is a challenge as of today. Not all asphalt cement in the RAP is blended with the virgin ac and it may have a detrimental impact on asphalt durability.

6. Warm Mix Asphalt

- WMA should be sued not only for low temperature paving. The City should take advantage of other benefits of the WMA technology.
- One of the WMA advantages can be the increased amount of RAP in mixes – should be considered.
- WMA specification is currently permissive. Special provisions will be developed for the City of Hamilton for WMA mix design.
- NCHRP Report 691 “” will be referenced for mix design.
- Currently a compaction temperature is stated in the specification, perhaps this may be removed.
- Likely start with a list of a few additives being allowed and over time more will be accepted.
- Current cost increase of WMA mixes is due to the necessary additives. It does not take into account cost reduction due to lower fuel consumption.
- Costs may go down when the completions increases.

7. Pavement Rehabilitation

- Commonly use pavement rehabilitation methods in the province:
  - Mill and overlay, reconstruction, pulverization (FDR) and overlay, full depth reclamation with foamed asphalt, cold in place recycling with emulsion, open graded cold mix
- Example of contractors who do pavement recycling/reclamation work will be provided in the report.
- Mill and overlay may not be suitable for number of circumstances, particularly if the pavement has extensive cracking with reflective cracking potential.
- Method of pavement rehabilitation should be considered on individual basis. Using only the information from asset management (network level) may often not be cost effective.
- Hot in place recycling is not used in Ontario although it is used in Alberta and BC.
- There will be an explanation in the report as to the behaviour of steel slag when it is milled (opened and reactivated)

8. Pavement Preservation

- Pavement preservation is the only way to maintain the network within available budget.
- Effective pavement preservation methodology shall be implemented not a random application of selected treatment.
- Pavement preservation should be correlated with the City’s asset management system
- Other methods should be considered
  - Microsurfacing, slurry seal, surface treatment, chip seal, double chip seal.
  - Fog seal, thin overlay, Metro Mat, Nova Chip

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9. Pavement Evaluation and Design

- The “of the shelf” method is not enough.
- As a short term solution the current matrix should be updated and include at least anticipated (or typical) traffic loading and soil type.
- Asset management is on the network level.
- “Project level” decision is required that will take into account the current pavement condition, future loading, soil type and feasible technology.
- If pavement life time limit is lowered then thinner pavements could be developed in design. Possibly need to discuss expectations for road condition and budget required to meet these expectations.

10. Staff Training

- Training will be provided to the City’s technical staff.

11. Workshop for Contractors and Consultants

- Recommended but currently not planned.

12. Implementation and Report

- Spring 2012

The participation from technical City staff during this meeting was substantial and significantly contributed to the effectiveness of this project. It was evident during the meeting that there was interest within the City staff to improve upon current practices where feasible and suitable. Detailed meeting minutes are included in Appendix A.

4.0 RESULTS REVIEW

One of the objectives of Phase II was to evaluate the current status of the practice in terms of asphalt pavement and update the specification to improve the typical performance of asphalt pavements in the City. In order to fully appreciate the state of the practice in the City it was important to understand the commonly supplied data and results. Results from 2010 and 2011 were compiled and reviewed for available portions of paving projects. The portions of the projects that were generally available were mix designs, construction compaction results and quality assurance test results of asphalt samples. These results and documentation are a reflection of the current state of the practice in the City, the current specifications and the existing adherence to the specifications.

4.1 Asphalt Mix Designs

The Design Department in the City currently uses Superpave asphalt mixes only, in pavement construction and rehabilitation as was identified during the meeting with the City’s technical staff. The Planning and Development, and Maintenance Departments use Marshall mixes. In the analyses of asphalt mix designs and pavement performance in this report both Superpave and Marshall mixes are included; however, the recommendations for asphalt paving specifications include only Superpave mixes.

Asphalt mix designs are required to be provided to the City prior to the initiation of the project. The mix designs should meet the requirements presented in the City's Materials and Construction Special Provisions. The City's Materials and Construction Special Provisions reference OPSS requirements generally. Specifically for HMA mixes, the Following specification should be followed unless modified by the City's special provisions.

- OPSS.MUNI 1151 Materials Specification for Superpave and Stone Mastic Asphalt Mixtures; and
- OPSS 310 Construction Specification for Hot Mix Asphalt.

A number of City of Hamilton Special Provisions for asphalt paving were developed in Phase II. Where feasible their numbering corresponds with the relevant OPSS specifications. The developed Special Provisions for asphalt paving are included in Appendix E and for Warm Mix Asphalt in Appendix F.

It is recommended that the most recent version of the specifications available during the design stage should be used. The City's Materials and Construction Special Provisions also require that the mix design be verified and record of this be provided to the City.

The 2010 and 2011 mix designs that were received by the City have been compiled and reviewed. Table 1 and 2 shows a summary of the Marshall and Superpave mix designs for 2010 and 2011, respectively. In total 31 mix designs were received in 2010 and 29 in 2011. Of these 60 mix designs, none included all required information; however, in general the missing information was similar between the mixes.

Table 1: Superpave and Marshall Mix Design Summary for 2010

Mix Design Type	Mix Design Worksheets and Plots	Material Proportions	FA/CA Designation	PGAC Source and Percentage	PGAC Temp. Viscosity Chart	Additives Info	Fines Returned to Mix	Gradation of all FA and CA	Aggregate Gradations	Individual Aggregate G_{sb}	Individual Aggregate SSD	Mix G_{mm} and G_{mb}	RAP Info	Visual Observations	Mixing and Comp Temp in Mix Design	Mix Weight for Gyratory Specimen	Certificate of Independent Verification
HL 3		x	x	x		na	x	x	x	x		x	x	x	x	x	
HL 8		x	x	x		na	x	x	x	x		x	x	x	x	x	
HL 8 15% RAP		x	x	x		na	x	x	x	x		x	x	x	x	x	
HL 8 HS		x	x	x		na	x	x	x	x		x	na	x	x	x	
HM3		x	x	x		na	x	x	x	x		x	na	x	x	x	
SP 12.5 mm Cat B		x	x	x		na	x	x	x	x		x		x	x	x	x
SP 12.5 mm Cat C		x	x	x		na	x	x	x	x		x	na	x	x	x	x
SP 12.5 mm Cat D		x	x	x		na	x	x	x	x	x	x	na	x	x	x	x
SP 12.5 mm FC2 Cat D		x	x	x		na	x	x	x	x	x	x	na	x	x	x	x
SP 12.5 mm FC2 Cat E		x	x	x		na	x	x				x	na	x	x	x	x
SP 12.5 mm FC2 Cat C		x	x	x		na	x	x	x	x		x	na	x	x	x	x
SP 19.0 mm Cat C		x	x	x		na	x	x	x	x		x	na	x	x	x	x
SP 19.0 mm Cat D		x	x	x		na	x	x	x	x	x	x	x	x	x	x	x
SP 19.0 mm Cat E		x	x	x		na	x	x	x	x	x	x	na	x	x	x	
SP 9.5 mm Cat C		x	x	x		na	x	x				x	na	x	x	x	x

Table 2: Superpave and Marshall Mix Design Summary for 2011

Mix Design Type	Mix Design Worksheets and Plots	Material Proportions	FA/CA Designation	PGAC Source and Percentage	PGAC Temp. Viscosity Chart	Additives Info	Fines Returned to Mix	Gradation of all FA and CA	Aggregate Gradations	Individual Aggregate G_{sb}	Individual Aggregate SSD	Mix G_{mm} and G_{mb}	RAP Info	Visual Observations	Mixing and Comp Temp in Mix Design	Mix Weight for Gyratory Specimen	Certificate of Independent Verification
HDBC		x	x	x		na	x	x	x	x		x	na	x	x	x	
HL 1		x	x	x		na	x	x	x	x		x	na	x	x	x	
HL 3 HS		x	x	x		na	x	x	x	x		x	na	x	x	x	
HL 8		x	x	x		na	x	x	x	x		x	x	x	x	x	
HL 8 15% RAP		x	x	x		na	x	x	x	x		x	x	x	x	x	
HL 8 HS	x	x	x	x		na	x	x	x	x		x	na	x	x	x	
HM3		x	x	x		na	x	x	x	x	x	x	na	x	x	x	
HM3 HD		x	x	x		na	x	x	x	x	x	x	na	w	x	x	
SP 12.5 mm Cat C	x	x	x	x		na	x	x				x	x	x	x	x	x
SP 12.5 mm Cat D		x	x	x		na	x	x				x	na	x	x	x	
SP 12.5 mm FC1 Cat C		x	x	x		na	x	x				x	na	x	x	x	
SP 12.5 mm FC2 Cat D	x	x	x	x	x	na	x	x	x	x		x	na	x	x	x	x
SP 12.5 mm FC2 Cat E		x	x	x		x	x	x				x	na	x	x	x	x
SP 19.0 mm Cat B		x	x	x		na	x	x				x	x	x	x	x	x
SP 19.0 mm Cat C	x	x	x	x		na	x	x				x	x	x	x	x	x
SP 19.0 mm Cat D		x	x	x		na	x	x	x	x		x	na	x	x	x	x
SP 9.5 mm Cat C	x	x	x	x	x	na	x	x	x	x		x	x	x	x	x	x

The mix designs received by the City generally included the following information:

- General information (mix type, project name);
- Material proportions;
- Fine and coarse aggregate designations;
- PGAC source and percentage;
- Fines returned to mix;
- Gradations of all fine aggregate and coarse aggregate;
- Aggregate gradations and individual;
- Aggregate G_{sb};
- Mix G_{mm} and G_{mb};
- Visual observations; and
- Typical weight for gyratory specimens.

As noted in Table 1 and 2, the following details were often missing from the mix designs:

- Worksheets and graphs;
- Aggregate SSD; and
- Independent verification.

In 2010 mix designs were submitted for HL 3, HL 8, HL 8 15% RAP, HM3, SP 12.5, SP 12.5 FC2, and SP 19.0 mixes. In 2011 mix designs were submitted for HDBC, HL 1, HL 3 HS, HL 8, HL 8 15% RAP, HL 8 HS, HM3, HM3 HD, SP 9.5, SP 12.5, SP 12.5 FC1, SP 12.5 FC2 and SP 19.0 mixes.

The information provided in the submitted mix designs did not include the information required in OPSS 1151, including full mix design information, temperature – viscosity charts for asphalt cements and required information about the aggregates. Also, independent mix verifications were not always included. The mixes generally met the OPSS 1151 gradation and volumetric requirements. Asphalt cement in the mix designs was as required in the City's Special Provisions.

Recommendations for mix designs are included in the special provisions in Appendix E. Superpave mixes can be of five categories, A to E. Table 3 taken from OPSS.MUNI 1151 shows Superpave and SMA design categories, the ESALs and typical application.

Table 3: Superpave and SMA Design Traffic Categories by ESALs

Ontario Traffic Category	20 year Design ESALs	Typical Applications
A	Less than 0.3 million	Low volume roads, parking lots, driveways, and residential roads
B	0.3 to 3.0 million	Minor collector roads
C	3.0 to 10.0 million	Major collector and minor arterial roads
D	10.0 to 30.0 million	Major arterial roads and transit routes
E	Greater than 30.0 million	Freeways, major arterial roads with heavy truck traffic, and special applications such as truck and bus climbing lanes or stopping areas
Note: ESAL for the projected traffic level expected in the design lane over a 20 year period, regardless of the actual design life of the pavement.		

Table 4 taken from the same specification shows typical Superpave and SMA mix use and proportions. Superpave 4.75 mm and 37.5 mm mixes are not used in Ontario.

Table 4: Typical Uses and Properties of Superpave and SMA mixes

Hot Mix Asphalt Type	Typical Hot Mix Use and Properties
Superpave 4.75	Fine, surface and levelling mixes similar to the traditional sand mixes for miscellaneous applications
Superpave 9.50	Fine, surface , padding, and levelling mixes for traffic category A and B roads and driveways
Superpave 12.5	Surface mix for Traffic Category B and C roads. Superpave 12.5 is similar to the traditional HL 3, HL 3 Fine, and HL 4 mixes according to OPSS 1150
Superpave 12.5 FC1	Surface mix for use on Traffic Category C roads that provides superior rutting resistance and skid resistance through aggregate selection. Superpave 12.5 FC1 is similar to the traditional HL 1 mix according to OPSS 1150
Superpave 12.5 FC2	Surface mix for use on Traffic Category D and E roads that provides superior rutting resistance and skid resistance through aggregate selection. Superpave 12.5 FC2 is similar to the traditional DFC mix according to OPSS 1150
Superpave 19.0	Binder course mix for Traffic Category A, B, C, D, and E roads. Superpave 19.0 is similar to the traditional HL 4, HL 8, and HDBC mixes according to OPSS 1150
Superpave 25.0 and 37.5	Large stone binder course mixes for use when thicker binder lifts are required
SMA 9.5 and 12.5	Gap-graded premium surface course mix with high frictional resistance, enhanced rutting resistance, water spray reduction, and potential noise reduction for Traffic Category D and E roads. 100% crushed aggregates from he DS<, are used for both fine and coarse fraction
SMA 19.0	Gap-graded premium binder course mix with enhanced rutting resistance for Traffic Category D and E roads. 100% crushed aggregates are used for both fine and coarse fraction

The same asphalt mixes should be used in composite pavements as in asphalt pavements.

The selection of a mix type for a particular road should be based on road category and traffic loading, required performance, and cost. The required lift thickness may also have an impact on the asphalt mix type selection. If the lift is less than 40 mm thick, Superpave 9.5 mix should be considered.

Effective control of the amount of RAP in the mix is a challenge as of today and there is no method of testing that will clearly identify the RAP content. Therefore effective method of mix production by an experienced staff is required. It should also be realized that not all asphalt cement in the RAP will blend with the virgin asphalt cement in the mix and this may have a negative impact on asphalt durability and pavement performance.

4.2 Granular Materials

The results that the City has from 2010 and 2011 projects were reviewed to assess if any granular material testing information was included. It was noted during the review that there is a lack of documentation of granular material properties testing. The only records were for compaction testing and these results included a variety of projects and all results were generally good.

It has been observed in the past that the granular materials for some sources can disintegrate. Therefore, it is important that the physical properties of granular materials are tested at least on an annual basis. It is also important that the performance history of granular material is checked.

Granular materials should meet the requirements of OPSS 1010 entitled “Materials Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material. Granular layer should be constructed in accordance with OPSS 314 entitled “Construction Specification for Untreated Granular Subbase, Base, Surface Shoulder and Stockpiling”.

If achieving the required compaction poses an issue and the granular materials are powdering under rollers, the properties of the materials should be checked and the method of compaction revised, particularly the thickness of the layers. Materials that have a history of disintegration should not be used.

4.3 Aggregate Materials

4.3.1 Polished Stone Value

The City requested that limestone from two local sources known for good quality material be assessed if it can be used in surface asphalt pavement mixes for various traffic levels. Limestone is commonly not used in surface asphalt mixes on major roads with high traffic volumes because of its tendency to polish. Polishing of the aggregate leads to the aggregate becoming smooth and therefore the micro texture can be drastically reduced. The reduction of the micro texture on the aggregate can cause the pavement to become slippery and create a safety concern as motorists may not be able to stop their vehicles efficiently, especially in wet conditions.

Representative samples were collected from Dufferin’s Quarry in Milton, Ontario and Lafarge’s Quarry in Dundas, Ontario. These two quarries are close in proximity to the City and are deemed to be sources of high quality limestone aggregate. The samples from each quarry consisted of 10 mm minus material. The samples were sent to Testconsult Ireland Limited in Ireland to be tested for Polished Stone Value (PSV). The PSV of an aggregate is a prediction of its skid resistance and is included in specifications for aggregates in hot mix asphalt in some regions of the world.

4.3.1.1 Results

The PSV testing was performed in accordance with BS EN 1097 – 8: 2000. The result of the testing for the sample from each quarry is shown in Table 5.

Table 5: Polished Stone Value (PSV) Test Results

Source	Test	PSV	Corrected PSV
Lafarge Dundas Quarry	A	41.7	41
	B	42.7	
	C	41.7	
	D	41.7	
Dufferin Milton Quarry	A	47.7	45
	B	45.0	
	C	45.0	
	D	45.0	

The results presented in Table 5 for the PSV testing show that the samples from the Dufferin Milton quarry consistently had higher results.

4.3.1.2 Specifications

PSV testing is not commonly included in specifications in Ontario for hot mix asphalt pavements, although in the past it sometimes has been referenced. In Ontario, OPSS 1003 requires that the amount of carbonates in surface course aggregates shall not exceed 40 % for SP 12.5 mixes. For SP 12.5 FC1 and FC2 mixes the aggregate shall be crushed dolomitic sandstone, traprock, diabase, andesite, meta-arkose, meta-gabbro or gneiss or crushed gravel for FC1 mixes. These aggregates offer good friction characteristics and resistance to polishing. Specification requirements from other countries that include PSV values have been summarized in Table 6.

Table 6: Polished Stone Value Requirements in Specifications

Specification	PSV Requirement (Minimum)
Design Manual for Roads and Bridges (2006) United Kingdom	50 - 60
Ministry of Defence Marshall Asphalt for Airfields (2008) United Kingdom	44 - 55
Design Manual for Roads and Bridges (2006) Transport Scotland	50 - 68

Table 6 shows PSV requirements in various specifications in the United Kingdom. The minimum required PSV ranges from 44 to 60 depending on the application. Research is trying to determine specifications in North America that reference PSV results. A minimum PSV of 50 was required for high volume roads in Ontario in 1991.

The PSV results of the samples tested from both quarries were lower than the required values for most of the specifications presented in Table 6. The sample from the Dufferin Milton quarry however, was equivalent to the minimum requirement in some applications shown in Table 6.

It was deemed that a representative sample was supplied from each quarry for testing. Testing for PSV generally has a low variation for a particular source and therefore it is not likely that the low results are a result of testing variation. The limestone aggregates tested are not considered suitable for surface course lifts on high volume/high speed roads.

4.4 Asphalt Cement

Routinely, PG 58-28 asphalt cement should be used in the Hamilton area. The asphalt cement should meet the requirements of OPSS.MUNI 1101 entitled "Material Specification for Performance Graded Asphalt Cement" and the City of Hamilton Special Provision SP1101. OPSS.MUNI 1101 requires that is the amount of RAP is from 21% to 40% the grade of asphalt cement should be changed to PG 52-34.

The asphalt cement grade should be bumped if the pavement will carry larger volume, heavy, slow moving, or stopping traffic. Table 7 taken from OPSS.MUNI 1101 shows the guidelines for bumping the performance grade of asphalt cement.

Table 7: Guideline for the Adjustment of PGAC High Temperature Grade Based on Roadway Classification and Traffic Conditions

Highway Type	Increase from Standard	Optional Additional Grade Increase
Urban Freeway	2 Grades	N/A
Rural Freeway Urban Arterial	1 Grade	1 Grade
Rural Arterial Urban Collector	Consider increasing by 1 grade if heavy truck traffic is greater than 20% of AADT	1 Grade
Rural Collector Rural Local Urban/Suburban Collector	No Change	1 or 2 Grades

Notes:

1. Upgrading of the high temperature grade is recommended for used in both surface and top binder courses i.e. top 80 to 100 mm of hot mix.
2. Consideration should be given to an increase in the high temperature grade of roadways which experience a high percentage of heavy truck or bus traffic at slow operating speeds, frequent stops and starts, and historical concerns with instability rutting.

It is recommended that asphalt cement of PG 64-28 and PG 70-28 should be polymer modified.

4.5 Quality Assurance

Quality Assurance (QA) testing provides the City with the information to check if the materials and product are as had been requested during the planning and design of the project and described in specifications. The QA results from 2010 and 2011 were provided to Golder by the City. The results included asphalt testing and compaction during construction.

4.5.1 Asphalt

The QA testing results of asphalt samples from 2010 and 2011 were compiled and analyzed. The QA results from 2010 are shown in Table C-1 and those from 2011 are in Table C-2, both in Appendix C. After the results were compiled they were analyzed to assess the trends throughout the results.

4.5.1.1 Gradations

The gradation results of each sample were compared to the Job Mix Formula (JMF) of the particular mix. The acceptable, borderline and rejectable variations from the JMF, provided in OPSS 310, were used to assess the gradation results. Table 8 shows a summary of this assessment for 2010 and Table 9 shows a summary for 2011. A few Marshall mix results are also included in the tables for more information on QA testing results. The weighted average in Table 8 and 9 describes the percentage of all sample results that were with each region (acceptable, borderline, rejectable) for each sieve designation.

Table 8: QA Gradations versus JMF 2010

Mix Type	Traffic Category	Number of Samples	Percentage of Results (%)								
			4.75 mm Sieve			0.600 mm Sieve			0.075 mm Sieve		
			Acceptable	Borderline	Rejectable	Acceptable	Borderline	Rejectable	Acceptable	Borderline	Rejectable
HL 8 HS	N/A	4	100	0	0	100	0	0	25	75	0
SP 12.5	B	11	18	18	64	73	0	27	82	18	0
SP 12.5 FC2	C	6	33	33	33	50	17	33	67	0	33
SP 12.5 FC2	D	59	71	15	14	81	3	15	97	3	0
SP 19.0	B	3	66	33	0	100	0	0	33	33	33
SP 19.0	C	10	60	30	10	100	0	0	100	0	0
SP 19.0	D	25	68	20	12	68	4	28	64	20	16
Weighted Average (%)			63	18	18	79	3	18	83	11	6

Table 9: QA Gradation versus JMF 2011

Mix Type	Traffic Category	Number of Samples	Percentage of Results (%)								
			4.75 mm Sieve			0.600 mm Sieve			0.075 mm Sieve		
			Acceptable	Borderline	Rejectable	Acceptable	Borderline	Rejectable	Acceptable	Borderline	Rejectable
HL 8	N/A	4	75	0	25	50	25	25	50	25	25
HM 3	N/A	2	100	0	0	100	0	0	100	0	0
SP 12.5	B	4	100	0	0	100	0	0	100	0	0
SP 12.5	D	4	50	25	25	50	50	0	100	0	0
SP 12.5 (WMA)	D	4	75	25	0	50	25	25	100	0	0
SP 12.5 FC1	C	5	60	0	40	100	0	0	100	0	0
SP 12.5 FC1	D	3	33	67	0	100	0	0	100	0	0
SP 12.5 FC2	D	28	86	4	11	57	21	21	96	4	0
SP 12.5 FC2 (WMA)	D	3	82	9	9	65	18	18	97	3	0
SP 19.0	B	1	100	0	0	100	0	0	100	0	0
SP 19.0	C	8	100	0	0	100	0	0	75	25	0
SP 19.0	D	22	81	18	0	91	9	0	91	9	0
SP 9.5	C	74	80	3	17	39	43	18	81	8	11
SP 9.5 (WMA)	C	12	83	8	8	17	33	50	92	8	0
Weighted Average (%)			81	7	12	56	28	16	87	8	5

Generally, gradations of asphalt mix samples were more consistent in 2011 than in 2010. In 2011 there were fewer rejectable results than in 2010 although there were still a number of results in the rejectable and borderline zones. In 2010 there were 11 SP 12.5 traffic category B results. These samples had poor results in comparison to other mixes with a similar number of samples or more. The 4.75 mm sieve results were 18 % acceptable, 18 % borderline and 64 % rejectable. In 2011 SP 9.5 HMA and WMA was used. The gradation results for the 0.600 mm sieve for both of the SP 9.5 mixes was poor. Only 17 % – 39 % were acceptable, 33 % - 43 % were borderline and 18 % - 50 % were rejectable. Both the SP 9.5 HMA and WMA had a significant number of test results, 74 and 12 respectively. Although a significant improvement of the asphalt mix gradation was observed from the 2010 and 2011 QA testing, it also clearly shows poor results for the SP 9.5 mix which should be of concern.

Figure 1 shows the variance of the 4.75 mm sieve gradation for SP 12.5 mixes in 2010. Figure 2 shows the variance of the 4.75 mm sieve gradation for SP 12.5 mixes in 2011. Similar figures, shown in Figures 3 to 14, were prepared for the SP 9.5, SP 12.5 and SP 19.0 mixes for each of the following sieve sizes: 4.75 mm, 0.600 mm and 0.075 mm. This was prepared for results from 2010 and 2011.

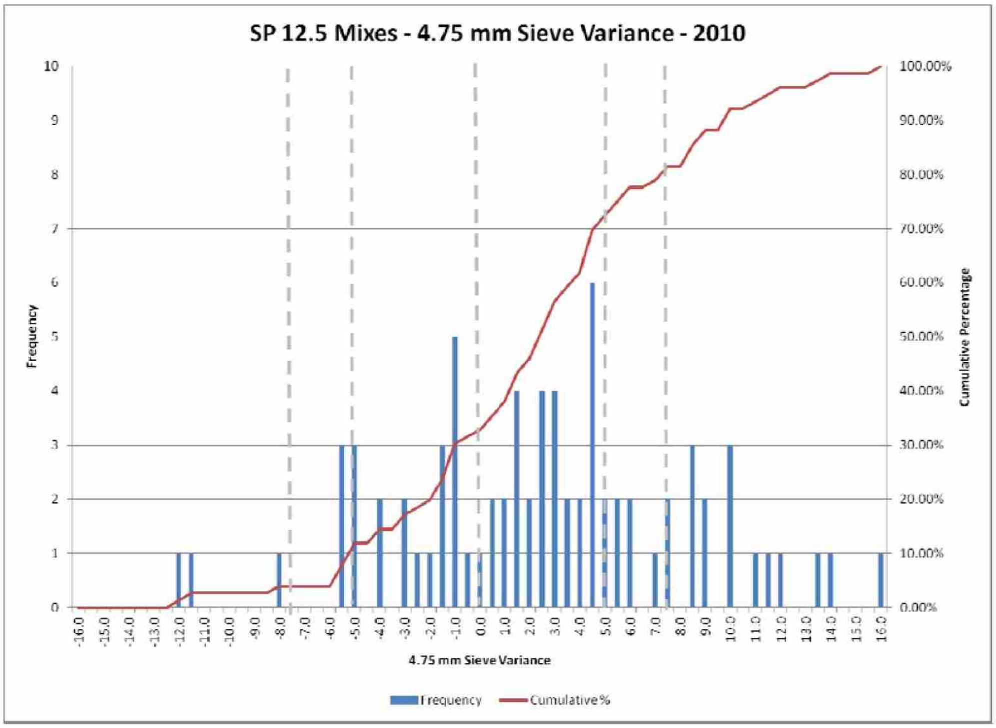

Figure 1: Variance of SP 12.5 QA Results for 4.75 mm in 2010

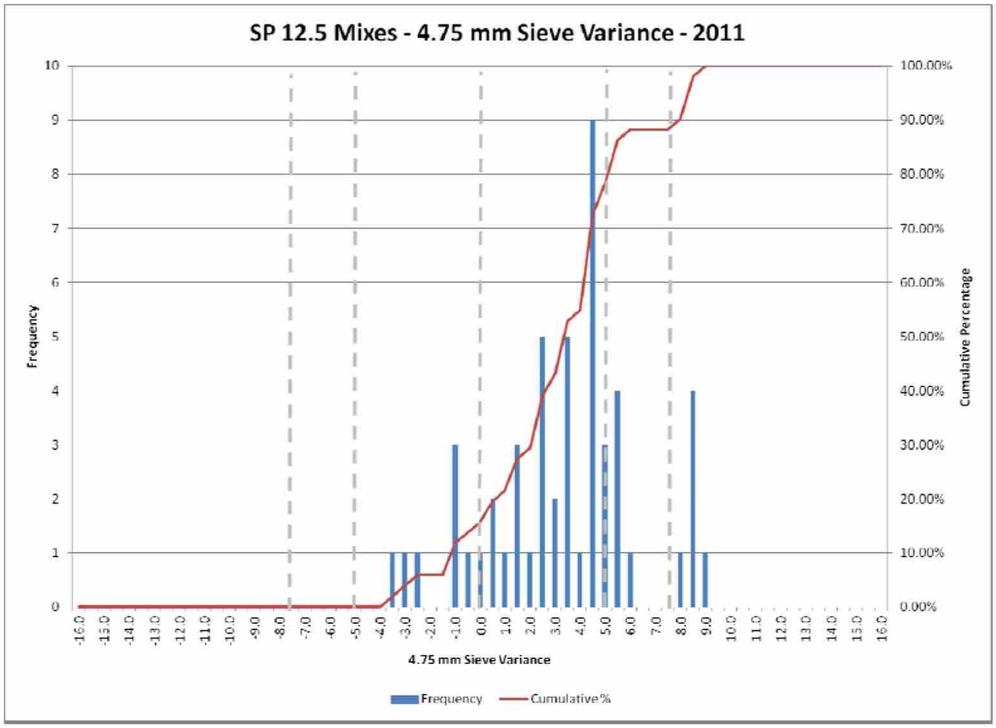

Figure 2: Variance of SP 12.5 QA Results for 4.75 mm in 2011

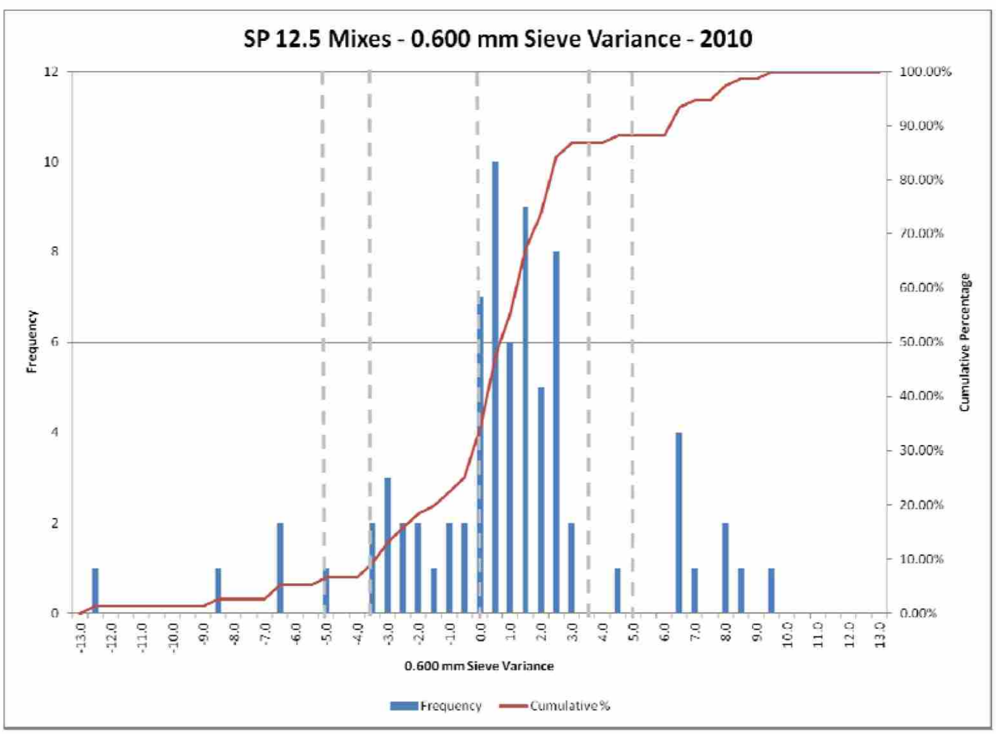

Figure 3: Variance of SP 12.5 QA Results for 0.600 mm Sieve in 2010

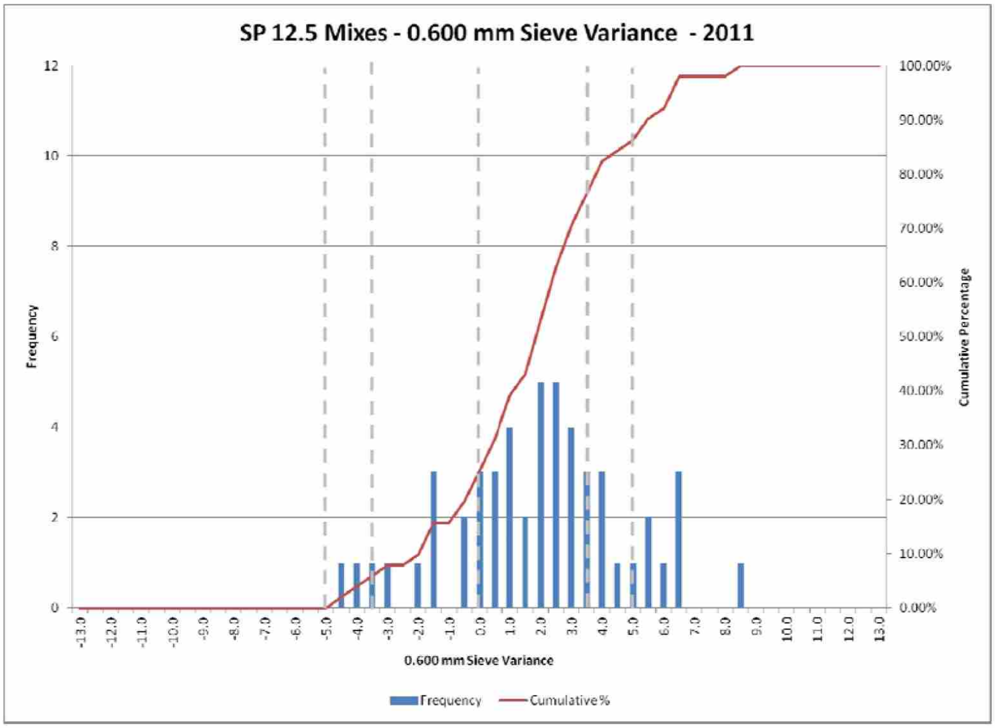

Figure 4: Variance of SP 12.5 QA Results for 0.600 mm Sieve in 2011

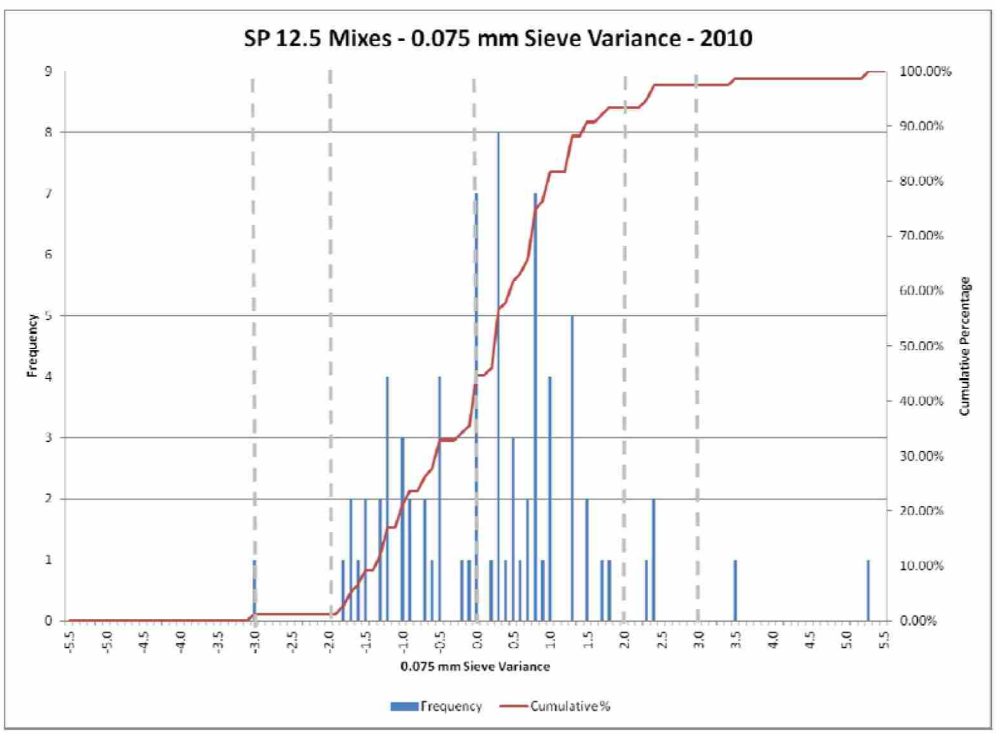

Figure 5: Variance of SP 12.5 QA Results for 0.075 mm Sieve in 2010

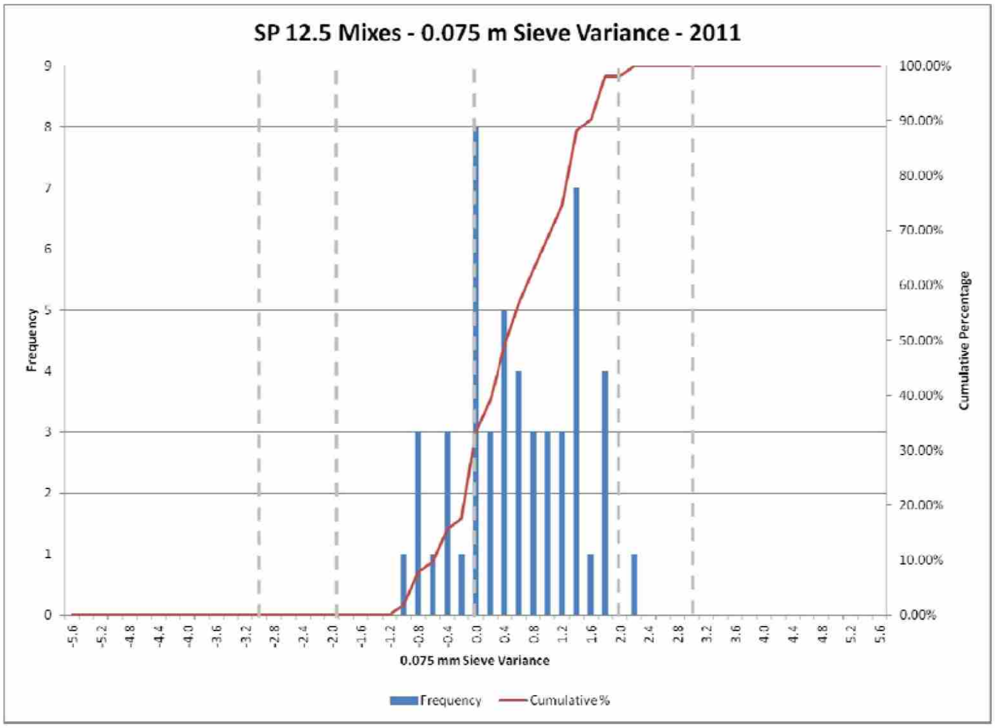

Figure 6: Variance of SP 12.5 QA Results for 0.075 mm Sieve in 2011

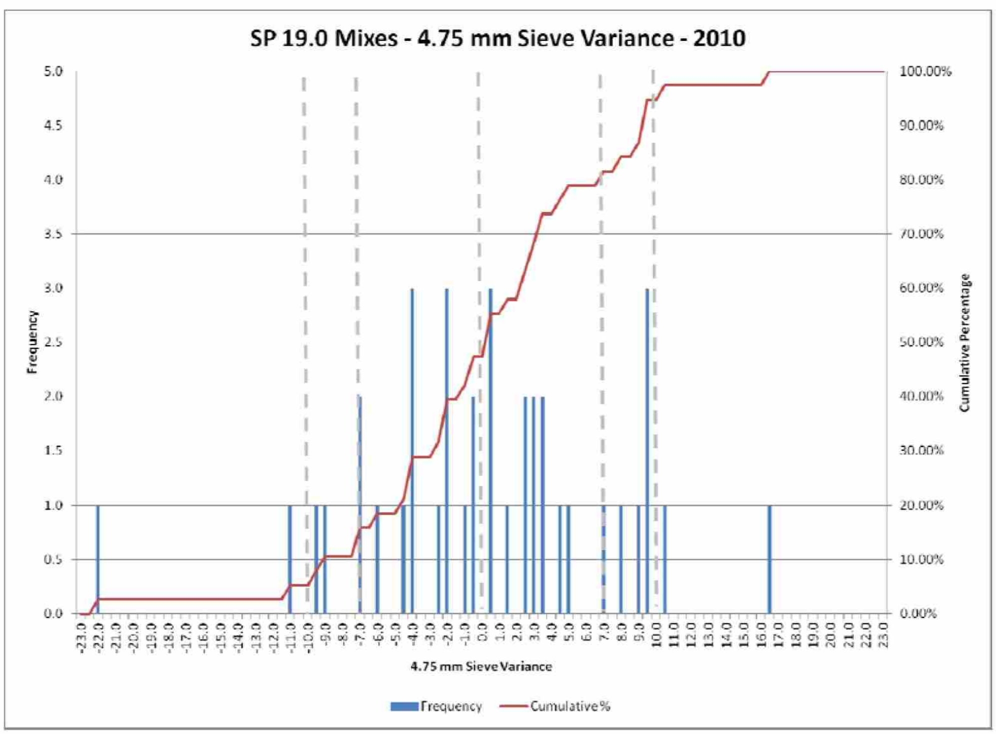

Figure 7: Variance of SP 19.0 QA Results for 4.75 mm Sieve in 2010

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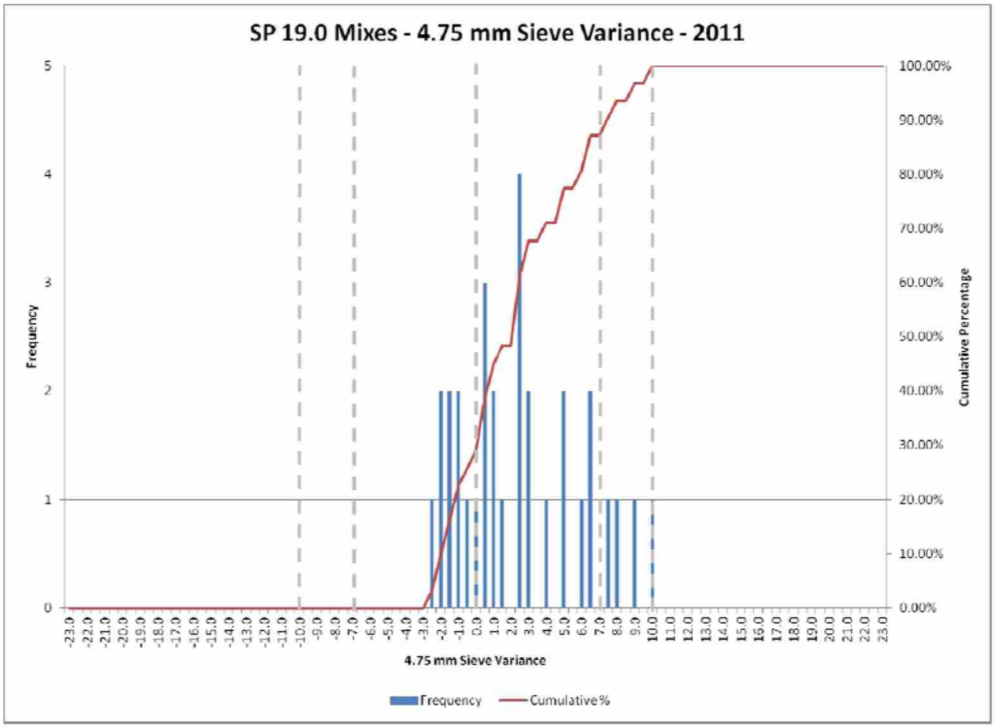

Figure 8: Variance of SP 19.0 QA Results for 4.75 mm Sieve in 2011

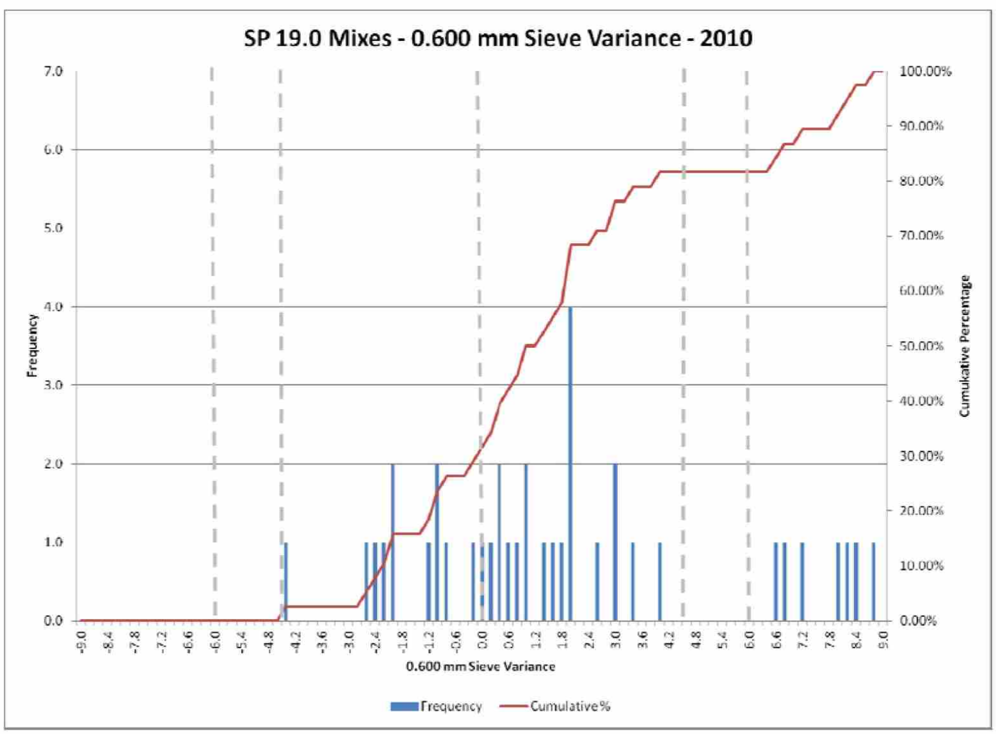

Figure 9: Variance of SP 19.0 QA Results for 0.600 mm Sieve in 2010

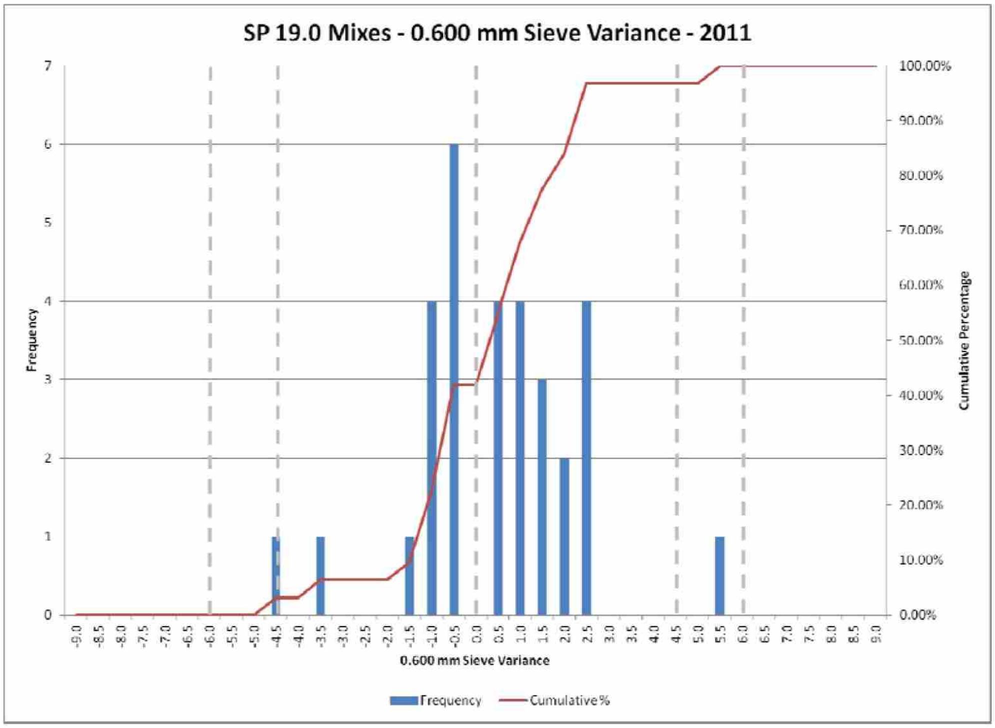

Figure 10: Variance of SP 19.0 QA Results for 0.600 mm Sieve in 2011

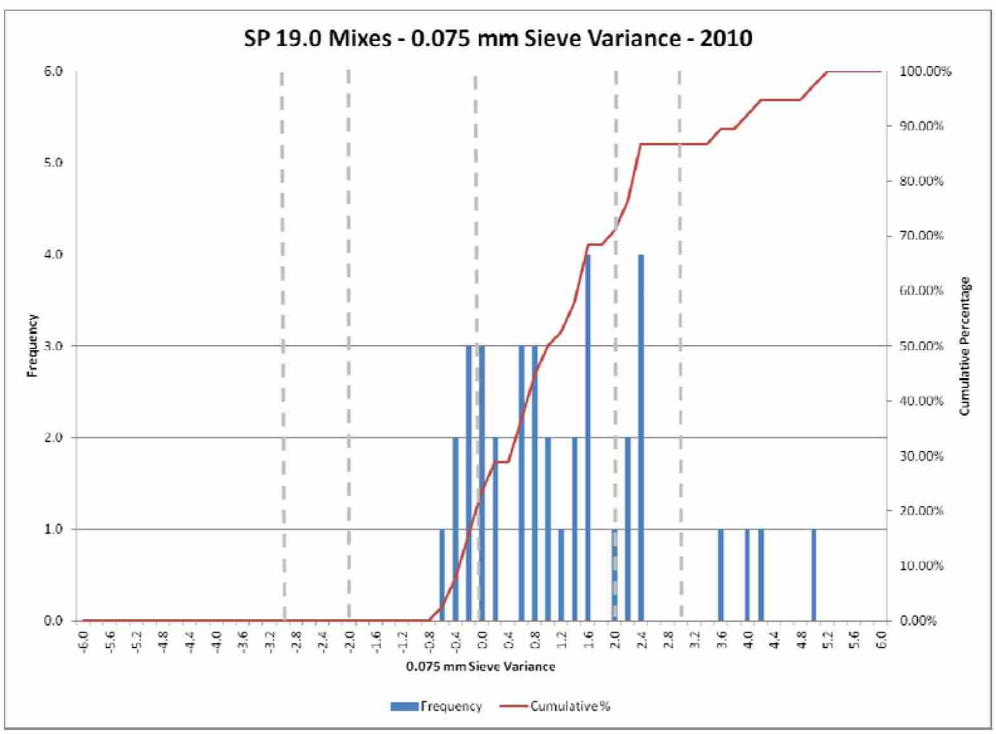

Figure 11: Variance of SP 19.0 QA Results for 0.075 mm Sieve in 2010

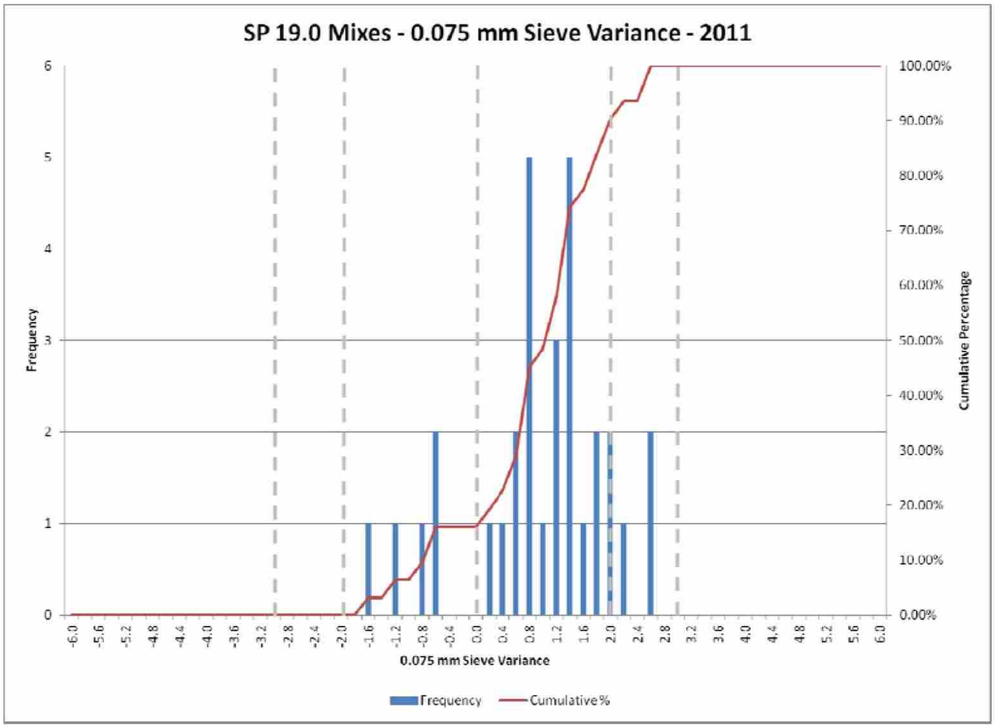

Figure 12: Variance of SP 19.0 QA Results for 0.075 mm Sieve in 2011

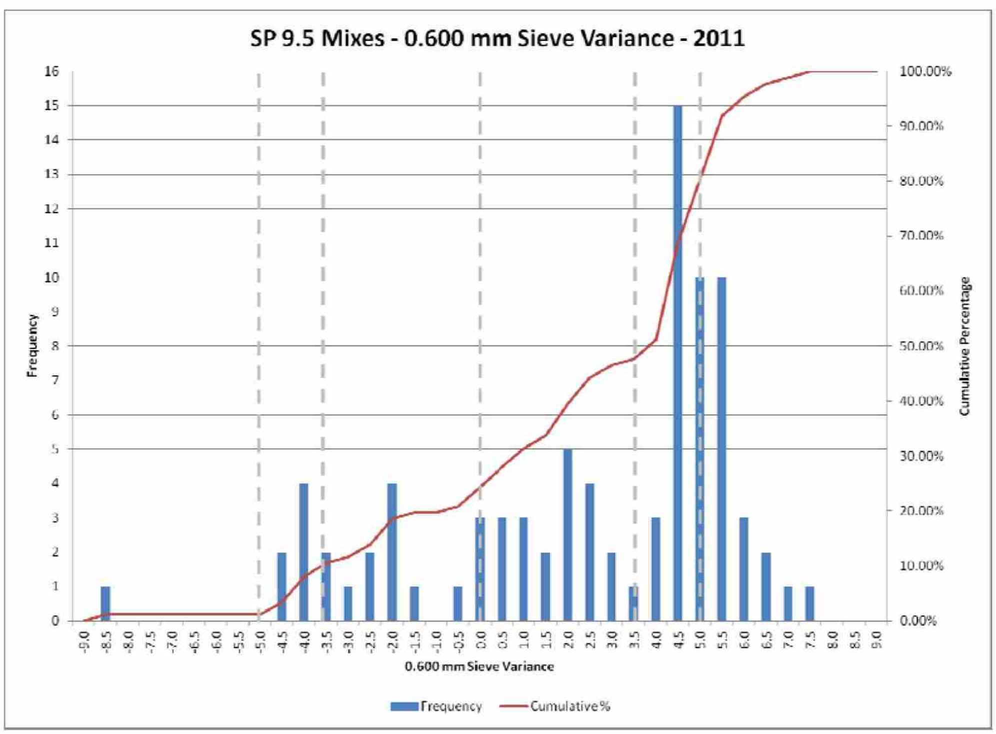

Figure 13: Variance of SP 9.5 QA Results for 0.600 mm Sieve in 2011

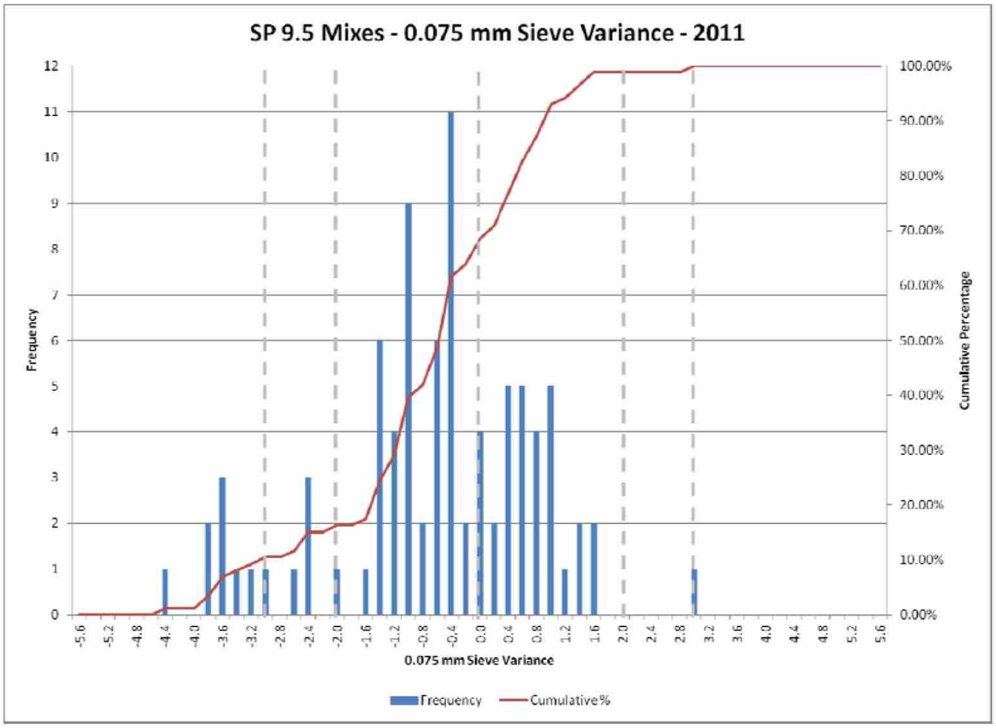

Figure 14: Variance of SP 9.5 QA Results for 0.075 mm Sieve in 2011

4.5.1.2 Asphalt Cement Content

The asphalt cement content of each of the QA samples was compiled and included in Tables C-1 and C-2. Table 10 shows a summary of the AC content for the different asphalt mixes used in the City in 2010 in comparison to the JMF. Table 11 shows the 2011 comparison.

Table 10: 2010 AC vs JMF

Mix Type	Traffic Category	Number of Samples	Percentage of Asphalt cement Content Results (%)		
			Acceptable	Borderline	Rejectable
HL 8 HS	N/A	4	100	0	0
SP 12.5	B	11	73	18	9
SP 12.5 FC2	C	6	50	50	0
SP 12.5 FC2	D	59	71	24	5
SP 19.0	B	3	67	33	0
SP 19.0	C	10	90	10	0
SP 19.0	D	25	72	24	4
Weighted Average (%)			73	23	4

Table 11: 2011 Asphalt Cement Content vs JMF

Mix Type	Traffic Category	Number of Samples	Percentage of Asphalt Cement Content Results (%)		
			Acceptable	Borderline	Rejectable
HL 8	N/A	4	75	25	0
HM 3	N/A	2	100	0	0
SP 12.5	B	4	75	25	0
SP 12.5	D	4	100	0	0
SP 12.5 (WMA)	D	4	100	0	0
SP 12.5 FC1	C	5	60	40	0
SP 12.5 FC1	D	3	33	33	33
SP 12.5 FC2	D	28	93	4	3
SP 12.5 FC2 (WMA)	D	3	88	6	6
SP 19.0	B	1	100	0	0
SP 19.0	C	8	100	0	0
SP 19.0	D	22	82	14	4
SP 9.5	C	74	80	16	4
SP 9.5 (WMA)	C	12	92	8	0
Weighted Average (%)			84	13	3

The AC content of the sampled asphalt mix was compared to that of the associated JMF to determine the difference between the two and the variance. Figures 15 and 16 show the AC variance for all 2010 and 2011 projects. The AC variance was also evaluated by mix type. Plots including all QA AC test results for a particular mix in a specific year were prepared and are included as Figure 17 to 21.

Overall, asphalt cement content was more consistent in 2011 than in 2010. In 2011 about 84 % of the results were in the acceptable zone and 13 % in the borderline zone. Only about 3 % of the asphalt cement content testing results were in the rejectable zone. Although in 2010 also only 4 % of the results were in the rejectable zone, only 73 % were in the acceptable zone and 23 % in the borderline zone. From the asphalt cement content point of view there was a significant improvement in the quality of asphalt mixes in 2011 in comparison to 2010.

In 2011 SP 9.5 mm mixes were included in projects. In prior years this mix had not been used. In 2011 many of the QA test results included AC contents which were borderline or rejectable. It is suspected that the high number of borderline and rejectable results are due to the mixes being new to the local suppliers. In consideration of this it is important to diligently monitor QA results and take action as necessary.

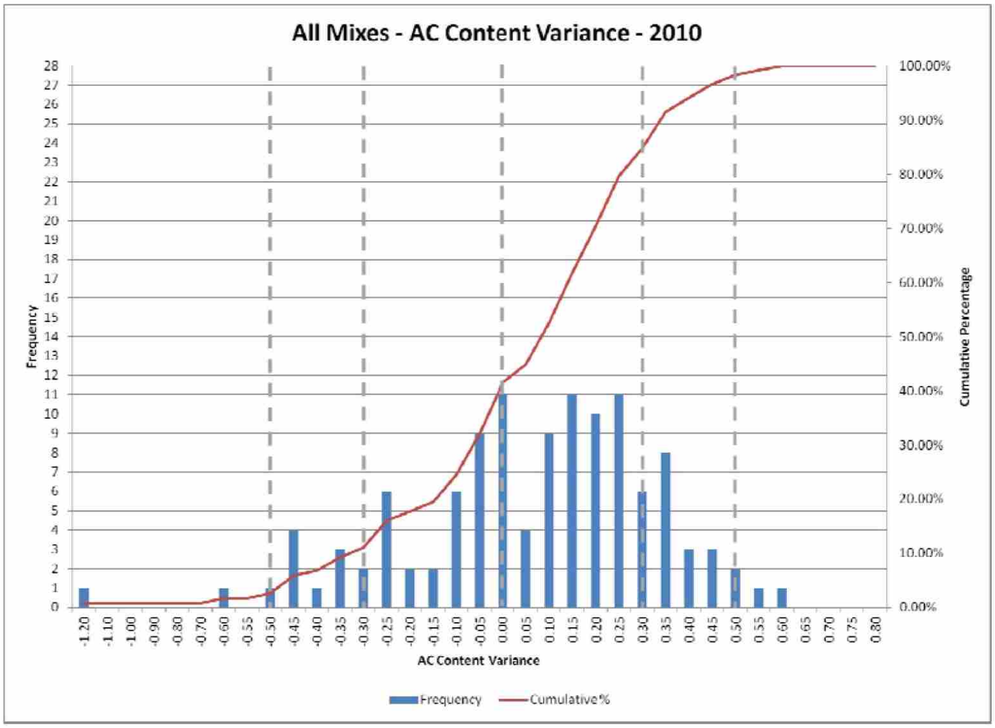

Figure 15: AC Variance for 2010 Construction

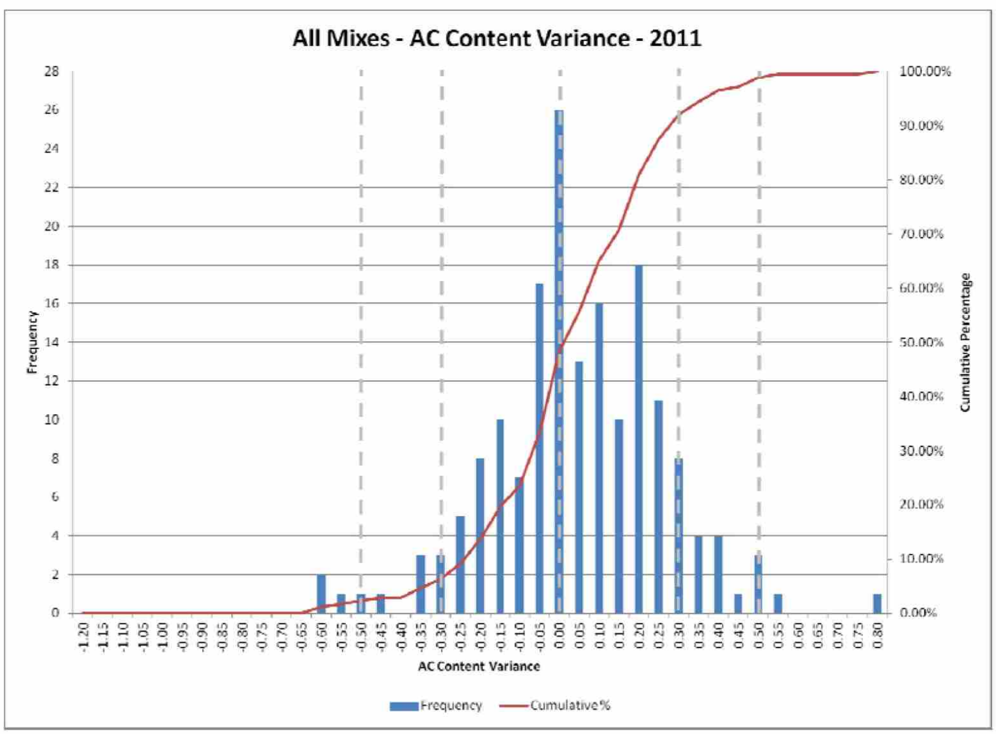

Figure 16: AC Variance 2011 Construction

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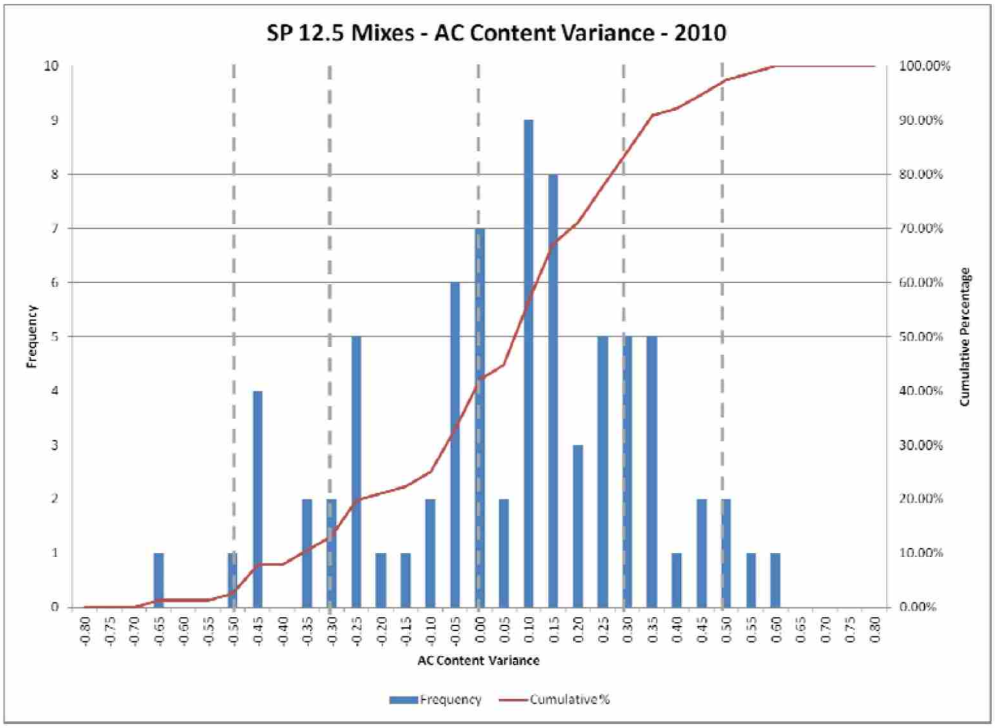

Figure 17: AC Content Variance for SP 12.5 Mixes for 2010 Construction

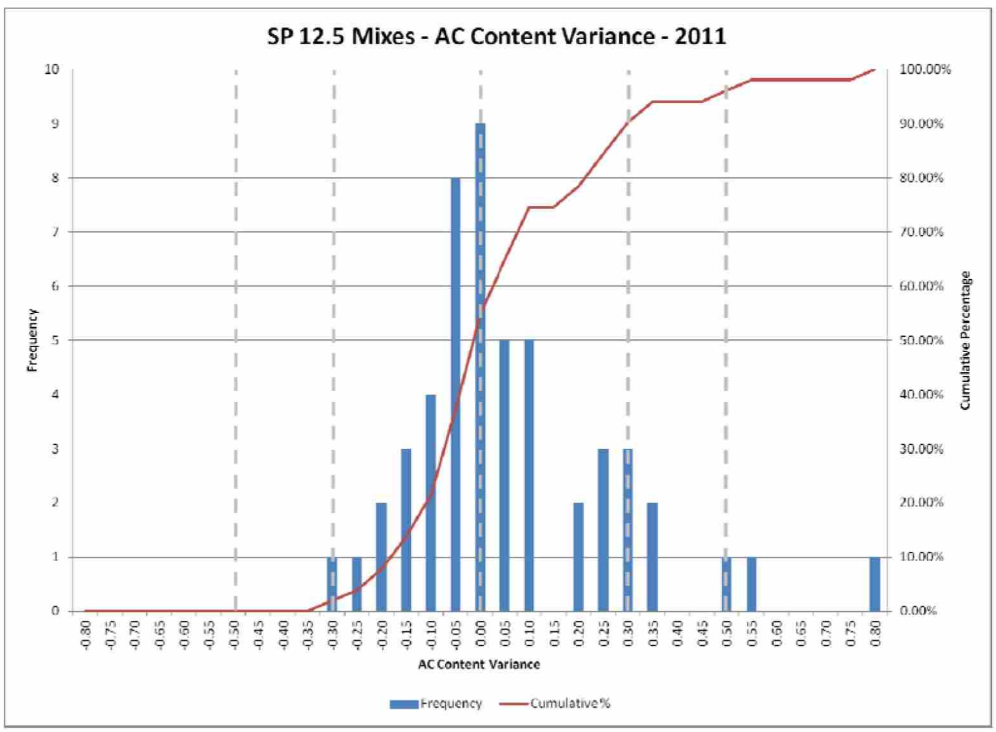

Figure 18: AC Content Variance for SP 12.5 Mixes for 2011 Construction

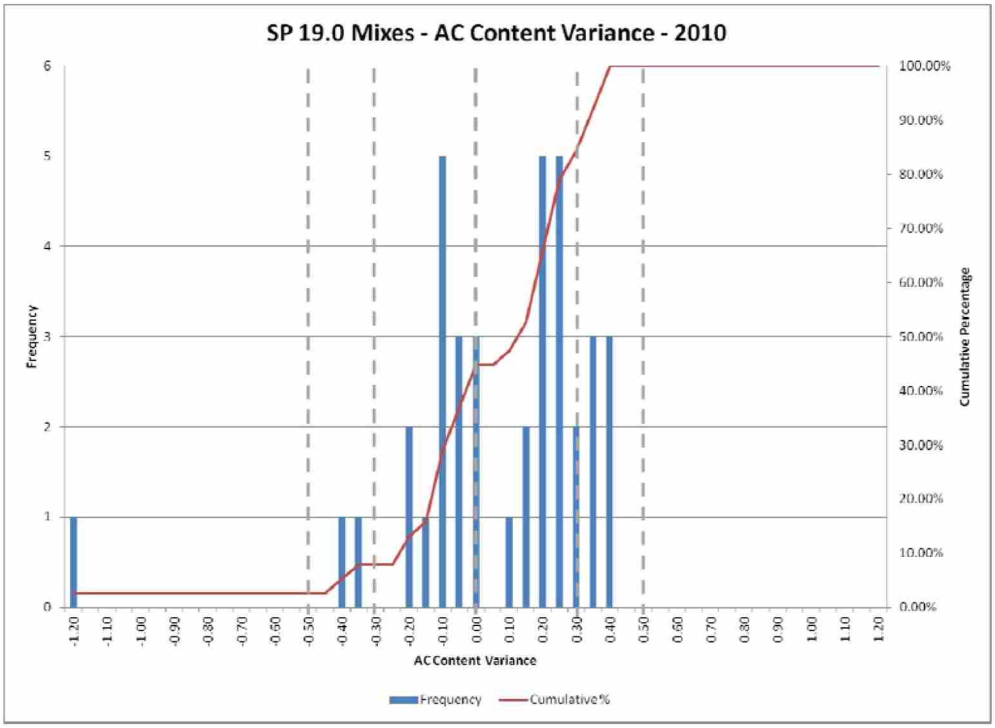

Figure 19: AC Content Variance for SP 19.0 Mixes for 2010 Construction

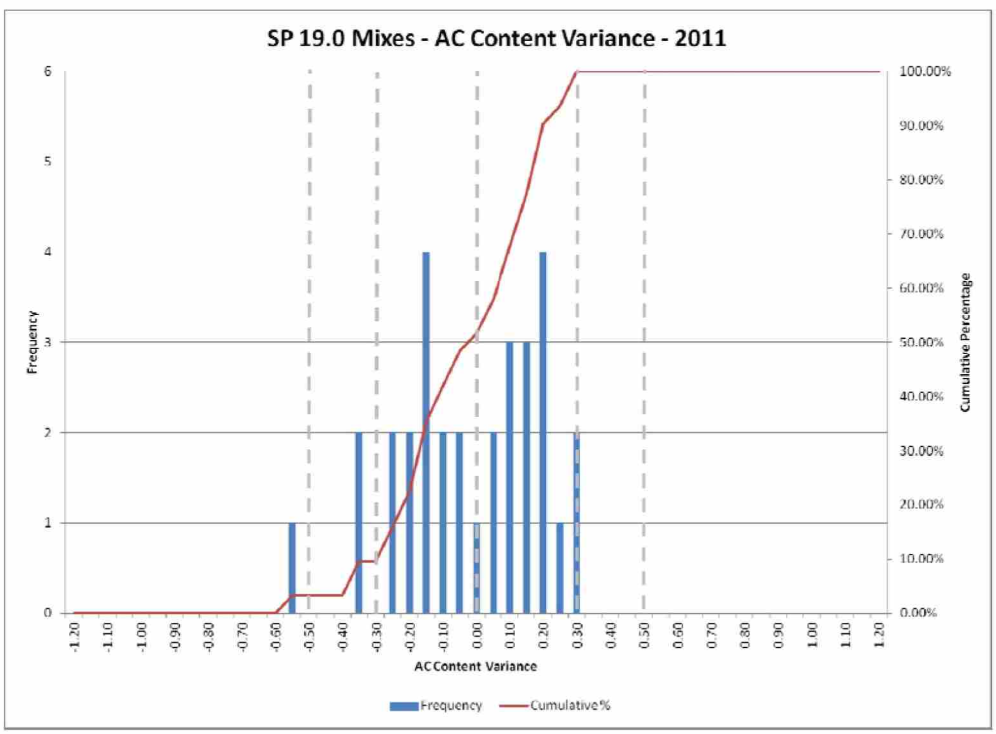

Figure 20: AC Content Variance for SP 19.0 Mixes for 2011 Construction

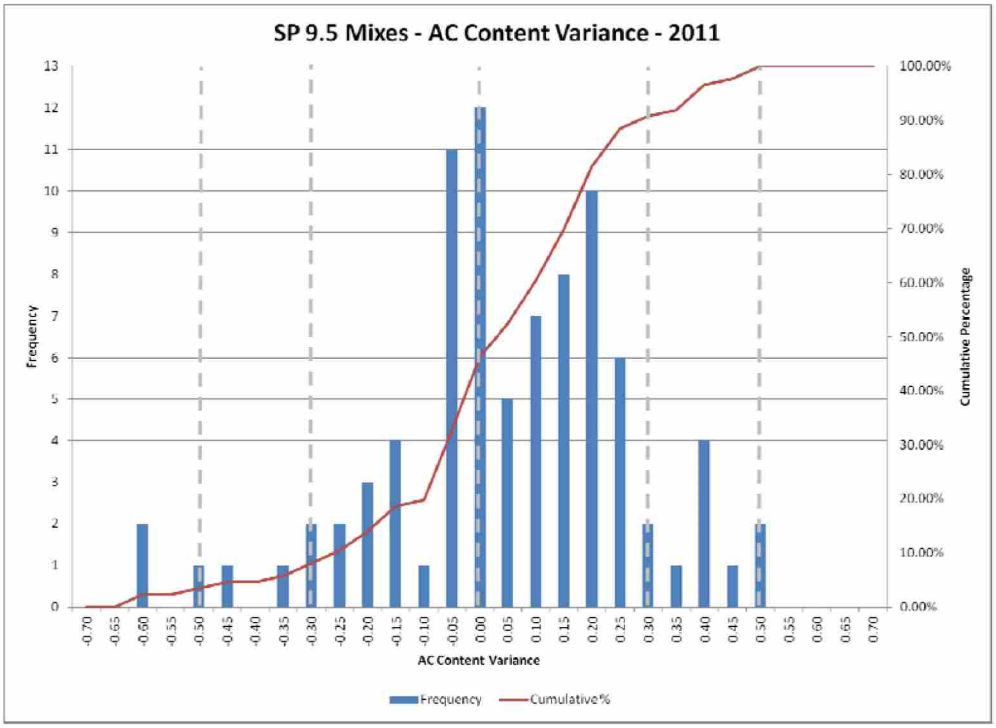

Figure 21: AC Content Variance for SP 9.5 Mixes for 2011 Construction

4.5.1.3 Air Voids

The air void results from the QA testing of sampled asphalt material were compiled for 2010 and 2011 projects. The results from 2010 are shown in Table C-1 and 2011 results are in Table C-2. A summary of the results in comparison to the allowable values are shown in Tables 12 and 13 for 2010 and 2011.

Table 12: 2010 QA Air Void Results

Mix Type	Traffic Category	Number of Samples	Percentage of Air Voids Results		
			Acceptable	Borderline	Rejectable
HL 8 HS	N/A	4	25	0	75
SP 12.5	B	11	36	18	45
SP 12.5 FC2	C	6	67	33	0
SP 12.5 FC2	D	59	47	39	14
SP 19.0	B	3	33	67	0
SP 19.0	C	10	30	70	0
SP 19.0	D	25	64	24	12
Weighted Average (%)			48	36	16

Table 13: 2011 Air Voids

Mix Type	Traffic Category	Number of Samples	Percentage of Air Voids Results		
			Acceptable	Borderline	Rejectable
HL 8	N/A	4	0	0	100
HM 3	N/A	2	100	0	0
SP 12.5	B	4	25	50	25
SP 12.5	D	4	100	0	0
SP 12.5 (WMA)	D	4	75	0	25
SP 12.5 FC1	C	5	40	60	0
SP 12.5 FC1	D	3	67	0	33
SP 12.5 FC2	D	28	89	7	4
SP 12.5 FC2 (WMA)	D	3	85	9	6
SP 19.0	B	1	100	0	0
SP 19.0	C	8	100	0	0
SP 19.0	D	22	86	9	5
SP 9.5	C	74	47	34	19
SP 9.5 (WMA)	C	12	33	42	25
Weighted Average (%)			62	23	15

Overall, in 2011 the QA air void results were generally more consistent and had more acceptable results than in 2010. In 2010 the percentage of air void results within a particular mix that were acceptable ranged from 25 % to 67 %. Mix types with 10 or more samples had between 30 % and 64 % acceptable results. For most of these mixes the remainder of the results were borderline. For SP 12.5 traffic category B however, more of the results were rejectable (45 %) than within the borderline (18 %) or acceptable (36 %) zones. In 2011, mix types, excluding SP 9.5, with more than eight (8) sample results had between 86 % and 100 % acceptable air void results. The air void results of the SP 9.5 mixes, both hot mix and warm mix were generally poor. The warm mix SP 9.5 mix had 33 % acceptable, 42 % borderline and 25 % rejectable results. The SP 9.5 hot mix results were 47 % acceptable, 34 % borderline and 19 % rejectable. Figures 22 and 23 show the 2010 and 2011 air voids results respectively for the sampled QA asphalt.

HL 8 mixes in 2011 and HL 8 HS mixes in 2010 were of poor quality from the air voids point of view with a high percentage of results in the rejectable zone.

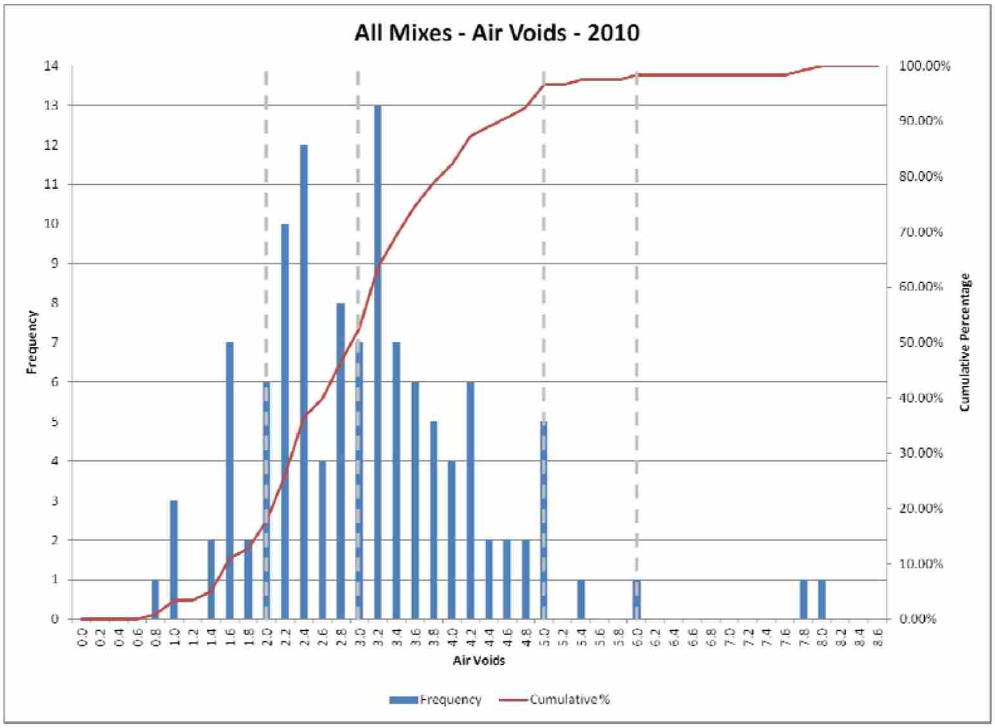

Figure 22: Air Voids in 2010

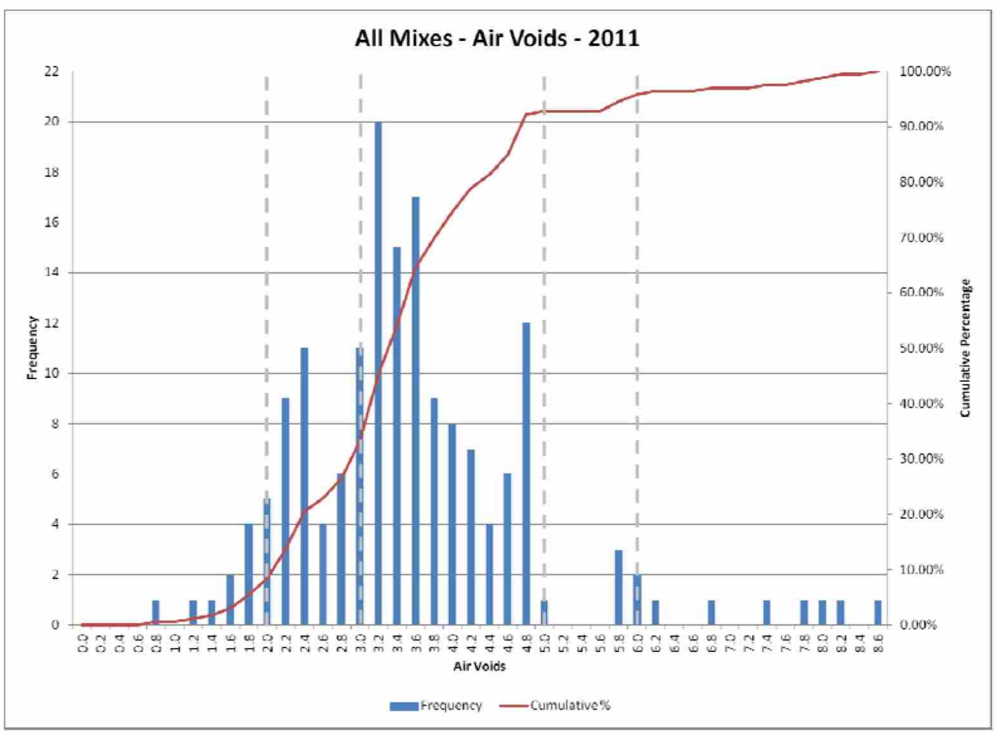

Figure 23: Air Voids in 2011

4.5.2 Construction

Quality assurance field testing was completed throughout the construction projects in the City. The testing primarily included measuring the compaction of the constructed asphalt layers. At some projects the compaction of the granular layers was also evaluated. Table 14 shows a summary of the HMA compaction results from 2010 and 2011 results are in Table 15. Compaction results from all HMA projects in 2010 and 2011 are included in Table D-3.

Table 14: HMA Compaction in 2010

Mix Type	Traffic Category	Number of Samples*	Percentage of Compaction Results (%)			
			< 91 %	> 91 %	< 92 %	> 92%
HL 8 HS	N/A	3	0	100		
HM 3 HD	N/A	1			14	86
SP 12.5	B	8			1	99
SP 12.5 FC2	C	1			0	100
SP 12.5 FC2	D	21			3	97
SP 19.0	B	2	0	100		
SP 19.0	C	7	0	100		
SP 19.0	D	16	1	99		
SP12.5	B	1			0	100
SP12.5 FC2	C	4			1	99
SP12.5 FC2	D	3			2	99

* Samples refers the number of sets of results

Table 15: HMA Compaction in 2011

Mix Type	Traffic Category	Number of Samples*	Percentage of Compaction Results (%)			
			< 91 %	> 91 %	< 92 %	> 92 %
HL 8	N/A	3	0	100		
SP 12.5	B	2			19	81
SP 12.5	D	2			0	100
SP 12.5 (WMA)	D	2			0	100
SP 12.5 FC1	D	1			0	100
SP 12.5 FC2	D	15			1	99
SP 12.5 FC2 (WMA)	D	1			0	100
SP 19.0	B	1	0	100		
SP 19.0	C	6	8	92		
SP 19.0	D	11	2	98		
SP 9.5	C	72			2	98

Mix Type	Traffic Category	Number of Samples*	Percentage of Compaction Results (%)			
			< 91 %	> 91 %	< 92 %	> 92 %
SP 9.5 (WMA)	C	16			0	100

* Samples refers the number of sets of results

Figure 24 shows the mean measured compaction results for projects from 2010 and Figure 25 shows the results of 2011 projects. In general the compaction results in 2010 and 2011 were good. However, compaction was poor on a number of projects in 2011. This may have been due to late season paving. The low compaction should be of concern as they may result in poor pavement performance. Figure 25 shows that there was one project where the mean compaction was 86 %. This was a project completed in October 2011 and it is anticipated that the late season paving is the reason for the low compaction results. Figure 26 and 27 show the maximum measured compaction results for 2010 and 2011, respectively. Similarly, Figure 28 and 29 shows the minimum measured compaction results for 2010 and 2011, respectively.

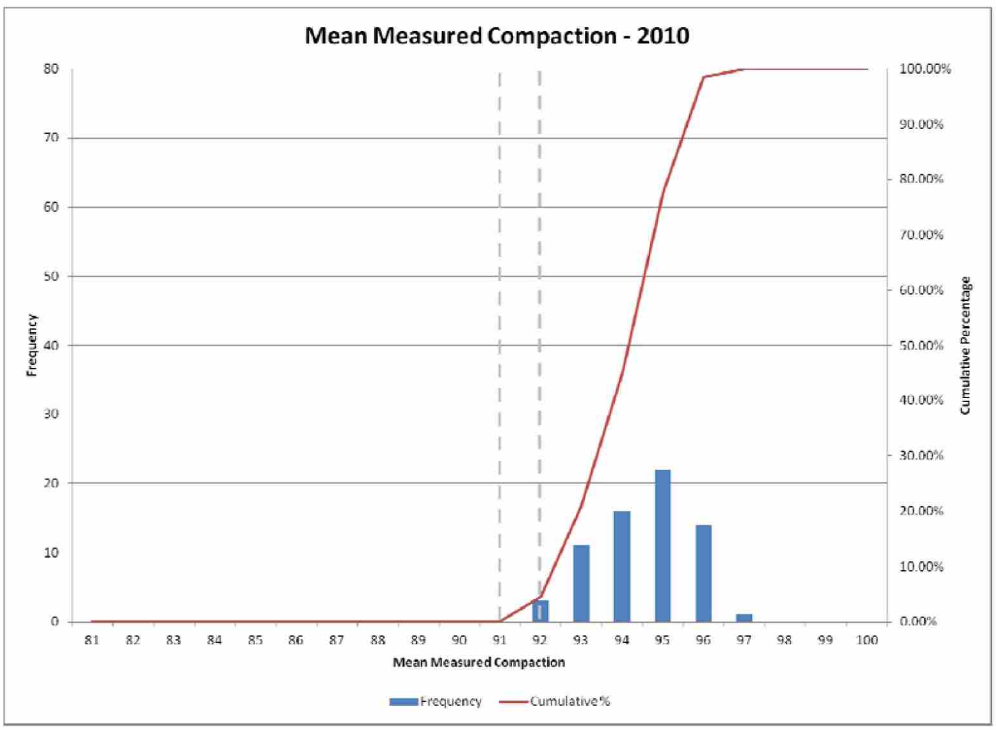

Figure 24: Mean Compaction in 2010

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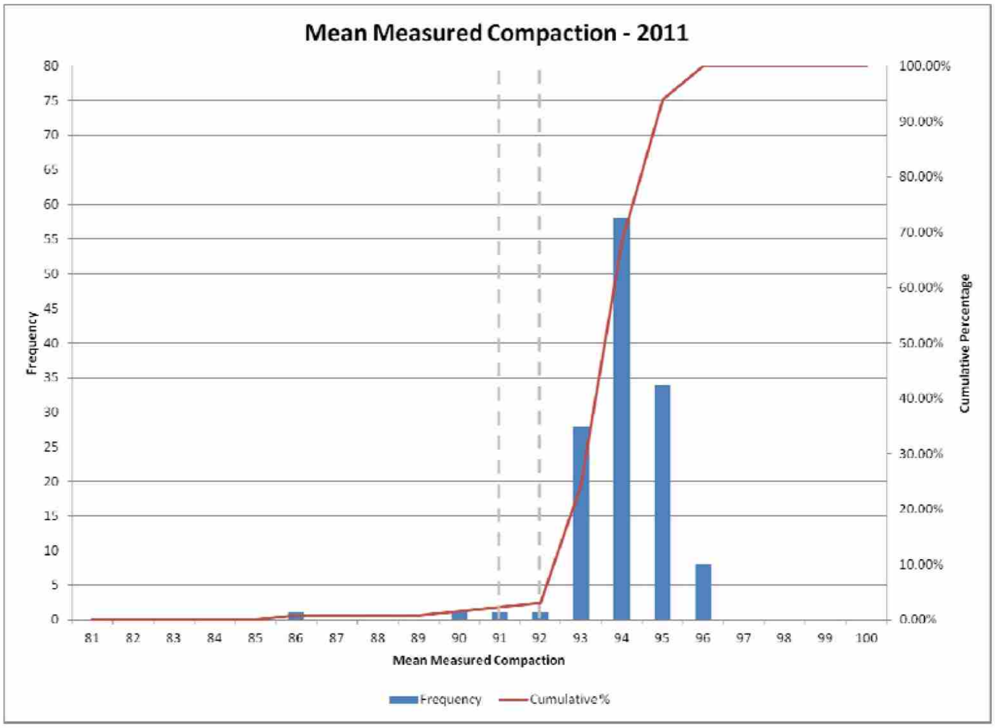

Figure 25: Mean Compaction in 2011

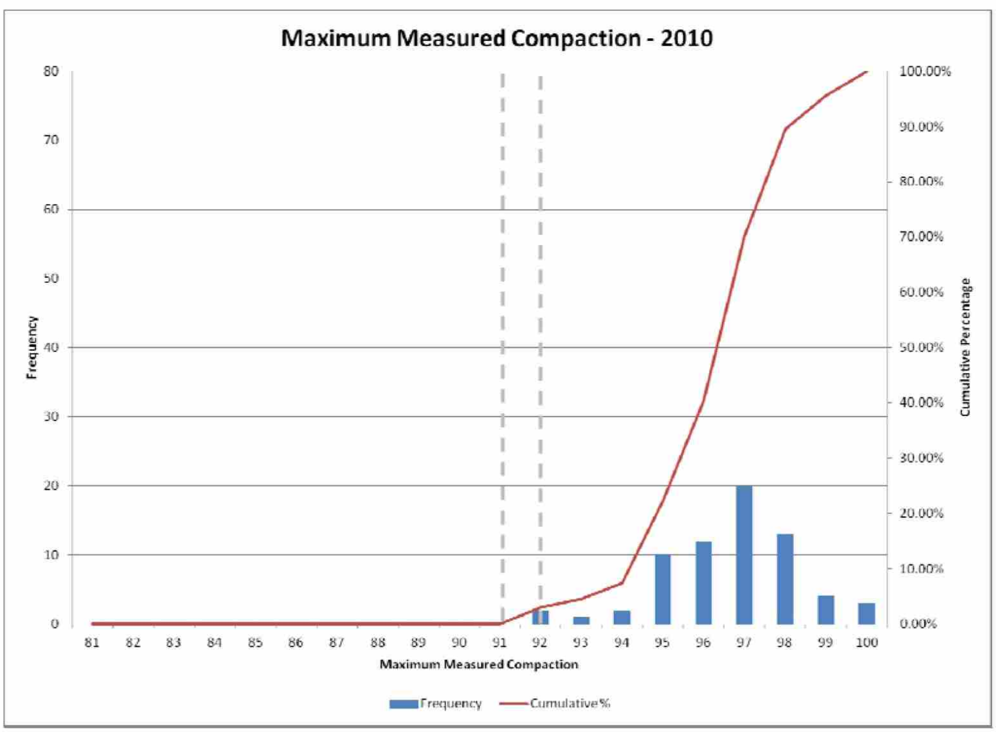

Figure 26: Maximum Compaction in 2010

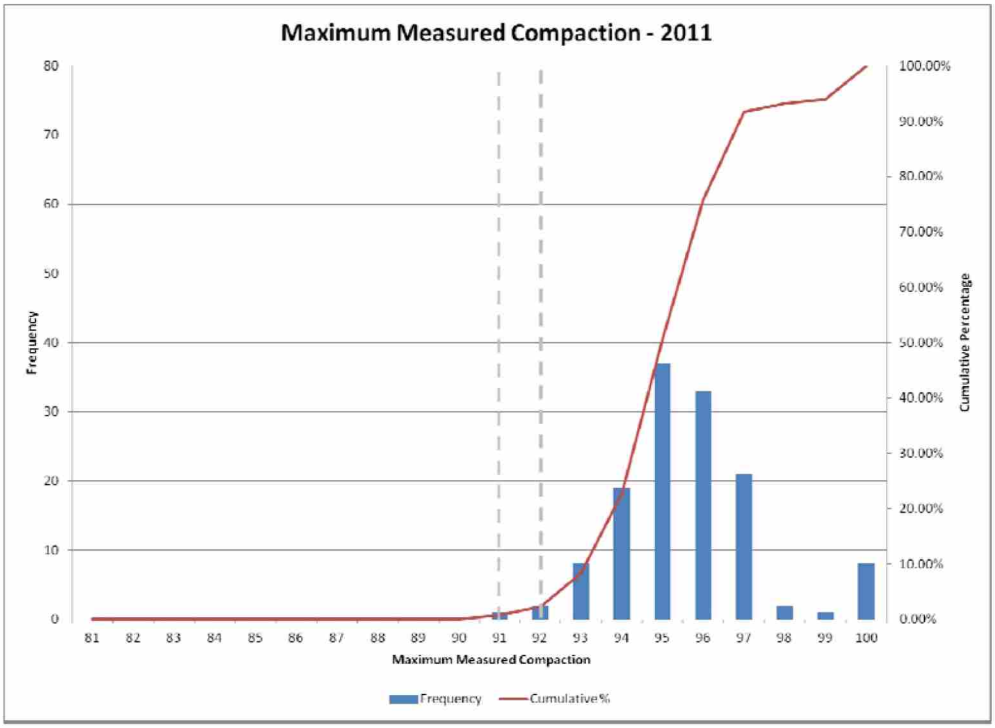

Figure 27: Maximum Compaction in 2011

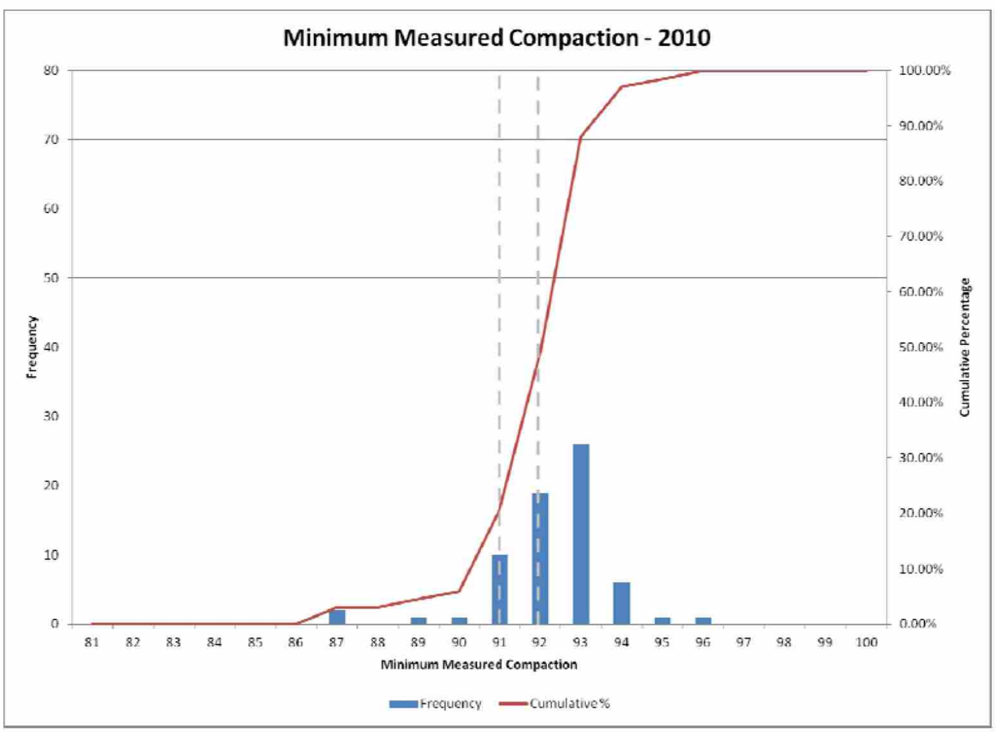

Figure 28: Minimum Compaction in 2010

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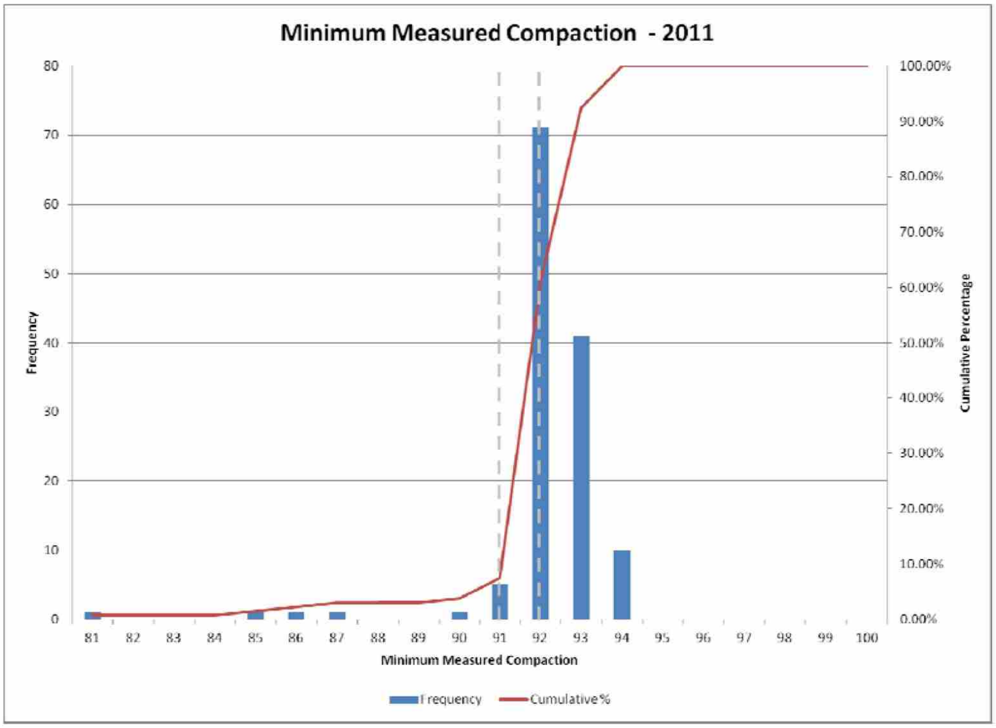

Figure 29: Minimum Compaction in 2011QA Results Review Summary

In general, in 2011 the quality of the asphalt mixes was better than in 2010 (Marshall and Superpave with the exception of SP 9.5). The quality of the mixes was improved (gradation, asphalt cement content and air voids). However, there were a few projects in 2011 where compaction was well below the specified requirements. This is likely due to late season paving. Poor Compaction on these projects will likely result in poor pavement performance.

The quality of SP 9.5 mixes was poor terms of gradation, AC content and air voids. A significant improvement in the quality of SP 9.5 mixes is required.

4.6 Pavement Surface Evaluation and Performance Analysis

In 2010 Golder was asked to evaluate poor surface appearance of relatively new pavement, constructed in 2007 to 2009. Table 16 shows a summary of surface distresses observed on these pavements and a guide summary of QA testing results. The condition of the pavements is shown in Appendix G. Figure G-1 to G-4 show typical example of observed distresses.

The main distresses were: extensive low to medium severity ravelling; very poor quality joints often ravelled and cracked; low to medium severity longitudinal cracking; and map cracking. The pavement had generally dry aged appearance.

The QA results analysis indicates that the main cause of these pavement distresses very early in the pavement life are due to low asphalt cement content, poor compaction and poor gradation. A potential impact of uncontrolled amount of RAP in the mix is discussed in Section 4.7.

Initial recommendations on asphalt mix bid asphalt cement content were recommended and implemented in 2010. The final asphalt cement content recommendations based on the observed pavement performance are included in the City of Hamilton Special Provision SP1151. It should be recognized that asphalt cement is a critical factor for pavement performance. Lean mixes that have low asphalt cement film thickness over the aggregates will oxidize quickly and then ravel and crack.

Asphalt compaction is another major factor. Poorly compacted asphalt lifts have high air void content that are interconnected forming pores. Asphalt with high void will be penetrated by water causing stripping and will oxidize causing the asphalt to become brittle.

Table 16: Summary of Surface Distresses Observed in 2010 Survey by Golder

Number	Contract Number	Road	Date Paved	Distresses Observed in 2010	Mix	Mix Design	Quality Assurance Testing			
							Test Type	Acceptable	Borderline	Rejectable
1	PW 07 – 23	Stonechurch	Nov-07	Low severity reveling, joint cracking, cracks	HL 3	No Verification	Gradation	2	2	-
							AC Content	3	1	-
							Air voids	5	-	-
							Stability	5	-	-
							Flow	5	-	-
							VMA	4	-	1
							Compaction	9	5	10
2	PW 05-49	Upper Wellington	Jul-07	Extensive low severity raveling, very poor joints – some opening	HL1 (SS)	No Verification	Gradation	-	-	10
							AC Content	1	2	7
							Air voids	2	4	4
							Stability	10	-	-
							Flow	10	-	-
							VMA	-	-	10
							Compaction	22	49	113
3	PW 07-13	Upper Wentworth	Jun-08	Very extensive low to medium severity raveling, poor joints, longitudinal and map cracking, aged appearance	SP 12.5 FC1 Cat C	Asphalt Cement Content 4.8% No Verification	Gradation	-	1	-
							AC Content	-	1	-
							Air voids	1	-	-
							VMA	1	-	-
							Compaction	19	-	-

Number	Contract Number	Road	Date Paved	Distresses Observed in 2010	Mix	Mix Design	Quality Assurance Testing			
							Test Type	Acceptable	Borderline	Rejectable
4	PW 07-12	Upper Wentworth	Nov-07	Extensive low to medium severity raveling, poor joints, map cracking, aged appearance	SP 12.5 FC2 Cat C	No Verification	Gradation	2	1	6
							AC Content	4	2	4
							Air voids	5	-	4
							VMA	5	-	4
							Compaction	89	-	
5	PW 07-17	Garth	Jun-07	Extensive reflective and some map cracking, some raveling, WMA lanes – no distresses	SP 12.5 FC1 Cat C	Asphalt Cement Content 5.0% Verification	N/A			
6	PW 07-11	Eastport	Jul-07	Extensive medium severity raveling, map cracking, aged appearance	SP 12.5 FC1 Cat C	Asphalt Cement Content 5.1% Verification	Gradation	-	4	3
							AC Content	5	2	3
							Air voids	4	3	1
							VMA	2	-	5
							Compaction	148	1	2
7	PW 08-06	Garth	Nov-08	No distresses	WMA Cat E	No Verification	Gradation	3	1	1
							AC Content	5	-	-
							Air voids	3	2	
							VMA	2	-	3
							Compaction	54	-	-

Number	Contract Number	Road	Date Paved	Distresses Observed in 2010	Mix	Mix Design	Quality Assurance Testing			
							Test Type	Acceptable	Borderline	Rejectable
8	PW 08-06	Garth	Nov-08	Low severity raveling, aged appearance	SP 12.5 FC2 Cat B	No Verification	Gradation	3	-	-
							AC Content	-	1	2
							Air voids	1	-	2
							VMA	3	-	-
							Compaction	24	-	-
9	PW 06-19	Mohawk	May-07	Low severity raveling, severe longitudinal crack	HL 1 (SS)	No Verification	Gradation	3	4	-
							AC Content	4	3	-
							Air voids	1	4	2
							Stability	7	-	-
							Flow	7	-	-
							VMA	7	-	-
							Compaction	16	28	10
10	PW 07-43	Garth	Oct-07	Extensive low to medium severity raveling, poor joints – opening, map and longitudinal cracking, aged appearance	SP 12.5 FC1 Cat C	No Verification	Gradation	-	2	-
							AC Content	1	1	-
							Air voids	2	-	-
							VMA	2	-	-
							Compaction	18	-	-

4.7 RAP in Asphalt Mixes

The amount of RAP in the mix may have a significant impact in mix performance. OPSS.MUNI 1151 allows up to 15 % of RAP in the surface course mixes and up to 30 % RAP in the binder course mies. OPSS.MUNI 1101 requires that the PG grade be changed if the amount of RAP is from 20 % to 40 %.

Besides the fact that the addition of RAP may harden the asphalt cement in the mix (the asphalt cement in RAP is typically aged and hard; often the penetration can be as low as 15-20 pen). Another issue is the fact that not all asphalt cement in the RAP will blend with the virgin asphalt cement added to the mix. RAP stockpiles are often very inconsistent from the gradation perspective and may contain a high amount of moisture. It is recommended that RAP to be used on the City's projects be used from certified stockpiles. Milled material from known locations can be properly crushed if necessary and stockpiled properly. Gradation should be checked on a regular basis. Proper drainage of stockpiles should be provided to prevent excess moisture in the aggregate.

Effective control of the amount of RAP added to asphalt mixes is a challenge as of today. The most effective way would be plant inspection during production by an experienced City staff or its representative. The requirements for RAP are covered in the City of Hamilton Special Provision 1103.

5.0 PAVEMENT DESIGN METHODOLOGY

Pavement design should take into account the following factors:

- Traffic loading (volume and percent of trucks) and road geometry (number of lanes);
- Type of soil/subgrade and water conditions;
- Materials available (granular materials, aggregates, asphalt cements and asphalt mixes, and concrete);
- Drainage;
- Environmental considerations/constraints;
- Sustainability; and
- Local experience (available pavement construction/rehabilitation technologies, contractor availability).

Currently the City uses an "off the shelf" method for pavement design. This method relies on the design engineer selecting a predetermined pavement structure based entirely on the type of road. Table 17 shows the four asphalt pavement structure options and the three composite pavement structure options.

Table 17: City of Hamilton Pavement Structure Designs

Road Classification	Layer Material Type and Thickness (mm)				
	Top Course Asphalt	Binder Course Asphalt	Concrete	Granular A	Granular B Type II
Urban/Rural Local Residential	40	80	--	150	300
Urban/Rural Collector Residential	40	100	--	150	300
Urban Local/Collector Commercial/Industrial	40	120	--	150	375
Minor/Major Arterial	40	120	--	150	450
Local	50	--	150	100	--
Minor Collector	50	--	175	100	--
Arterial/Major Collector/Industrial	50	--	200	100	--

It is our opinion that Table 17 oversimplifies the pavement design process and in some cases may result in poor pavement performance. It does not reflect the traffic loadings, soil and water conditions. It is recommended that, as a short term solution, the pavement design matrix should be expanded to reflect the traffic and soil conditions. Traffic information for all road classes and typical soil types in the City would be required in order to update the current matrix.

As a long tem solution, the pavement design methodology outlined in ASSHTO 93 should be followed especially for major roads with higher traffic volumes. Ultimately, Mechanistic Empirical Pavement Design Guide (MEPDG) should be followed. However its implementation requires significant experience and practical training is recommended for pavement design engineers. In the short term it is anticipated that upgrading the design matrix would be adequate.

6.0 PAVEMENT REHABILITATION

There is an array of options of pavement rehabilitation. All rehabilitation treatments are not equal and many have significant limitations with respect to their ability to solve specific road distresses. Thus, a straight cost comparison of rehabilitation treatment can be totally misleading.

As the pavement condition deteriorates, there comes a point when regular maintenance treatments are no longer effective and rehabilitation is required. Major pavement rehabilitation treatments can be divided into the following categories:

- Structural Overlays
- Recycling
  - Hot In-Place Recycling (HIR)
  - Cold In-Place Recycling (CIR)

- Cold In-Place Recycling with Emulsion
- Cold In-Place Recycling with Expanded Asphalt Mix (CIREAM)

– Full Depth Reclamation (FDR) with expended asphalt

- Total Pavement Reconstruction

Structural Overlays

This represents the traditional and simplest pavement rehabilitation technology. It involves placing a new hot mix asphalt overlay directly on an old deteriorated pavement. In numerous cases in order to maintain the existing elevation, mill and overlay methodology is used. Typical overlay thicknesses are in the range of 40 to 100 mm. A properly designed and constructed overlay will add structural strength, correct surface defects and provide a smooth riding surface. With prior hot mix padding, substandard cross-fall and superelevation can be corrected. The major limitation with a conventional overlay is that it only masks and does not eliminate most of the underlying pavement distresses. In particular, transverse and longitudinal cracking will reflect through the overlay, sometimes within as little as one to three years. To enhance the long-term performance of a hot mix overlay, some pre-treatments can be undertaken to the existing pavement. Options could include: cold milling, localized patching and partial- depth or full depth crack repairs to mitigate reflective cracking.

Hot In-Place Recycling (HIR)

With HIR, 100 percent recycling of the existing asphalt pavement is completed on site. HIR reconstitutes the upper portion of an existing asphalt pavement. In HIR the typical processing depths are 25 to 50 mm and the old asphalt is heated to at least 110° C and softened so that it can be scarified or hot rotary mixed. A recycling agent is usually added to rejuvenate the old asphalt cement binder. Fine aggregate can also be added to improve the hot mix properties, particularly air voids. HIR is generally performed with a dedicated recycling train and some processes allow the placement of an integral hot mix overlay above the recycled layer. HIR was used in Ontario in the early 1990s but is currently not used here at all. It is still being used in Alberta and British Columbia.

HIR has proved to be an effective means of rehabilitating urban streets, where there are severe constraints on grade raises due to curbs and private and commercial entrances. One disadvantage with the process is that it only restores the upper portion of the old asphalt and so many of the more severe pavement distresses can remain below. Further, pavement with extensive crack sealing or patching can create problems with maintaining the quality of the rejuvenated mix. However, with the use of perpetual (long-life) pavements with occurrence of only top-down cracking (TDC), HIR can be more effective in renewing pavement surface with TDC cracking. A coring program is needed to assess the suitability of the existing asphalt for HIR. The performance of properly designed and executed HIR projects has been good and it has even been used successfully for the rehabilitation of municipal and military airport runways.

Cold In-Place Recycling (CIR)

This process involves milling the existing asphalt partial depth or sometimes almost full depth, sizing the RAP, adding a bituminous binder (i.e. asphalt emulsion, sometimes with rejuvenators and/or recycling agents), re-spreading and compacting. Typical processing depths are 50 to 125 mm. CIR is usually performed using a recycling train. The blended material is deposited in a windrow where it is then picked up and placed using conventional paving equipment. Since this is a cold process, it requires favourable weather conditions for the emulsion to break and allow the compacted layer to gain adequate strength. The completed cold recycled layer can sustain traffic. However, for long term performance it should be protected with a conventional hot mix overlay or thin surfacing. The wearing course shall not be placed until the CIR mix has been allowed to cure for a minimum of 14 days.

Another method of CIR is cold in-place recycling using expanded asphalt mix (CIREAM), in which expanded (foamed) asphalt is used to bind the mix, instead of emulsified asphalt. One of the advantages of CIREAM over the conventional CIR with emulsified asphalt is its short curing period. A 2-day curing period is required for CIREAM as compared to 14-day period required for CIR with emulsified asphalt prior to placement of the new HMA overlay (provided moisture and compaction requirements are met).

One of the significant advantages of CIR, when compared to a straight hot mix overlay, is that it removes the majority of the asphalt distresses, such as wheel ruts, potholes and cracking. It also allows the old pavement to be re-profiled with restoration of crossfall. Since CIR does not treat the entire asphalt layer, there is a concern that over time, previous severe transverse cracks could reflect through the new pavement. The potential for this is generally low, since cold mix asphalt has been shown to be much more resistant to crack propagation than hot-mix asphalt. Recent experience has shown that provided the mix is properly designed, cold mix attains a relatively high stability and is sufficiently rut-resistant to be used on busy arterials (high volume roads).

Full Depth Reclamation (FDR)

In full depth reclamation (FDR), the asphalt surfacing is pulverized and blended into the underlying granular base. Additives can be used to produce a stabilized base course. Typical additives include foamed (expanded) asphalt, asphalt emulsions, Portland cement, lime, fly ash and calcium chloride. The emphasis here is on the FDR with expanded asphalt which provides asphalt stabilized base and hence increases the structural capacity of the existing pavement and eliminates existing pavement distresses. FDR is usually followed by placement of a wearing surface course. This treatment is especially useful where a pavement has inadequate structural capacity and where the pavement is severely distressed. It eliminates the risk of reflective cracking.

In addition, where a stabilizing additive will not be used, it is usually desirable to pulverize to a depth at least twice the thickness of asphalt. This ensures that the blended mix will have performance characteristics similar to a granular base. Maximum processing depths are about 300 mm. Maximum depth of foamed asphalt stabilization is 150 mm. It is usually necessary to verify that cobbles (such as coarse, pit-run subbase) will not be encountered within the depth to be in-place processed. In addition, it is important to verify that the existing granular base extends to the full in-place processing depth. Otherwise, the final pulverized product will become contaminated with sandy subbase or subgrade soils.

Total Pavement Reconstruction

Clearly, this is the most expensive form of road rehabilitation and can only be justified where no other recycling options are feasible. It involves complete removal of existing granulars and asphalt surfacing. Following subgrade preparation, a new pavement section is constructed. Recycling options for some of the materials removed should be explored. For example, if the asphalt layers are removed by milling, the RAP can be used in recycled hot-mix, or blended with granular base, typically up to 50 percent or can be used 100 percent on shoulder rounding to minimize erosion. Old granular base can be re-used as subbase and old subbase used for minor road platform widening.

The most frequent application of pavement reconstruction is to address localized poor performing areas. These can be areas of persistent frost heaves, poor transition treatments at rock cuts or sections of pavement above topsoil or organic layers. These problems cannot be addressed by overlays or in-place recycling and must be dealt with effectively to avoid on-going and costly maintenance. The problem areas can only be identified by a detailed review of the pavement history, maintenance records and a thorough investigation by knowledgeable and experienced practitioners. Total reconstruction may also be needed where an existing road is to be upgraded to a higher level of service and where vertical and horizontal alignment adjustments are required to improve road geometrics and operational safety.

7.0 PAVEMENT PRESERVATION

The major goal of pavement preservation is to keep good roads good. Pavement preservation is a program employing a network level, long term strategy that enhances functional pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety, and meet motorist expectations. Pavement preservation system includes five key components: pavement management system (PMS), long-term network planning, optimization, cost-effective selection criteria, and sustainable financing. Based on these five components, pavement preservation systematically minimizes the destructive impact of climate and traffic through timely application of remedial/maintenance treatments to the pavement. The key is to apply these treatments when the pavement is still in relatively good condition with no structural damage.

The types of remedial treatments that are typically employed in a pavement preservation program include routine maintenance, preventive maintenance, and minor rehabilitation. Routine maintenance is the day-to-day maintenance activities; examples include cleaning ditches, filling cracks in the pavement, etc. Preventive maintenance is the most critical treatment type in pavement preservation; it is applied to the existing pavements to retard the rate of future deterioration, and maintain and improve the functional condition of the pavement without increasing structural capacity. Applying the right preventive treatment at the right time is the key to the success of a pavement preservation program. Minor rehabilitation extends the original pavement service life by increasing the pavement structural capacity; examples include thin overlays and, cold in-place surface recycling, for instance.

Asphalt pavement preservation treatments include:

- Crack sealing;
- Crack filling;
- Fog seals;
- Rejuvenating seals;
- Chip seals;
- Slurry seals;
- Cape seals;
- Sand seals;

- Microsurfacing;
- Non-structural HMA overlay; and
- Surface milling and non-structural overlay.

Emerging technologies include Nova Chip and Metro Mat^{TM}. The pavement preservation technologies that are commonly used in Ontario are described below.

Asphalt Crack Sealing/ Crack Filling

Asphalt crack sealing generally targets the working cracks. It involves routing or sawing a reservoir, preparing the reservoir through abrasive blasting, and thoroughly cleaning it with compressed air. Hot-poured, rubberized asphalt sealants are most commonly used to seal the reservoir.

Asphalt crack filling is used for treating of non-working cracks. It includes cleaning the cracks with dried, compressed air and filling it with asphaltic material.

Fog Seal and Rejuvenating Seal

Fog seal is a light application of diluted asphalt emulsion to renew surfaces and seal small cracks and surface voids.

Rejuvenating seal is an application of emulsion of specific petroleum oils to penetrate dry and weathered asphalt pavements to restore its original desirable properties, plasticity and ductility in asphalt cement and restore pavement durability. Reclamite is a rejuvenating agent formulated from petroleum maltenes. It is used by number of municipalities in Ontario.

Reclamite is diluted at a ratio of 2 parts Reclamite to 1 part water and applied at rates between 0.30 liters/m^2 to 0.65 liters/m^2. The pavement is then sanded at an application rate of 0.5 to 1.0 kg/m^2 sand with 2 to 12 percent passing 75 μm sieve. Normal treatment can provide about 5 years of pavement additional life.

Chip Seal/ Surface Treatment

Chip seal consists of an application of asphalt emulsion followed immediately by a thin layer of aggregate. The goal is to have the aggregate particles approximately 70 percent embedded into the asphalt layer.

Chip seal can waterproof the pavement surface, provide sealing of low severity cracks, and restore surface friction. The chip seal membrane also slows down the asphalt cement oxidation process within the original asphalt surface layer. On the other hand, chip seal is not effective on pavements exhibiting medium to severe fatigue, linear or block cracking, rutting, roughness and shoving. The serviceable life of a chip seal treatment is considered to be 3 to 6 years with a typical average of 4 years under low to moderate traffic.

Chip seal is affected greatly by weather conditions; rain can cause problems when chip sealing process is carried out. Also, the asphalt binder needs time to cure. Due to the risk of loose chips and excessive noise, chip seal is used mainly on low volume roads in Ontario.

Slurry Seal

Slurry seal is a mixture of slow setting emulsified asphalt, well graded fine aggregate, mineral filler (most often Portland Cement), and water. It is considered a thermal process. The process takes from two to eight hours depending on the heat and humidity. As slurry seal has to set; it should not be placed during rainy weather and the temperature should not be lower than 10°C.

Slurry seal will not perform well if the underlying pavement exhibits medium to severe fatigue, linear or block cracking, rutting, roughness or shoving. It should be applied where the existing surface is stable with only low-severity cracking.

Slurry seal is used to seal the existing pavement surface, fill cracks in the pavement, restore a uniform surface texture, seal the surface against water and air intrusion, and to improve skid resistance. They are effective where the primary problem is excessive oxidation and hardening of the asphalt concrete or where there are aggregate "pop-outs" in asphalt wearing courses associated with soft limestone. Slurry seal does not have a strong skeleton and are typically applied as one aggregate layer thick. They are not suitable to correct surface irregularities and rutting.

The life of a slurry seal is from 3 to 5 years. Experienced slurry seal contractors are available throughout Ontario and the product is highly reliable.

Cape Seal

Cape seal is basically a type of slurry seal; it has gained some popularity in Ontario over the past several years. In this process, a slurry seal is applied to a newly constructed chip seal surface to improve the retention of the stone chips and seal the open voids. The cape seal treatment has a life expectancy of 9 to 15 years, with the typical life of about 9 years before re-application.

Micro-Surfacing

Micro-surfacing is a mixture of polymer-modified asphalt emulsion, well graded crushed mineral aggregate (typically 9.5 mm minus), mineral filler (normally Portland cement), water, and chemical additives, properly proportioned, mixed, and spread on a paved surface. The aggregates are tough in terms of hardness and resistance to polishing.

Micro-surfacing is a chemically controlled process. The materials are mixed in a truck mounted travelling plant and then deposited into a spreader box. No compaction is needed and traffic may be allowed on the mat within an hour after placement. Micro-surfacing typically involves two coats including a scratch or leveling coat followed by a surface coat. It is applied at ambient temperatures and has low energy requirements. Due to its quick application rate, it causes minimum disruption to traffic.

Micro-surfacing is applied on roads carrying medium to high volume traffic. The pavements should be in good structural condition and not exhibiting any significant structural distresses. A single course micro-surfacing applied to a pavement will retard oxidation and improve skid resistance. A multiple-course micro-surfacing application will correct certain pavement surface deficiencies including rutting, minor surface profile irregularities, polished aggregates or low slid resistance, and light to moderate raveling.

Micro-surfacing can extend the life of pavement by about 7 years. However, there are examples where properly applied microsurfacing can extend the life by more than 10 years.

Non-structural Thin HMA Overlay

Dense graded HMA mixes are typically used in non-structural thin HMA overlays in Ontario to improve the functional condition of a pavement including smoothness, skid resistance and roadway profile correction. Gap graded mixes (such as Stone Mastic Asphalt) can also be used. Thin overlays add little or no structural improvement to the pavement. Prior milling may be required if more severe surface distresses are present or where curb reveal needs to be maintained. Thin overlay thicknesses typically range from 20 to 40 mm. The mixes are sometimes modified with polymers for better field performance. Thin overlays will correct some small surface irregularities and low severity rutting; however, more severe irregularities should be repaired before the thin overlay application.

Thin asphalt overlays should be applied prior to the onset of fatigue-related pavement cracking. Candidate pavements may exhibit surface distresses such as moderate to severe ravelling, and moderate longitudinal and transverse cracks with some secondary cracking. Isolated structural distresses, such as alligator cracking must be patched prior to overlay. Thin overlays are particularly suitable for high volume roads in urban areas. The life of a thin overlay ranges from about 5 to 10 years with the average of about 8 years.

Surface Milling/ Non-Structural HMA Overlay

Surface milling is the removal of an existing asphalt surface through cold milling followed by a non-structural thin HMA overlay with a maximum thickness of 20 to 40 mm. This preventive treatment improves the functional condition of a pavement such as smoothness and skid resistance, corrects roadway profile, and matches curb and gutter grades.

8.0 WARM MIX ASPHALT

Warm Mix Asphalt (WMA) is a group of technologies that allow mixing and placement of asphalt mixes at significantly reduced temperatures. It has been used on number of projects in the US and Europe [Appendix H]. The benefits of using WMA can be divided into economic, environmental, social and technical. They are as follows:

- Economical
  - Much less fuel (up to 30%) can be required to heat the aggregates during mix production.
  - Since the WMA technologies are still relatively new, the cost of additives and required asphalt plant modification is still higher than the reduced fuel cost, on average about $3.0 as reported in the US [Appendix H].
- Environmental
  - Significant reduction of green house gas emission (up to 50%)
  - Drastic reduction in fumes;
- Social
  - Paving crews benefit from less fumes

  - Public satisfaction from fumes reduction and lower green house gas emission; and
- Technical
  - Ability of pave in lower temperatures – potential for paving season extension
  - Longer hauling distances are possible
  - Compaction improvements
  - Less thermal segregation
  - Reduced asphalt cement aging at the plant
  - Potential for higher RAP content in WMA mixes

Besides the above benefits, there are some concerns that shall be addressed, particularly at the WMA mix design stage. The major concerns are:

- Lack of experience with WMA mix design – the recommended procedure for the City of Hamilton in described in Special Provision SP1 included in Appendix F of this report;
- Changes to mix design procedures are required – as described in the recommended Special Provision SP2 included in Appendix F of this report;
- Moisture resistance of WMA mixes – is likely the major issue with the WMA mixes. Golder has been involved in three WMA failure evaluation in Ontario, all related to poor moisture resistance;
- Rutting resistance of WMA mixes may be lower than that of HMA; and
- Some researchers report that the resistance to thermal cracking of WMA mixes may be of concern.

WMA has been used in number of projects in US and Europe [Appendix H]. It has also been used in Ontario including MTO projects and on a few projects in the City of Hamilton. The use of WMA in Hamilton has been successful to date. There have been a few cases of WMA poor performance in Ontario.

Special provisions developed for the City of Hamilton for WMA process selection (SP1) and mix design (SP2) are included in Appendix F of this report.

WMA is currently used by the City only for low temperature paving. It is recommended that the City should take advantage of other benefits of WMA technologies and use it in the major season paving. The compaction temperature for WMA is currently specified by the City. Since different WMA technologies will likely require different compaction temperature, it is recommended that the compaction temperature should be based on WMA additive manufacturer's recommendations.

9.0 ENGINE OIL RESIDUE

In has been reported that Engine Oil Residue (EOR) has been blended with a significant fraction of asphalt cements used in Ontario [Appendix H] to meet certain temperature grades. Although EOR can provide a low-cost method of PG grade adjustment, it should be recognized that it has negative impact on asphalt pavement performance.

The paraffinic nature of EOR and the presence of detergents reduce the adhesion to aggregates and increases moisture damage and the rate of ravelling. The presence of metals such as iron, copper and chromium that act as catalysts speed up the asphalt cement oxidation process and cause the asphalt mat to become brittle.

The recommended special provision (SP3) is attached to this report in Appendix E.

10.0 IMPLEMENTATION OF RECOMMENDATIONS

It is anticipated that training with the City staff will be carried out in April 2012.

11.0 CLOSURE

We trust the contents of the report adequately address the project scope and are sufficient for your current needs. If you have any questions, or require any additional information, please do not hesitate to contact us.

Report Signature Page

GOLDER ASSOCIATES LTD.

Vimy Henderson, Ph.D.
Pavement and Materials Engineering

Ludomir Uzarowski, Ph.D., P.Eng.
Principal, Pavement and Materials Engineering

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APPENDIX A

Golder and Technical City Staff Meeting Minutes
December 19, 2011

Meeting with City of Hamilton

December 19, 2011 2:00 pm – 3:30 pm

In attendance:

Mike Becke, City of Hamilton
Jeff Pidsadny, City of Hamilton
Susan Jacob, City of Hamilton
Taufeek Ameer, City of Hamilton
Jie Zeng, City of Hamilton
Andrew Felinczak, City of Hamilton
Onio Ajaiji, City of Hamilton
Chris McCafferty, City of Hamilton
Vimy Henderson, Golder Associates Ltd.
Ludomir Uzarowski, Golder Associates Ltd.

1) Paving Specifications – General Discussion

Discussion

- Design and Construction Department uses Superpave mixes only.
- Planning and Development uses Marshall mixes (this involves work such as new subdivisions) – Sally and Lee are the contacts.
- Maintenance uses Marshall mixes.
- Marshall and Superpave specifications should be updated.
- WMA – new technology, used by the City on for late season paving. Very important that source material and additive are compatible. Is it worthwhile to work with the additive supplier at the mix design stage?
- Bidding AC content and absolute minimum for design.

Suggestions

- Only Superpave mixes will be covered in this report.
- The mixes and construction will be generally based on OPSS.MUNI 1151 and OPSS 310 as amended by City of Hamilton Special Provisions.
- Special provisions will be developed when modifications to OPSS are required or special mix design or construction requirements are needed.
- The report will include what mixes should be used for what particular conditions and locations.
- A special provision prohibiting the use of Engine Oil Residue (EOR) will be developed.
- WMA is covered in Item 6.

2) Granular Materials

Discussion

- Is the source the issue or the specification?
- One particular source deteriorated over time when stock piled.
- Jeff, Gerd and Gary can provide information on the various granular sources.
- Should granular sources be tested more than once a year, to watch for changes in characteristics?
- Use OPSS A, B Type II and Recycled A. Recycled A has a tendency to hold water. Anticipated that this occurs because the material is hard to compact, in the process of trying to compact it some material is crushed, producing fines.
- The new fines create an impermeable material that then holds water. Often significant movement of the road occurs in the first season after construction. Important to construct at the right time of year such that there will be ample time for the material to dry.
- Generally only compaction results are received by the City; sometime also gradations from sources and contractors.
- Ensuring compaction is achieved is a challenge.

Suggestions

- There is lack of documentation of the results of granular materials physical properties testing. The only records are for compaction testing.
- Granular materials should meet the requirements of OPSS 1010 and constriction should be in accordance with OPSS 314.
- Physical properties testing results must be submitted for each type of granular material, minimum on an annual basis.
- Performance history of granular materials from particular sources should be reviewed and accepted.
- Any granular materials deteriorating in stockpiles should not be used in pavement layers.
- If compaction of granular layers is an issue, the physical properties of the materials and the methods of compaction should be checked.

3) Aggregates

Discussion

- OPSS allows higher percentages of Reclaimed Asphalt Pavement (RAP) than City of Hamilton. City does not want to increase RAP percentages at this time.
- Steel slag recommendations are required in the specifications.
- Can limestone aggregates be used in the surface course on high volume roads?

Suggestions

- Asphalt mix aggregates should meet the requirements of OPSS 1001 and 1003 and City of Hamilton Special Provision.
- Aggregate properties must be included in any asphalt mix design.
- Different amounts of RAP can be allowed in asphalt mixes for different road/street categories.
- RAP quality can be very variable. We have to know what we are putting in our asphalt mixes.
- Consider certified RAP stockpiles to reduce the impact of inconsistency.
- Besides the OPSS specified properties Polished Stone Value (PSV) should be taken into consideration. PSV testing has been carried out and this was discussed, as well as the impact of

having low PSV results. Discussion regarding the effectiveness in terms of performance and cost of using trap rock initially in surface mixes or using limestone and micro surfacing in the future. The City could not recall issues in the last 10 years related to polishing of the aggregate in the surface mix. Ludomir noted that he has seen this occur in mixes in York Region and Toronto.

- Results of testing in Ireland: 41 and 45
- Lafarge Dundas – 41
- Dufferin Milton – 45

4) Asphalt Cement

Discussion

- Routinely use PG 58 – 28. PG 64 – 28 is used on higher volume roads.
- The LINC is the only case where PG 70 – 28 PM was used.
- Other uses of PG 70 – 28 in the future (Burlington Street).

Suggestions

- Asphalt cement should meet the requirements of OPSS.MUNI 1101 and City of Hamilton Special Provisions.
- Bumping the asphalt cement grade should follow the OPSS procedure. A grade bumping table will be included in the report. It will also be covered in the training.
- Polymer modification of asphalt cement is the recommended way of bumping the grade.
- A comment regarding using polymer modified PG 70 – 28 will be included in the specification.

5) Asphalt Mixes

Discussion

- Currently working with several composite pavement structures. Should the Superpave specification for the surface mix be different than what would be only used in a pavement structure with granular and asphalt?
- Overriding importance of rutting resistance in composite pavement structures.
- OPSS is currently followed for constructing the concrete road base.

Suggestions

- Superpave mixes should meet the OPSS.MUNI 1151 requirements. Construction should be to OPSS 310. Any modifications to the OPSS requirements will be covered in City of Hamilton Special Provisions.
- The City of Toronto has similar composite pavements and uses their typical surface mix.
- The report will clarify what mix types should be used on what road categories and take into account required pavement life and anticipated traffic loading. Training will be provided.
- Mix type and cost shall be verified against the required pavement performance.
- The required thickness of asphalt layer will have an impact on what mix types should be used. For thin lifts (< 40 mm) Superpave 9.5 mix can be considered.
- Effective control of the amount of RAP added to asphalt mixes is a challenge as of today. Not all asphalt cement in the RAP is blended with the virgin ac and it may have a detrimental impact on asphalt durability.

6) Warm Mix Asphalt

Discussion

- Introduced briefly the WMA topic.

Suggestions

- WMA should be sued not only for low temperature paving. The City should take advantage of other benefits of the WMA technology.
- One of the WMA advantages can be the increased amount of RAP in mixes – should be considered.
- WMA specification is currently permissive. City of Hamilton Special Provisions will be developed for the City of Hamilton for WMA mix design.
- NCHRP Report 691 "" will be referenced for mix design.
- Currently a compaction temperature is stated in the specification, perhaps this may be removed.
- Likely start with a list of a few additives being allowed and over time more will be accepted.
- Current cost increase of WMA mixes is due to the necessary additives. It does not take into account cost reduction due to lower fuel consumption.
- Costs may go down when the completions increases.

7) Pavement Rehabilitation

Discussion

- The most commonly used method of pavement rehabilitation is mill and overlay.
- It is not well explored subject in the city.
- Steel slag is not used around water mains, when is it alright to use RAP containing steel slag?

Suggestions

- Commonly use pavement rehabilitation methods in the province:
  - Mill and overlay, reconstruction, pulverization (FDR) and overlay, full depth reclamation with foamed asphalt, cold in place recycling with emulsion, open graded cold mix
- Example of contractors who do pavement recycling/reclamation work
  - Nor John
  - Seely Arnil
  - Hard Rock
  - Roto Mill
  - Miller
- Mill and overlay may not be suitable for number of circumstances, particularly if the pavement has extensive cracking with reflective cracking potential.
- Method of pavement rehabilitation should be considered on individual basis. Using only the information from asset management (network level) may often not be cost effective.
- Hot in place recycling is not used in Ontario although it is used in Alberta and BC.
- There will be an explanation in the report as to the behaviour of steel slag when it is milled (opened and reactivated)

8) Pavement Preservation

Discussion

- Commonly used:
  - Joint sealing
  - Crack sealing or filling (has not been done a lot recently however maintenance is doing it more, not clear if sealing or filling).

Suggestions

- Pavement preservation is the only way to maintain the network within available budget.
- Effective pavement preservation methodology shall be implemented not a random application of selected treatment.
- Pavement preservation should be correlated with the City's asset management system
- Other methods should be considered
  - Microsurfacing, slurry seal, surface treatment, chip seal, double chip seal.
  - Fog seal, thin overlay, Metro Mat, Nova Chip

9) Pavement Evaluation and Design

Discussion

- Using "off the shelf" templates in all scenarios currently, Chris will provide these to Ludomir.
- Primarily four roads in City: residential (no buses); arterial (few buses daily); truck route; LINC/RHVP. Roads/lanes with buses are deteriorating early/prematurely.
- Is a table/matrix sufficient or should further investigation and alternatives be carried out on some projects (such as SP 12.5 vs. SP 9.5)?
- If a project looks wet/swampy during construction then additional material is excavated and 300 mm of pit run slag is placed.
- Templates are available for an asphalt and granular pavement structure and for an asphalt and concrete pavement structure. It is not clear if the template provides designs that are equivalent in life and performance or if one pavement structure is a superior design.
- Information processing order between Asset Management and Design will change in the future.
- Asset Management will review more information, including GPR before forwarding projects to Design.

Suggestions

- The "of the shelf" method is not enough.
- As a short term solution the current matrix should be updated and include at least anticipated (or typical) traffic loading and soil type.
- Asset management is on the network level.
- "Project level" decision is required that will take into account the current pavement condition, future loading, soil type and feasible technology.
- If pavement life time limit is lowered then thinner pavements could be developed in design. Possibly need to discuss expectations for road condition and budget required to meet these expectations.

10) Staff Training

- Training will be provided to the City's technical staff.

11) Workshop for Contractors and Consultants

- Recommended but currently not planned.

12) Implementations and Report

- Spring 2012.

APPENDIX B

Marshall and Superpave Mix Designs Summary

TABLE B-1
JOB MIX FORMULA FOR 2010 CONSTRUCTION

Project Number	Document Type	Mix Type	Mix Category	Road	Job Mix Formula														
					25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
PW-10-19(H)	QA	SP 12.5	B	Van Wagners Beach Road	100	100	100	96.8	84.9	54.8	31.3	19	12.9	8.9	6.4	4.9	5.6	2.515	2.413
PW-10-19(H)	QA	SP 12.5	B	Van Wagners Beach Road	100	100	100	96.8	84.9	54.8	31.3	19	12.9	8.9	6.4	4.9	5.6	2.515	2.413
PW-10-19(H)	QA	SP 12.5	B	Van Wagners Beach Road	100	100	100	96.8	84.9	54.8	31.3	19	12.9	8.9	6.4	4.9	5.6	2.515	2.413
PW-10-11(H)	QA	SP 19.0	C	Hwy 52 at Jerseyville Road Rodabout	100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
PW-10-11(H)	QA	SP12.5 FC2	C	Hwy 52 at Jerseyville Road Rodabout	100	100		96.5	78.7	51.3	39	30.1	22.6	13.9	7.6	4.7	5	2.823	2.709
PW-10-11(H)	QA	SP12.5 FC2	C	Hwy 52 at Jerseyville Road Rodabout	100	100		96.5	78.7	51.3	39	30.1	22.6	13.9	7.6	4.7	5	2.823	2.709
PW-10-43(H)	QA	SP 12.5 FC2	C	McNiven Road	100	100		96.5	78.7	51.3	39	30.1	22.6	13.9	7.6	4.7	5	2.823	2.709
PW-10-43(H)	QA	SP 12.5 FC2	C	McNiven Road	100	100		96.5	78.7	51.3	39	30.1	22.6	13.9	7.6	4.7	5	2.823	2.709
PW-10-40(H)	QA	SP 12.5 FC2	D	Stone Church Road W	100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
PW-10-40(H)	QA	SP 12.5 FC2	D	Stone Church Road W	100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
PW-10-40(H)	QA	SP 12.5 FC2	D	Stone Church Road W	100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
PW-10-40(H)	QA	SP 12.5 FC2	D	Stone Church Road W	100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
PW-10-40(H)	QA	SP 12.5 FC2	D	Stone Church Road W	100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
PW-10-40(H)	QA	SP 12.5 FC2	D	Stone Church Road W	100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
PW-10-40(H)	QA	SP 12.5 FC2	D	Stone Church Road W	100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
PW-10-40(H)	QA	SP 12.5 FC2	D	Stone Church Road W	100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
PW-10-40(H)	QA	SP 12.5 FC2	D	Stone Church Road W	100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
PW-10-40(H)	QA	SP 12.5 FC2	D	Stone Church Road W	100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
PW-09-10(HSW)	QA	SP 12.5 FC2	D	Cannon Street East	100	100	100	96.7	82.1	55.1	45.3	29.9	19.4	13.2	8.6	5.9	5	2.653	2.546
PW-09-10(HSW)	QA	SP 12.5 FC2	D	Cannon Street East	100	100	100	96.7	82.1	55.1	45.3	29.9	19.4	13.2	8.6	5.9	5	2.653	2.546
PW-09-10(HSW)	QA	SP 12.5 FC2	D	Cannon Street East	100	100	100	96.7	82.1	55.1	45.3	29.9	19.4	13.2	8.6	5.9	5	2.653	2.546
PW-09-10(HSW)	QA	SP 12.5 FC2	D	Cannon Street East	100	100	100	96.7	82.1	55.1	45.3	29.9	19.4	13.2	8.6	5.9	5	2.653	2.546
PW-08-45(HSW)	QA	SP 12.5	B	Millen Road, Red oak Avenue and Federal Avenue	100	100	100	98	83.1	52.4	40.8	29.7	18.8	9.9	6.7	5.2	5	2.514	2.414
PW-08-45(HSW)	QA	SP 12.5	B	Millen Road, Red oak Avenue and Federal Avenue	100	100	100	98	83.1	52.4	40.8	29.7	18.8	9.9	6.7	5.2	5	2.514	2.414
PW-08-45(HSW)	QA	SP 12.5	B	Millen Road, Red oak Avenue and Federal Avenue	100	100	100	98	83.1	52.4	40.8	29.7	18.8	9.9	6.7	5.2	5	2.514	2.414
PW-08-45(HSW)	QA	SP 12.5	B	Millen Road, Red oak Avenue and Federal Avenue	100	100	100	98	83.1	52.4	40.8	29.7	18.8	9.9	6.7	5.2	5	2.514	2.414
PW-10-39(HSW)	QA	SP 19.0	D	Twenty Road East and Nebo Road	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-39(HSW)	QA	SP 19.0	D	Twenty Road East and Nebo Road	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-39(HSW)	QA	SP 19.0	D	Twenty Road East and Nebo Road	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-37(HSW)	QA	SP 19.0	D	London Street	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-37(HSW)	QA	SP 19.0	D	London Street	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-37(HSW)	QA	SP 19.0	D	London Street	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-39(HSW)	QA	SP 19.0	D	Twenty Road	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-28(HSW)	QA	SP 19.0	D	Lewis Road from Barton St E to S. Service Rd	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-28(HSW)	QA	SP 19.0	D	Lewis Road from Barton St E to S. Service Rd	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-28(HSW)	QA	SP 19.0	D	Lewis Road from Barton St E to S. Service Rd	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-28(HSW)	QA	SP 19.0	D	Lewis Road from Barton St E to S. Service Rd	100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
PW-10-07(HSW)	QA	SP 19.0	C	Margaret Avenue	100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
PW-10-07(HSW)	QA	SP 19.0	C	Margaret Avenue	100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
PW-10-07(HSW)	QA	SP 19.0	C	Margaret Avenue	100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44

TABLE B-1

JOB MIX FORMULA FOR 2010 CONSTRUCTION

Project Number	Document Type	Mix Type	Mix Category	Road	Job Mix Formula														
					25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
PW-10-07(HSW)	QA	SP 19.0	C	Margaret Avenue	100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
PW-10-07(HSW)	QA	SP 19.0	C	Margaret Avenue	100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
PW-10-07(HSW)	QA	SP 12.5	B	Margaret Avenue	100	100		100	86.3	52.8	42.8	31.7	20.3	10.3	6.6	5.4	5	2.535	2.434
PW-10-07(HSW)	QA	SP 19.0	C	Margaret Avenue	100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
PW-10-07(HSW)	QA	SP 19.0	C	Margaret Avenue	100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
	QA	SP 12.5 FC2	C	Longwood Road	100	100		97	82.4	51.7	44.1	27.9	17	10.7	6.9	4.7	5.1	2.552	2.453
	QA	SP 12.5 FC2	C	Longwood Road	100	100		97	82.4	51.7	44.1	27.9	17	10.7	6.9	4.7	5.1	2.552	2.453
PW-10-25(H)	QA	SP 12.5 FC2	D	Main Street West	100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-10-25(H)	QA	SP 12.5 FC2	D	Main Street West	100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-10-25(H)	QA	SP 12.5 FC2	D	Main Street West	100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-10-25(H)	QA	SP 12.5 FC2	D	Main Street West	100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-10-25(H)	QA	SP 12.5 FC2	D	Main Street West	100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-10-25(H)	QA	SP 12.5 FC2	D	Main Street West	100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-10-25(H)	QA	SP 12.5 FC2	D	Main Street West	100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-10-25(H)	QA	SP 12.5 FC2	D	Main Street West	100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-09-08(HSW)	QA	SP 12.5	B	East 28th Street	100	100		98.1	80.7	50.5	46.2	29.5	18.2	11.1	7	4.9	5	2.567	2.463
PW-09-08(HSW)	QA	SP 12.5	B	East 28th Street	100	100		98.1	80.7	50.5	46.2	29.5	18.2	11.1	7	4.9	5	2.567	2.463
PW-09-08(HSW)	QA	SP 12.5	B	East 28th Street	100	100		98.1	80.7	50.5	46.2	29.5	18.2	11.1	7	4.9	5	2.567	2.463
PW-10-13(HSW)	QA	HL 8 HS		Nebo Road	100	97.7	89.9	81.9	67.4	49.7	43.7	27.4	16.4	10	6.3	4.4	5.3	2.547	2.467
PW-10-13(HSW)	QA	HL 8 HS		Nebo Road	100	97.7	89.9	81.9	67.4	49.7	43.7	27.4	16.4	10	6.3	4.4	5.3	2.547	2.467
PW-10-13(HSW)	QA	HL 8 HS		Nebo Road	100	97.7	89.9	81.9	67.4	49.7	43.7	27.4	16.4	10	6.3	4.4	5.3	2.547	2.467
PW-10-13(HSW)	QA	HL 8 HS		Nebo Road	100	97.7	89.9	81.9	67.4	49.7	43.7	27.4	16.4	10	6.3	4.4	5.3	2.547	2.467
	QA	SP 19.0	D	Longwood Road	100	96.2		75.7	65	52.7	47.9	31.5	19.2	11.1	6.4	4.3	4.65	2.568	2.465
	QA	SP 19.0	D	Longwood Road	100	96.2		75.7	65	52.7	47.9	31.5	19.2	11.1	6.4	4.3	4.65	2.568	2.465
	QA	SP 19.0	D	Longwood Road	100	96.2		75.7	65	52.7	47.9	31.5	19.2	11.1	6.4	4.3	4.65	2.568	2.465
	QA	SP 19.0	D	Lake Avenue	100	96.8		78.4	68.4	53.3	42.4	27.1	18	11.7	7.3	4.4	5	2.556	2.453
	QA	SP 19.0	D	Lake Avenue	100	96.8		78.4	68.4	53.3	42.4	27.1	18	11.7	7.3	4.4	5	2.556	2.453
	QA	SP 19.0	D	Lake Avenue	100	96.8		78.4	68.4	53.3	42.4	27.1	18	11.7	7.3	4.4	5	2.556	2.453
	QA	SP 19.0	D	Lake Avenue	100	96.8		78.4	68.4	53.3	42.4	27.1	18	11.7	7.3	4.4	5	2.556	2.453
	QA	SP 12.5 FC2	D	York Blvd	100	100		94.5	78.8	54	44.8	30	20	13	8.2	5.3	5	2.534	2.433
	QA	SP 12.5 FC2	D	York Blvd	100	100		94.5	78.8	54	44.8	30	20	13	8.2	5.3	5	2.534	2.433
	QA	SP 12.5 FC2	D	Queen St	100	100		94.5	78.8	54	44.8	30	20	13	8.2	5.3	5	2.534	2.433
PW-09-02(HSW)	QA	SP 12.5 FC2	D	King Street East	100	100	100	94.8	79.4	55.3	46.2	30.8	20.2	13	7.9	5	5	2.531	2.43
PW-09-02(HSW)	QA	SP 12.5 FC2	D	King Street East	100	100	100	94.8	79.4	55.3	46.2	30.8	20.2	13	7.9	5	5	2.531	2.43
PW-09-02(HSW)	QA	SP 12.5 FC2	D	King Street East	100	100	100	94.8	79.4	55.3	46.2	30.8	20.2	13	7.9	5	5	2.531	2.43
PW-09-32(HSW)	QA	SP 19.0	D	Stone Church Road	100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
PW-09-32(HSW)	QA	SP 19.0	D	Stone Church Road	100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
PW-09-32(HSW)	QA	SP 19.0	D	Stone Church Road	100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
PW-09-32(HSW)	QA	SP 19.0	D	Stone Church Road	100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
PW-09-32(HSW)	QA	SP 19.0	D	Stone Church Road	100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47

TABLE B-1
JOB MIX FORMULA FOR 2010 CONSTRUCTION

Project Number	Document Type	Mix Type	Mix Category	Road	Job Mix Formula														
					25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
PW-09-32(HSW)	QA	SP 19.0	D	Stone Church Road	100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
PW-09-32(HSW)	QA	SP 19.0	D	Stone Church Road	100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
PW-10-34(HW)	QA	SP 12.5 FC2	D	Upper Wellington Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-34(HW)	QA	SP 12.5 FC2	D	Upper Wellington Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-34(HW)	QA	SP 12.5 FC2	D	Upper Wellington Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-34(HW)	QA	SP 12.5 FC2	D	Upper Wellington Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-45(H)	QA	SP 12.5 FC2	D	Wilson Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-45(H)	QA	SP 12.5 FC2	D	Wilson Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-45(H)	QA	SP 12.5 FC2	D	Wilson Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-09(HSW)	QA	SP 12.5 FC2	D	East 43rd St	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-09(HSW)	QA	SP 12.5 FC2	D	East 43rd St	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-09(HSW)	QA	SP 12.5 FC2	D	East 43rd St	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-09(HSW)	QA	SP 12.5 FC2	D	East 43rd St	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
	QA	SP 12.5 FC2	D	Woodward Ave	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
	QA	SP 12.5 FC2	D	Woodward Ave	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
	QA	SP 12.5 FC2	D	Woodward Ave	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
	QA	SP 12.5 FC2	D	York Blvd	100	100		94.5	78.8	54	44.8	30	20	13	8.2	5.3	5	2.534	2.433
	QA	SP 12.5 FC2	D	Woodward Ave	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
	QA	SP 12.5 FC2	D	Woodward Ave	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
	QA	SP 12.5 FC2	D	Woodward Ave	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-09-32(HSW)	QA	SP 12.5 FC2	D	Stone Church Road	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-09-32(HSW)	QA	SP 12.5 FC2	D	Stone Church Road	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-09-32(HSW)	QA	SP 12.5 FC2	D	Stone Church Road	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-09-32(HSW)	QA	SP 12.5 FC2	D	Stone Church Road	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-09-32(HSW)	QA	SP 12.5 FC2	D	Stone Church Road	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-09-32(HSW)	QA	SP 12.5 FC2	D	Stone Church Road	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-34(HW)	QA	SP 12.5 FC2	D	Upper Wellington Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-34(HW)	QA	SP 12.5 FC2	D	Upper Wellington Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-34(HW)	QA	SP 12.5 FC2	D	Upper Wellington Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-38	QA	SP 12.5 FC2	D	King Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-38	QA	SP 12.5 FC2	D	King Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-38	QA	SP 12.5 FC2	D	King Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-38	QA	SP 12.5 FC2	D	King Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-19(H)	QA	SP 19.0	B	Van Wagners Beach Road	100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
PW-10-19(H)	QA	SP 19.0	B	Van Wagners Beach Road	100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
PW-10-19(H)	QA	SP 19.0	B	Van Wagners Beach Road	100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
PW-10-11(H)	QA	SP 19.0	C	Hwy 52 at Jerseyville Road Rodabout	100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
PW-10-11(H)	QA	SP 19.0	C	Hwy 52 at Jerseyville Road Rodabout	100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461

TABLE B-2

JOB MIX FORMULA FOR 2011 CONSTRUCTION

Project Number	Document Type	Mix Type	Mix Category	Road	Job Mix Formula														
					25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
PW-11-43(H)	QA	SP 19.0	C	East 31st Street	100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
PW-11-43(H)	QA	SP 19.0	C	Queendale Avenue	100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
PW-11-43(H)	QA	SP 19.0	C	Queendale Avenue	100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
PW-11-43(H)	QA	SP 19.0	C	Brucedale Avenue	100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
PW-11-43(H)	QA	SP 19.0	C	Brucedale Avenue	100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
PW-11-43(H)	QA	SP 19.0	C	Brucedale Avenue	100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
PW-11-06(HSW)	QA	SP 19.0	D	Park Row North	100	95.4		81.7	75	58.4	37.8	22.3	14.6	9.4	6.4	4.3	5	2.542	2.44
PW-11-06(HSW)	QA	SP 19.0	B	Park Row North	100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
PW-11-42(H)	QA	SP 9.5	C	Bendamere Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	Bendamere Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	West 27th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	West 27th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-43(H)	QA	SP 9.5	C	Queensdale Avenue	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	Brucedale Avenue	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	Brucedale Avenue	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	Brucedale Avenue	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	East 34th Street	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	East 35th Street	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	East 35th Street	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	East 31st Street	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	East 27th Street	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	East 34th Street	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	East 38th Street	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	East 32nd Street	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	East 33rd Street	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	HL 8		Acadia Drive	100	95.6	89.7	82.8	72.7	49.4	29.9	17.2	10.1	7	5.1	4.1	5.3	2.534	2.454
PW-11-43(H)	QA	HL 8		Acadia Drive	100	95.6	89.7	82.8	72.7	49.4	29.9	17.2	10.1	7	5.1	4.1	5.3	2.534	2.454
PW-11-43(H)	QA	SP 9.5	C	Acadia Drive	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	Acadia Drive	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 9.5	C	East 38th Street	100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
PW-11-43(H)	QA	SP 19.0	C	East 38th Street	100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
PW-11-22(HSW)	QA	SP 19.0	C	Crockett Street	100	98.4		86.4	74.3	55.5	43.9	29.8	18.8	9.9	5.9	3.9	4.8	2.563	2.461
PW-11-55(H)	QA	SP 19.0	D	Glover Road	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-55(H)	QA	SP 19.0	D	Glover Road	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-55(H)	QA	SP 19.0	D	Glover Road	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-55(H)	QA	SP 19.0	D	Glover Road	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-55(H)	QA	SP 19.0	D	Glover Road	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-55(H)	QA	SP 19.0	D	Glover Road	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-55(H)	QA	SP 19.0	D	Glover Road	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-55(H)	QA	SP 19.0	D	Glover Road	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465

TABLE B-2

JOB MIX FORMULA FOR 2011 CONSTRUCTION

Project Number	Document Type	Mix Type	Mix Category	Road	Job Mix Formula														
					25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
PW-11-11(HSW)	QA	SP 19.0	D	Rymal Road	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-11(HSW)	QA	SP 19.0	D	Upper James Street	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-11(HSW)	QA	SP 19.0	D	Upper James Street	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-11(HSW)	QA	SP 19.0	D	Upper James Street	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-11(HSW)	QA	SP 19.0	D	Upper James Street	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-11(HSW)	QA	SP 19.0	D	Upper James Street	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-11(HSW)	QA	SP 19.0	D	Upper James Street	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-11(HSW)	QA	SP 19.0	D	Upper James Street	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-11(HSW)	QA	SP 19.0	D	Upper James Street	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-11(HSW)	QA	SP 19.0	D	Upper James Street	100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
PW-11-11(HSW)	QA	SP 12.5 FC2	D	Rymal Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-11(HSW)	QA	SP 12.5 FC2	D	Upper James Street	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-11(HSW)	QA	SP 12.5 FC2	D	Upper James Street	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-11(HSW)	QA	SP 12.5 FC2	D	Upper James Street	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-11(HSW)	QA	SP 12.5 FC2	D	Upper James Street	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-11(HSW)	QA	SP 12.5 FC2	D	Upper James Street	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-11(HSW)	QA	SP 12.5 FC2	D	Upper James Street	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-44(H)	QA	SP 12.5 FC2	D	Upper Paradise Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-55(H)	QA	SP 12.5 FC2 (WMA)	D	Glover Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-55(H)	QA	SP 12.5 FC2 (WMA)	D	Glover Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-55(H)	QA	SP 12.5 FC2 (WMA)	D	Glover Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-44(H)	QA	SP 12.5 FC2	D	Sanatorium Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-44(H)	QA	SP 12.5 FC2	D	Sanatorium Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-44(H)	QA	SP 12.5 FC2	D	Sanatorium Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-44(H)	QA	SP 12.5 FC2	D	Upper Paradise Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-44(H)	QA	SP 12.5 FC2	D	Upper Paradise Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-44(H)	QA	SP 12.5 FC2	D	Sanatorium Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-44(H)	QA	SP 12.5 FC2	D	Sanatorium Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-11-44(H)	QA	SP 12.5 FC2	D	Sanatorium Road	100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
PW-10-37(HSW)	QA	SP 12.5	B	London Street	100	100		99.2	86.5	51.7	40.3	29.9	18.3	8.8	6.1	5.2	5	2.514	2.414
PW-10-07(HSW)	QA	SP 12.5	B	Margaret Avenue	100	100		100	86.3	52.8	42.8	31.7	20.3	10.3	6.6	5.4	5	2.535	2.434
PW-10-07(HSW)	QA	SP 12.5	B	Margaret Avenue	100	100		100	86.3	52.8	42.8	31.7	20.3	10.3	6.6	5.4	5	2.535	2.434
PW-10-07(HSW)	QA	SP 12.5	B	Margaret Avenue	100	100		100	86.3	52.8	42.8	31.7	20.3	10.3	6.6	5.4	5	2.535	2.434
PW-11-36(H)	QA	SP 9.5	C	Glenview East	100	100	100	100	91.5	71.6	56.1	40	24	11.8	6.9	4.7	5.3	2.521	2.419
PW-11-44(H)	QA	SP 9.5	C	Leslie Avenue	100	100	100	100	91.5	71.6	56.1	40	24	11.8	6.9	4.7	5.3	2.521	2.419
PW-11-44(H)	QA	SP 9.5	C	Bendamere Avenue	100	100	100	100	91.5	71.6	56.1	40	24	11.8	6.9	4.7	5.3	2.521	2.419
PW-11-44(H)	QA	SP 9.5	C	Elmwood Avenue	100	100	100	100	91.5	71.6	56.1	40	24	11.8	6.9	4.7	5.3	2.521	2.419
PW-11-08(HSW)	QA	SP 12.5 FC1	C	Birge Street	100	100	100	98.1	80.1	52	43	30.1	20.8	11.7	6.1	3.5	4.9	2.636	2.53
PW-11-08(HSW)	QA	SP 12.5 FC1	C	Wellington Street	100	100	100	98.1	80.1	52	43	30.1	20.8	11.7	6.1	3.5	4.9	2.636	2.53
PW-11-08(HSW)	QA	SP 12.5 FC1	C	Wellington Street	100	100	100	98.1	80.1	52	43	30.1	20.8	11.7	6.1	3.5	4.9	2.636	2.53

TABLE B-2
JOB MIX FORMULA FOR 2011 CONSTRUCTION

Project Number	Document Type	Mix Type	Mix Category	Road	Job Mix Formula														
					25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
PW-11-08(HSW)	QA	SP 12.5 FC1	C	Wellington Street	100	100	100	98.1	80.1	52	43	30.1	20.8	11.7	6.1	3.5	4.9	2.636	2.53
PW-11-08(HSW)	QA	SP 12.5 FC1	C	Wellington Street	100	100	100	98.1	80.1	52	43	30.1	20.8	11.7	6.1	3.5	4.9	2.636	2.53
PW-11-61(H)	QA	SP 12.5 FC2	D	Mohawk Road	100	100	100	96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-11-34(H)	QA	SP 12.5	D	Inverness Avenue	100	100	100	98.3	83.9	52.3	34.4	25.3	18.7	10.6	5.5	3.5	4.8	2.544	2.441
PW-11-34(H)	QA	SP 12.5	D	Inverness Avenue	100	100	100	98.3	83.9	52.3	34.4	25.3	18.7	10.6	5.5	3.5	4.8	2.544	2.441
PW-10-09(HSW)	QA	SP 12.5 FC2	D	East 43rd Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-09(HSW)	QA	SP 12.5 FC2	D	East 43rd Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-45(H)	QA	SP 12.5 FC2	D	Wilson Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-45(H)	QA	SP 12.5 FC2	D	Wilson Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-45(H)	QA	SP 12.5 FC2	D	Wilson Street	100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
PW-10-31(P)	QA	HL 8		Centre Road	100	97.8	91.6	82.9	69.6	50	34.2	24.1	15.6	9.2	6.4	5	5.3	2.54	2.455
PW-10-31(P)	QA	HL 8		Centre Road	100	97.8	91.6	82.9	69.6	50	34.2	24.1	15.6	9.2	6.4	5	5.3	2.54	2.455
PW-10-31(P)	QA	HM 3		Centre Road	100	100	100	100	100	83.8	50.9	32.6	19.6	9.3	5.9	4.3	6.3	2.513	2.42
PW-10-31(P)	QA	HM 3		Centre Road	100	100	100	100	100	83.8	50.9	32.6	19.6	9.3	5.9	4.3	6.3	2.513	2.42
PW-11-31(S)	QA	SP 9.5 (WMA)	C	Milton Avenue	100	100	100	100	91.5	71.1	56.6	46.1	32.5	15.4	7	4.2	5.3		
PW-11-31(S)	QA	SP 9.5	C	Hazel Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-31(S)	QA	SP 9.5	C	Gibson Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-31(S)	QA	SP 9.5	C	Stirton Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-31(S)	QA	SP 9.5	C	Greenaway Rd	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-31(S)	QA	SP 9.5	C	Chestnut Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-31(S)	QA	SP 9.5	C	Madison Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-31(S)	QA	SP 9.5	C	Madison Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-31(S)	QA	SP 9.5	C	Holton Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-36(H)	QA	SP 9.5	C	Main Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-36(H)	QA	SP 9.5	C	Main Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-36(H)	QA	SP 9.5	C	Beland Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-36(H)	QA	SP 9.5	C	Main Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-36(H)	QA	SP 9.5	C	Main Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-36(H)	QA	SP 9.5	C	Main Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-36(H)	QA	SP 9.5	C	Beland Avenue South	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-36(H)	QA	SP 9.5	C	Glencarry Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-36(H)	QA	SP 9.5	C	Taylor Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-36(H)	QA	SP 9.5	C	Beland Court	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5 (WMA)	C	Juanita Drive	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5 (WMA)	C	Brenlyn Court	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5 (WMA)	C	Darlington Court	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5 (WMA)	C	Darlington Court	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5 (WMA)	C	West 22nd Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5 (WMA)	C	West 23rd Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	Fisher Crescent	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432

TABLE B-2
JOB MIX FORMULA FOR 2011 CONSTRUCTION

Project Number	Document Type	Mix Type	Mix Category	Road	Job Mix Formula														
					25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
PW-11-42(H)	QA	SP 9.5	C	Fisher Crescent	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	West 24th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	West 24th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	Elmwood Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	Elmwood Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	Elmwood Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	Fisher Crescent	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	West 22nd Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	West 23rd Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	West 21st Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	West 23rd Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	Colquhoun Crescent	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5 (WMA)	C	Brucedale Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5 (WMA)	C	Brucedale Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5 (WMA)	C	East 5th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5 (WMA)	C	Empress Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5 (WMA)	C	Empress Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	East 8th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	East 8th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	East 7th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	East 6th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	Brucedale Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	Brucedale Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	East 8th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	East 8th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	Queensdale Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	Queensdale Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	Queensdale Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	Prince George Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	Queendale Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	Prince George St	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-34(H)	QA	SP 9.5	C	Churchill Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	Bendamere Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	Bendamere Avenue	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	West 27th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-42(H)	QA	SP 9.5	C	West 27th Street	100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
PW-11-30(H)	QA	SP 12.5 (WMA)	D	Nash Road	100	100		97.4	83.5	54.5	41	32.8	23.7	11.3	6.1	3.4	5.2		
PW-11-30(H)	QA	SP 12.5 (WMA)	D	Nash Road	100	100		97.4	83.5	54.5	41	32.8	23.7	11.3	6.1	3.4	5.2		
PW-11-30(H)	QA	SP 12.5 (WMA)	D	Nash Road	100	100		97.4	83.5	54.5	41	32.8	23.7	11.3	6.1	3.4	5.2		
PW-11-30(H)	QA	SP 12.5 (WMA)	D	Nash Road	100	100		97.4	83.5	54.5	41	32.8	23.7	11.3	6.1	3.4	5.2		

TABLE B-2
JOB MIX FORMULA FOR 2011 CONSTRUCTION

Project Number	Document Type	Mix Type	Mix Category	Road	Job Mix Formula														
					25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
PW-10-15(HW)	QA	SP 12.5	D	Lake Avenue Drive	100	100		94.6	76.4	51.3	40.1	25.8	17.5	11.6	7.5	4.7	5.2	2.54	2.439
PW-10-15(HW)	QA	SP 12.5	D	Lake Avenue Drive	100	100		94.6	76.4	51.3	40.1	25.8	17.5	11.6	7.5	4.7	5.2	2.54	2.439
PW-11-49(H)	QA	SP 12.5 FC1	D	Centre Road	100	100		96.2	80.4	52.5	50.9	31	18.4	10.9	6.6	4	5		
PW-11-49(H)	QA	SP 12.5 FC1	D	Centre Road	100	100		96.2	80.4	52.5	50.9	31	18.4	10.9	6.6	4	5		
PW-11-49(H)	QA	SP 12.5 FC1	D	Centre Road	100	100		96.2	80.4	52.5	50.9	31	18.4	10.9	6.6	4	5		
PW-11-58(H)	QA	SP 12.5 FC2	D	Barton Street West	100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-11-58(H)	QA	SP 12.5 FC2	D	John Street South	100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-11-58(H)	QA	SP 12.5 FC2	D	James Street South	100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-11-58(H)	QA	SP 12.5 FC2	D	John Street South	100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-11-58(H)	QA	SP 12.5 FC2	D	James Street South	100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-11-58(H)	QA	SP 12.5 FC2	D	Markland Street	100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
PW-11-49(H)	QA	SP 19.0	D	Centre Road	100	98.4		87.4	73.6	50.4	48.5	29.3	17.5	10.5	6.4	4	4.6	2.569	2.467
PW-11-58(H)	QA	SP 19.0	D	James Street South	100	98.4		87.4	73.6	50.4	48.5	29.3	17.5	10.5	6.4	4	4.6	2.569	2.467
PW-11-58(H)	QA	SP 19.0	D	Markland Street	100	98.4		87.4	73.6	50.4	48.5	29.3	17.5	10.5	6.4	4	4.6	2.569	2.467

APPENDIX C

Asphalt Quality Assurance Test Results 2010 and 2011

TABLE C-1
QUALITY ASSURANCE TEST RESULTS FOR 2010 CONSTRUCTION

		Sample Results																								Job Mix Formula														
Mix Type	Mix Category	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	Air Voids	VMA	VFA	Dust	Stability	Flow	G_{mm}	G_{mb}	N_{ini}	N_{des}	N_{max}	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
HL 8 HS		100	98.5	89.2	78.7	63.2	48.5	39.4	24.7	16.4	12.3	9.7	6.9	5.36	0.9	12.7			15435	16.5	2.555	2.532				100	97.7	89.9	81.9	67.4	49.7	43.7	27.4	16.4	10	6.3	4.4	5.3	2.547	2.467
HL 8 HS		100	98.2	89.2	82.7	67.1	52.1	44.3	29.2	18.9	13.5	10.1	6.6	5.44	1.4	12.9			16335	16.4	2.563	2.528				100	97.7	89.9	81.9	67.4	49.7	43.7	27.4	16.4	10	6.3	4.4	5.3	2.547	2.467
HL 8 HS		100	97.9	90.7	83.1	67.2	50.9	41.5	26.4	17.2	12.5	9.5	6.5	5.45	1.5	11.9			14248	15.5	2.554	2.517				100	97.7	89.9	81.9	67.4	49.7	43.7	27.4	16.4	10	6.3	4.4	5.3	2.547	2.467
HL 8 HS		100	97.5	90.7	82.5	71.1	51.9	42.7	26.5	16.5	11.4	8.5	5.5	5.47	3.1	13.2			13425	12.5	2.478	2.557				100	97.7	89.9	81.9	67.4	49.7	43.7	27.4	16.4	10	6.3	4.4	5.3	2.547	2.467
SP 12.5	B	100	100	100	97.1	88	66.4	43.7	30.2	21.4	13.7	8.2	5.9	6.15	0.9	12.8					2.503	2.481	90.2	-	-	100	100	100	96.8	84.9	54.8	31.3	19	12.9	8.9	6.4	4.9	5.6	2.515	2.413
SP 12.5	B	100	100	100	97.4	90.5	70.7	45.7	31.1	22.2	14.9	9.5	7.3	5.83	0.7	12.3					2.503	2.487	90.4	-	-	100	100	100	96.8	84.9	54.8	31.3	19	12.9	8.9	6.4	4.9	5.6	2.515	2.413
SP 12.5	B	100	100	100	94.8	85.5	63.6	42.4	29.5	20.9	13.6	8.1	5.8	5.88	1.9	12.7					2.525	2.477	89.4	-	-	100	100	100	96.8	84.9	54.8	31.3	19	12.9	8.9	6.4	4.9	5.6	2.515	2.413
SP 12.5	B	100	100	100	97.8	85.3	58	43.2	34.1	20.9	9	5.9	5.2	5.06	4.9	15.2					2.552	2.426	88.5			100	100	100	98	83.1	52.4	40.8	29.7	18.8	9.9	6.7	5.2	5	2.514	2.414
SP 12.5	B	100	100	100	96.4	85.6	59.5	44.2	34.7	20.7	8.7	5.5	5.1	5.07	4.7	15.4					2.54	2.42	88.6			100	100	100	98	83.1	52.4	40.8	29.7	18.8	9.9	6.7	5.2	5	2.514	2.414
SP 12.5	B	100	100	100	97.1	84.4	56.6	41.8	32.8	19.9	9.1	6	5.8	4.9	4.9	14.6					2.563	2.439	88.2			100	100	100	98	83.1	52.4	40.8	29.7	18.8	9.9	6.7	5.2	5	2.514	2.414
SP 12.5	B	100	100	100	96.7	89.3	62	46.2	36.1	21	9.2	6	4.7	5.09	5	15.1					2.555	2.427	88.4			100	100	100	98	83.1	52.4	40.8	29.7	18.8	9.9	6.7	5.2	5	2.514	2.414
SP 12.5	B	100	100	99.6	96.5	80.9	52	39.9	29.7	20.7	11.8	7.3	4.9	5.12	2.7	14.4					2.531	2.464	88.3			100	100		100	86.3	52.8	42.8	31.7	20.3	10.3	6.6	5.4	5	2.535	2.434
SP 12.5	B	100	100	100	98.5	87.2	60.2	51.8	32.1	18.4	11.3	7.6	6.2	4.64	7.9	17.3					2.586	2.381	84.1			100	100		98.1	80.7	50.5	46.2	29.5	18.2	11.1	7	4.9	5	2.567	2.463
SP 12.5	B	100	100	100	99.2	88.1	61.3	52.5	32.9	20.3	13.8	10	7.3	4.92	6	15.8					2.585	2.43	85.4			100	100		98.1	80.7	50.5	46.2	29.5	18.2	11.1	7	4.9	5	2.567	2.463
SP 12.5	B	100	100	100	99.5	89.6	64.1	55.4	34.7	20.6	13.1	8.8	6.6	4.65	7.7	16.9					2.592	2.392	84.2			100	100		98.1	80.7	50.5	46.2	29.5	18.2	11.1	7	4.9	5	2.567	2.463
SP 12.5 FC2	C	100	92.7		94.4	85.2	55.7	43.4	32.2	23.8	14.6	7.1	3.5	5.15	4.2	16.5	74.4				2.799	2.681	89.2	95.8	-	100	100		96.5	78.7	51.3	39	30.1	22.6	13.9	7.6	4.7	5	2.823	2.709
SP 12.5 FC2	C	100	99.2		92.9	76.5	47.3	36.7	28	21.2	13	6.2	3.4	4.51	4.5	16.4	72.5				2.79	2.664	88.9	95.5	-	100	100		96.5	78.7	51.3	39	30.1	22.6	13.9	7.6	4.7	5	2.823	2.709
SP 12.5 FC2	C	100	100	100	95.1	83.4	61.3	51.8	35.2	23.2	16.3	12.2	8.2	5.22	3.3	14.08	76.6	1.9			2.572	2.487	88.4			100	100		97	82.4	51.7	44.1	27.9	17	10.7	6.9	4.7	5.1	2.552	2.453
SP 12.5 FC2	C	100	100	100	99.6	89	63.2	50.8	33.4	23.1	17.9	14.4	10	5.11	2.4	13.18	81.8	2.3			2.572	2.51	88.8			100	100		97	82.4	51.7	44.1	27.9	17	10.7	6.9	4.7	5.1	2.552	2.453
SP 12.5 FC2	C	100	100		96	81.2	46	34.7	25.6	19.1	12.1	6.4	3.5	4.51	4.2	14.8	71.7				2.834	2.715	88.3	95.8	-	100	100		96.5	78.7	51.3	39	30.1	22.6	13.9	7.6	4.7	5	2.823	2.709
SP 12.5 FC2	C	100	100		96.9	83.2	46.2	34.5	25.8	19.6	12.5	6.4	3.2	4.53	5.4	15	64				2.864	2.709	87.4	94.6	-	100	100		96.5	78.7	51.3	39	30.1	22.6	13.9	7.6	4.7	5	2.823	2.709
SP 12.5 FC2	D	100	100	100	97.3	83.3	53.1	43.3	37.7	32.9	16.6	8.9	5.4	5.29	2.2	14.1					2.455	2.401	91.4			100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	97.7	85.2	55.7	44.7	38.5	33.2	17.1	9.3	5.3	5.44	1.6	13.9					2.453	2.413	91.9			100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	96.7	81.5	52.2	42.1	36.9	32	15.9	8.6	5.4	5.03	1.8	13.1					2.469	2.424	91.8			100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	97.4	83.2	54.9	43.6	37.1	31.7	16.3	9.3	6.3	5.08	1.4	13.2					2.457	2.423	92.3			100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	96.5	75.5	42.9	32.5	26.4	21.8	12.2	7.1	4.7	5.27	1	12.3					2.477	2.452	90.4			100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	97.1	80.3	52.8	41	34.3	28	12.7	6.6	4.1	4.86	2.1	13.2					2.47	2.418	91.6			100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	97	79.5	48.9	37.8	31.2	25.9	12.2	6.5	4.3	4.93	2.3	13.3					2.472	2.416	91.2			100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	97.3	82.6	53.1	41.1	33.8	28.1	14.7	7.8	4.6	5.34	2	13.7					2.464	2.415	91.3			100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	97.7	82	51.6	41.4	36	31.5	15.2	8.1	4.9	4.84	3.5	14.2					2.475	2.388	90.5			100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	97.5	81.4	49.3	40.1	35.1	30.7	14.6	7.4	4.2	4.73	3.7	14.5					2.468	2.376	89.8			100	100	100	97.5	82.8	54.5	44.1	39.2	34.6	14.5	8	5.9	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	97.8	86.8	56.1	44.7	33.2	25.5	15.6	9.5	6.1	5.32	3.3	15.7					2.633	2.546	89.4			100	100	100	96.7	82.1	55.1	45.3	29.9	19.4	13.2	8.6	5.9	5	2.653	2.546
SP 12.5 FC2	D	100	100	100	98.8	83.5	53.4	43.9	30.1	20.6	14.1	9.4	6.2	5.13	3.1	13.5					2.693	2.609	88.9			100	100	100	96.7	82.1	55.1	45.3	29.9	19.4	13.2	8.6	5.9	5	2.653	2.546
SP 12.5 FC2	D	100	100	100	98.1	83.5	50.7	41.9	28.1	18.6	11.9	7.6	5	4.91	3	13.9					2.671	2.591	88.8			100	100	100	96.7	82.1	55.1	45.3	29.9	19.4	13.2	8.6	5.9	5	2.653	2.546
SP 12.5 FC2	D	100	100	100	97	81.6	53.3	44.6	27.4	19	12.2	7.8	5.2	4.93	3.1	15.4					2.627	2.545	88.2			100	100	100	96.7	82.1	55.1	45.3	29.9	19.4	13.2	8.6	5.9	5	2.653	2.546
SP 12.5 FC2	D	100	100	100	95.4	78	44.4	30.9	24.6	18.3	11.2	5	2.2	4.79	3.2	14.2					2.842	2.751	89.7			100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100	100	97.8	81.8	47	32.3	25.4	19	11.9	5.5	2.5	4.82	4.2	15.3					2.835	2.717	88.9			100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100	100	96.2	79.5	47	32.5	25.1	18.4	11.2	4.9	2.2	4.76	4.9	15.7					2.844	2.704	88.4			100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100	100	96.9	81.8	49.3	33.7	25.8	19.1	12.3	6.2	3.9	4.79	3.9	15.1					2.834	2.723	89.2			100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100	100	97.7	79.6	49.3	36.4	28.7	20.9	12.6	4.6	3.2	4.85	5	15.9					2.839	2.697	88.2			100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100	100	99.3	87.1	53.8	39.5	30.4	21.5	12.8	5.8	4	5.05	3.5	15.9					2.801	2.703	89.7			100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100	100	98	82.9	51.1	33.8	29.7	21.7	13.2	6.3	4.1	5.07	3.8	15.2					2.834	2.727	89.9			100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100	100	97.8	83.3	52.9	38.7	29.9	21.3	12.8	6.1	4.2	5.09	3.6	15.9					2.807	2.705	89.8			100	100	100	97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100		98.9	84.6	55.6	43.5	33.3	26.2	13.8	7.4	3.7	5.17	1.9	14.71	87.1	0.8			2.482	2.435	91.7			100	100		94.5	78.8	54	44.8	30	20	13	8.2	5.3	5	2.534	2.433
SP 12.5 FC2	D	100	100		98.6	84	54.8	43.5	33.7	26.6	14	7.3	3.5	4.71	4	15.47	74.1	0.8			2.5	2.401	90.2			100	100		94.5	78.8	54	44.8	30	20	13	8.2	5.3	5	2.534	2.433
SP 12.5 FC2	D	100	100		93.3	76.9	55.1	45.5	29.7	19.7	13.4	9.1	6.3	5.31	1.5	13.77	89.1	1.3			2.502	2.465	89.8			100	100		94.5	78.8	54	44.8	30	20	13	8.2	5.3	5	2.534	2.433
SP 12.5 FC2	D	100	100	100	98.9	91.1	62.1	45.8	28.3	18.2	12.2	8	6.2	5.47	3.7	15.1					2.533	0.244	86.9			100	100	100	94.8	79.4	55.3	46.2	30.8	20.2	13	7.9	5	5	2.531	2.43
SP 12.5 FC2	D	100	100	100	95.7	85.6	57.5	47.3	29.6	18.1	11	6.6	5.7	5.4	4.8	15.9					2.535	2.415	86.7			100	100	100	94.8	79.4	55.3	46.2	30.8	20.2	13	7.9	5	5	2.531	2.43
SP 12.5 FC2	D	100	100	100	90.7	74.8	56.5	46.1	28.2	17.2	10.6	6.4	4.1	5.5	4.1	15.8					2.524	2.422	87.4			100	100	100	94.8	79.4	55.3	46.2	30.8	20.2	13	7.9	5	5	2.531	2.43
SP 12.5 FC2	D	100	100		96.8	84.9	61.1	52.1	33.6	22.1	14	8.9	6	5.11	2.9	15.7	81.4	1.21			2.674	2.596	88.3	97.1		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		95.8	82.7	57	48.9	31.5	20.8	13.2	8.3	5.6	4.97	2.8	15.2	81.9	1.14			2.68	2.606	88.1	97.2		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		94.7	79.2	55.4	47.1	30.1	19.8	12.5	8.1	5.6	4.72	2.9	14.9	80.5	1.19			2.687	2.609	87.8	97.1		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		92.6	69.4	40.5	33.4	21.7	14.7	9.9	7	5.2	4.32	4.6	14.8	69.3	1.3			2.725	2.601	85.4	95.4		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591

TABLE C-1

QUALITY ASSURANCE TEST RESULTS FOR 2010 CONSTRUCTION

		Sample Results																								Job Mix Formula														
Mix Type	Mix Category	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	Air Voids	VMA	VFA	Dust	Stability	Flow	G_{mm}	G_{mb}	N_{ini}	N_{des}	N_{max}	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
SP 12.5 FC2	D	100	100		97.9	85.8	61.5	52.7	32.3	20.3	12.4	8	5.6	5.2	2.4	16.8	85.9	0.98			2.627	2.565	88.6	97.6		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.1	81.2	56.5	47.3	30.9	20.6	12.9	8.3	5.7	4.95	2.1	15.5	86.4	1.09			2.652	2.596	88.6	97.9		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.1	80.1	51.5	45	29.6	19.5	11.1	5.1	2.3	4.98	3.7	16.9	77.9	0.43			2.654	2.555	87.3	96.3		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		95.5	80.8	57.4	49.2	30.9	19.9	12.3	7.7	5.2	4.99	2.1	14.9	85.7	1.04			2.673	2.616	88.5	97.9		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.2	81.9	57.5	49.4	31.5	20.4	12.7	7.9	5.3	4.93	2.5	15	83.1	1.09			2.68	0.2612	88.4	97.5		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		95.6	83.1	60.2	51.7	32.8	21.5	13.6	8.7	6.1	5.24	2	15.5	87.3	1.16			2.658	2.606	99.7	98		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.2	85.8	61.1	52	32.7	21.1	13	8	5.3	5.21	2.8	15.9	82.5	1.04			2.667	2.593	88.1	97.2		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		99.2	84.3	55.7	46.1	31.3	20.3	13	8.6	5.9	5.35	3.1	16.11	80.8	0.8			2.672	2.589	88			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		98.3	83.7	56.8	46.9	31.5	20	12.5	7.9	5.3	5.39	3.9	17.18	77.3	0.7			2.662	2.557	87.4			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		91.3	78.8	57.9	47.2	32.8	21	12.5	7.7	5	5.05	2.3	17.28	86.7	0.7			2.605	2.545	89.6			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97	83	56.4	44.7	35	27.7	14.8	8	4	5.06	2.3	14.78	84.4	0.9			2.488	2.43	91.5			100	100		94.5	78.8	54	44.8	30	20	13	8.2	5.3	5	2.534	2.433
SP 12.5 FC2	D	100	100		98.4	84	58.7	48.5	32.9	21.1	13.5	8.9	6.2	5.11	3.2	16.5	80.6	0.9			2.656	2.57	88.1			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.7	84.6	61.2	49.6	33.2	21	13	8.3	5.5	5.27	3.3	16.88	80.5	0.8			2.651	2.563	88			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.8	80.7	56.9	46.9	31.9	20.8	13.2	8.7	6	5.13	2.8	16.01	82.5	0.8			2.662	2.586	88.4			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.2	82	52.3	44	30.1	19.4	12.3	8	5.6	5.32	2.3	16.3					2.643	2.582	88.7			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.9	81.5	54.8	45.9	31.1	19.8	12.5	8.1	5.5	5.12	3.4	16.3					2.667	2.577	87.7			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.6	85.5	58.1	49	32.7	20.6	13	8.1	5.7	5.44	2.2	16.3					2.645	2.585	88.7			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		98.3	84.2	57	48.2	32.6	21	13.6	9.2	6.7	5.31	2.5	15.9					2.662	2.595	88.6			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.7	80	55.4	46.8	31.5	20.1	12.8	8.3	5.6	5.17	2.4	15.8					2.658	2.594	88.5			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		99.3	89.1	66.2	55.9	37.6	24	15.5	10.5	7.6	5.55	2.2	16.6					2.638	2.58	88.7			100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		95.4	79.7	51.3	43.2	29	20	13	8.6	6.1	4.48	3.4	14.6	76.5	1.39			2.704	2.611	87.9	96.6		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		98.4	83.1	56	47.7	31.5	21.5	14	9.3	6.5	4.75	2.3	14.1	83.7	1.44			2.697	2.635	88.7	97.7		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		95.3	81.5	54.5	46.2	30.6	21.1	13.9	9.4	6.8	4.89	1.7	14	88	1.42			2.686	2.641	89.4	98.3		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		96.5	82.5	55.5	47.4	31	20.7	12.9	8.4	5.8	4.73	3	14.9	79.8	1.24			2.689	2.608	88.2	97		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		96.9	82.7	56.2	47.7	31.8	22	14.4	9.7	7	4.92	1.6	13.9	88.2	1.49			2.69	2.646	89.5	98.3		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		96.3	83.7	56.3	48.3	31.6	21.7	14.1	9.3	6.5	4.7	3	14.7	79.8	1.42			2.694	2.614	88.3	97		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.9	83.1	55.2	47	31.2	21.4	13.8	9.2	6.5	5.08	2.1	14.7	86	1.31			2.68	2.625	89.2	97.9		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 19.0	B	100	93.2	87.5	78.1	69.1	52.4	43.2	31.6	21.2	13	7.4	5	4.8	3.5	13.1					2.567	2.477	88.9			100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
SP 19.0	B	100	98.2	94.5	88.3	77.5	56.7	40.6	28.7	19.9	13.5	9	6.7	5.14	2.2	12.7					2.554	2.497	89.1			100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
SP 19.0	B	100	97.6	96	90.9	83	62.3	43.8	30.8	21.6	15	10.4	7.9	5.31	2	12.8					2.551	2.499	89.7			100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
SP 19.0	C	100	92.7		77.2	68.2	49.1	39.9	29.2	21.4	13.1	6.9	4.6	4.87	2.2	12.7	82.4				2.548	2.491	90.3	97.7		100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
SP 19.0	C	100	97.5	89.1	79.3	66.1	48.9	41	29.8	19.6	11.3	7.4	5.2	4.73	2.7	13.5					2.539	2.471	89.9			100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
SP 19.0	C	100	95.8	89.8	82.8	69.8	48.3	39.7	29.3	20.1	11.8	7.5	5.1	4.77	2.8	13.5					2.545	2.473	89.9			100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
SP 19.0	C	100	98	90.4	82.3	69.7	50.6	41.3	29.7	20.4	12.2	8.1	5.5	5.06	3.5	13.1					2.582	2.493	89.8			100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
SP 19.0	C	100	95.7	87.1	76.6	63.6	46.6	38.7	28.6	19.9	12.4	8	5.2	5.13	2.4	12.9					2.56	2.499	89.9			100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
SP 19.0	C	100	99.1	91.9	81.8	68.2	51.6	43.2	32.3	22.9	14.6	10.2	7.4	4.53	2.4	12.1					2.568	2.506	90.4			100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
SP 19.0	C	100	98.5	97.8	84.2	75	55.8	47.7	35.3	23.7	13	8.1	5.3	4.78	3	13.6					2.547	2.469	90			100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
SP 19.0	C	100	99.3	92.9	85.8	75.5	57.1	49	35.6	23.9	13.2	8.2	5.1	5.06	3.1	13.8					2.549	2.47	90.1			100	98.4		86.3	74.1	58	50.6	36.1	22.4	12	7.5	5.6	4.9	2.542	2.44
SP 19.0	C	100	93.6		78.9	68.8	49	42.2	32.1	23.6	14.5	8.1	5.6	4.9	2.1	12.8	83.7	1.28			2.542	2.489	90.8	97.9		100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
SP 19.0	C	100	96.2		78.7	68.5	49.5	42.3	32.3	24	15	8.2	5.7	4.76	2	12.3	83.8	1.34			2.549	2.498	91	98		100	95		77	69.7	53.5	47.7	33.3	21	11.8	6.8	4.5	5	2.564	2.461
SP 19.0	D	100	99.2	93.9	87.1	74.4	57.9	51.9	34.3	20.9	12.1	7.3	4.8	4.97	4.2	15.2					2.549	2.442	88			100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	98.1	93.5	87.2	70.1	52.6	47.1	31.8	19.9	11.4	6.6	4	4.73	3.3	14.1					2.55	2.467	89.1			100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	94.9	86.1	80.7	67.1	51.1	45.9	29.6	18	10.5	6.4	4.1	4.79	3.7	14.7					2.545	2.452	88.6			100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	99.3		84	73.3	52.7	44.2	29.9	20	12.1	8.2	5.3	4.76	3.1	13.2	76.8	1.27			2.571	2.492	89.2	96.9		100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	95.7		83.2	71.6	55.3	47.4	29.6	20	12.2	7.3	4.6	4.86	3	13.5	77.7	1.06			2.563	2.485	89.8	97		100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	98.3		87.4	77.6	61.9	53.3	37.7	25.8	14.3	8.6	5.6	5.2	1.5	13.4	89.1	1.14			2.536	2.499	91.6	98.5		100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	97.4	91.8	83.4	74	56.6	45.4	27.6	16.6	10.7	7.4	4.9	4.96	4.1	14.87	72.4	1.2			2.555	2.449	87.6			100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	93.9		58.2	46.3	32.9	27.6	19.7	13.5	7.7	4.7	3.2	3.58	3.2	11.5	71.9	0.95			2.593	2.509	88.2	96.8		100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	99.3		83.8	75.9	57.6	47.4	29.1	18.9	12.4	8.8	6.1	4.94	1.6	12.5	87.2	1.38			2.559	2.518	89.6	98.4		100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	99.4		88.2	78	58.4	48.2	29.5	19	12	8.2	5.4	4.75	2.5	12.9	80.7	1.27			2.565	2.501	89	97.5		100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	96.4		86.2	77.1	54.2	44.7	31.8	19.8	10	5.8	3.9	4.36	2.4	12.9	81.1	0.92			2.554	2.492	90.6	97.6		100	97.8		85.9	74.3	55.1	46.9	29.8	18	10	5.9	4	4.8	2.567	2.465
SP 19.0	D	100	97.7		78.3	67.1	53	46.8	30	18.3	11.5	7.7	4.9	4.86	4	14.09	71.6	1.2			2.574	2.47	88.1			100	96.2		75.7	65	52.7	47.9	31.5	19.2	11.1	6.4	4.3	4.65	2.568	2.465
SP 19.0	D	100	94.9		68.1	60.6	45.6	39.7	26.6	17.1	11.2	7.7	5	4.88	1.5	12.15	87.7	1.2			2.565	2.526	90.5			100	96.2		75.7	65	52.7	47.9	31.5	19.2	11.1	6.4	4.3	4.65	2.568	2.465

TABLE C-1
QUALITY ASSURANCE TEST RESULTS FOR 2010 CONSTRUCTION

Mix Type	Mix Category	Sample Results																								Job Mix Formula														
		25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	Air Voids	VMA	VFA	Dust	Stability	Flow	G_{mm}	G_{mb}	N_{ini}	N_{des}	N_{max}	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
SP 19.0	D	100	99		78.5	66.8	53	46.5	29.8	18.2	11.5	7.8	5.2	4.94	3.6	14.16	74.6	1.2			2.56	2.469	88.4			100	96.2		75.7	65	52.7	47.9	31.5	19.2	11.1	6.4	4.3	4.65	2.568	2.465
SP 19.0	D	100	97.1		82.6	73.1	58.2	47.3	30.3	19.9	13.2	9.2	6	5.39	2.8	13.44	79.2	1.4			2.531	2.459	88.9			100	96.8		78.4	68.4	53.3	42.4	27.1	18	11.7	7.3	4.4	5	2.556	2.453
SP 19.0	D	100	95.9		80	70.7	57.7	49	32	21.4	14.9	10.4	6.7	5.33	2.5	12.69	80.3	1.6			2.542	2.479	89.4			100	96.8		78.4	68.4	53.3	42.4	27.1	18	11.7	7.3	4.4	5	2.556	2.453
SP 19.0	D	100	95.2		76.2	64.5	51.2	42.4	27.6	18.3	12.8	9	5.9	4.91	3.3	12.89	74.4	1.5			2.546	2.462	88.2			100	96.8		78.4	68.4	53.3	42.4	27.1	18	11.7	7.3	4.4	5	2.556	2.453
SP 19.0	D	100	98.1		80.3	68.6	55.4	45.3	28.3	17.6	11.5	7.9	5	5.31	4.4	14.25	69.1	1.2			2.547	2.434	87.1			100	96.8		78.4	68.4	53.3	42.4	27.1	18	11.7	7.3	4.4	5	2.556	2.453
SP 19.0	D	100	98.6	92	83.9	72	52.8	38.8	29.1	20.3	12.8	8.4	6	4.56	2.4	11.4					2.583	2.52	89.6			100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
SP 19.0	D	100	100	92.4	82.5	72.7	55.1	41.6	31.4	21.6	13.6	9.2	8.8	4.78	2.8	12.3					2.574	2.5	89.7			100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
SP 19.0	D	100	100	99	92.1	80.4	61.2	45.3	33.4	22.3	13.7	9	7.4	4.96	3.1	12.5					2.579	2.499	89.3			100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
SP 19.0	D	100	100	94.2	81	67.1	47.9	34.6	25.6	17.5	11	7.2	6	4.46	4.4	12.4					2.604	2.489	87.2			100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
SP 19.0	D	100	100	97.5	90.6	76.8	54	39.3	29.5	20.6	13.2	8.8	8.5	4.89	3.1	12.5					2.577	2.497	89.1			100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
SP 19.0	D	100	100	92	85	72.3	54.1	46.9	33	21.9	14.4	10	7.7	4.84	3.2	12.9					2.567	2.485	88.8			100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47
SP 19.0	D	100	100	96.7	87.1	74.1	54.4	40.5	29.8	20.2	12.3	8	5.9	4.81	3.1	12.3					2.578	2.5	88.8			100	97.2		82.6	68.5	44.9	31.8	21.2	13.6	7.6	4.9	3.6	4.6	2.574	2.47

TABLE C-2

QUALITY ASSURANCE TEST RESULTS FOR 2011 CONSTRUCTION

Mix Type	Mix Category	Sample Results																								Job Mix Formula														
		25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	Air Voids	VMA	VFA	Dust	Stability	Flow	G_{mm}	G_{mb}	N_{ini}	N_{des}	N_{max}	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
HL 8		100	95.4	89.1	85.4	74.7	54.9	35.6	22.6	15.3	11	8.3	6.7	5.41	1.7	13.6			14448	15	2.524	2.48				100	95.6	89.7	82.8	72.7	49.4	29.9	17.2	10.1	7	5.1	4.1	5.3	2.534	2.454
HL 8		100	96.4	92.1	88.1	76.2	56	36.3	23.6	16.4	11.9	9.1	7.3	5.64	1.3	13.7			13516	17.3	2.514	2.483				100	95.6	89.7	82.8	72.7	49.4	29.9	17.2	10.1	7	5.1	4.1	5.3	2.534	2.454
HL 8		100	98	94.6	87	74.4	55.1	38.6	28.2	18.9	11.5	7.9	5.6	5.58	1.2	12.3			18846	17.3	2.548	2.517				100	97.8	91.6	82.9	69.6	50	34.2	24.1	15.6	9.2	6.4	5	5.3	2.54	2.455
HL 8		100	100	97.4	89.7	79.6	60.1	40.2	28.6	19.2	12.2	8.8	6.6	5.59	1.6	12.7			15797	17.8	2.545	2.504				100	97.8	91.6	82.9	69.6	50	34.2	24.1	15.6	9.2	6.4	5	5.3	2.54	2.455
HM 3		100	100	100	100	98.2	82	47.6	32.8	20.7	11.3	7.2	5.3	6.33	3.5	16.4			15305	14.6	2.53	2.441				100	100	100	100	100	83.8	50.9	32.6	19.6	9.3	5.9	4.3	6.3	2.513	2.42
HM 3		100	100	100	100	99.9	82.6	44.9	30.1	18.8	10.8	7.2	5.1	6.37	3.8	16.8			15556	11.4	2.526	2.431				100	100	100	100	100	83.8	50.9	32.6	19.6	9.3	5.9	4.3	6.3	2.513	2.42
SP 12.5	B	100	100		97.4	81.3	53.9	41.7	26.6	16.7	11.3	8.2	5.2	4.89	3	13.6	77.9	1.17			2.538	2.461	88	97		100	100		99.2	86.5	51.7	40.3	29.9	18.3	8.8	6.1	5.2	5	2.514	2.414
SP 12.5	B	100	100	99.6	97.5	77.6	49	38.7	25.6	17	12	9	6.3	5.21	1.7	12.8					2.558	2.515	89.3			100	100		100	86.3	52.8	42.8	31.7	20.3	10.3	6.6	5.4	5	2.535	2.434
SP 12.5	B	100	100	100	96.4	82.6	54.1	41.5	27.2	18.1	12.9	9.9	7.1	5.34	2.2	13.4					2.554	2.498	88.7			100	100		100	86.3	52.8	42.8	31.7	20.3	10.3	6.6	5.4	5	2.535	2.434
SP 12.5	B	100	100	100	98	83.4	55.3	42.5	28.2	18.7	12.8	9.6	6.9	5.26	2	13.2					2.554	2.503	88.9			100	100		100	86.3	52.8	42.8	31.7	20.3	10.3	6.6	5.4	5	2.535	2.434
SP 12.5	D	100	100	100	9.5	94.8	60.6	40.1	29.3	20.1	11.8	7.2	4.8	5.07	4.6	12.4					2.589	2.469	87			100	100	100	98.3	83.9	52.3	34.4	25.3	18.7	10.6	5.5	3.5	4.8	2.544	2.441
SP 12.5	D	100	100	100	100	94.1	57.4	37.5	27.5	19	11.2	6.8	4.6	5.05	4.1	12.4					2.574	2.469	87.2			100	100	100	98.3	83.9	52.3	34.4	25.3	18.7	10.6	5.5	3.5	4.8	2.544	2.441
SP 12.5	D	100	100		95.9	81.5	50.6	34.5	19.8	13.2	8.6	5.6	3.9	5.03	4.4	13.8	68.1	0.98			2.54	2.428	86.1	95.6		100	100		94.6	76.4	51.3	40.1	25.8	17.5	11.6	7.5	4.7	5.2	2.54	2.439
SP 12.5	D	100	100		97.4	82	52.3	36.2	20.7	13.8	9	6	3.8	4.97	3.9	13.6	71.2	0.93			2.532	2.433	86.7	96.1		100	100		94.6	76.4	51.3	40.1	25.8	17.5	11.6	7.5	4.7	5.2	2.54	2.439
SP 12.5 (WMA)	D	100	100	99.5	96.7	83.3	60	48.1	37.5	28.9	14.3	6.4	3.7	5.2												100	100		97.4	83.5	54.5	41	32.8	23.7	11.3	6.1	3.4	5.2		
SP 12.5 (WMA)	D	100	100	100	96.2	80.9	58.8	46.9	35.8	27.7	13.6	5.9	3.4	5.03	3.3	14.2	76.8	0.86			2.486	2.404	90.7			100	100		97.4	83.5	54.5	41	32.8	23.7	11.3	6.1	3.4	5.2		
SP 12.5 (WMA)	D	100	100	100	99.2	85.1	59.1	44.9	35.2	25.8	11.3	5.6	3.2	5.21	3.1	14.3	78	0.78			2.485	2.407	90.9			100	100		97.4	83.5	54.5	41	32.8	23.7	11.3	6.1	3.4	5.2		
SP 12.5 (WMA)	D	100	100	100	97.1	85.6	58.9	41.3	36.3	26.9	12.1	4.9	2.3	5.13	3.6	14.3	74.4	0.6			2.497	2.406	90.4			100	100		97.4	83.5	54.5	41	32.8	23.7	11.3	6.1	3.4	5.2		
SP 12.5 FC1	C	100	100	100	99.2	85.6	59.6	48.1	35	23.7	14	8.4	5.3	5.25	2.3	17.6					2.606	2.546	89.9			100	100	100	98.1	80.1	52	43	30.1	20.8	11.7	6.1	3.5	4.9	2.636	2.53
SP 12.5 FC1	C	100	100	100	99.5	89.9	60.1	47.3	33.9	22.7	13.2	7.9	4.8	5.2	2.8	17.4					2.625	2.551	89.5			100	100	100	98.1	80.1	52	43	30.1	20.8	11.7	6.1	3.5	4.9	2.636	2.53
SP 12.5 FC1	C	100	100	100	99.1	84.8	55.3	44.6	32.5	21.8	12.8	7.9	4.7	5.1	2.6	17.3					2.619	2.551	89.8			100	100	100	98.1	80.1	52	43	30.1	20.8	11.7	6.1	3.5	4.9	2.636	2.53
SP 12.5 FC1	C	100	100	100	99.1	82.5	53.5	43.4	31.9	21.7	12.8	7.9	4.8	4.94	3.6	17.1					2.648	2.554	88.9			100	100	100	98.1	80.1	52	43	30.1	20.8	11.7	6.1	3.5	4.9	2.636	2.53
SP 12.5 FC1	C	100	100	100	98.3	80.9	52	41.4	30.2	21.2	12.6	7.8	4.6	4.88	3.5	16.9					2.652	2.56	88.8			100	100	100	98.1	80.1	52	43	30.1	20.8	11.7	6.1	3.5	4.9	2.636	2.53
SP 12.5 FC1	D	100	100	100	98.1	83.6	57.3	51.6	30.5	16.7	10.3	6.4	3.9	5.21	3.9	15.8	75.3	0.88			2.612	2.51	90			100	100		96.2	80.4	52.5	50.9	31	18.4	10.9	6.6	4	5		
SP 12.5 FC1	D	100	100	100	97.2	87.7	57.6	49.7	30.2	18.1	11.8	7.9	4.9	5.46	3.8	16.4	76.5	1.1			2.599	2.499	90			100	100		96.2	80.4	52.5	50.9	31	18.4	10.9	6.6	4	5		
SP 12.5 FC1	D	100	100	100	97.3	85.8	58.1	51.6	31.9	18.6	11.7	7.2	4.4	5.54												100	100		96.2	80.4	52.5	50.9	31	18.4	10.9	6.6	4	5		
SP 12.5 FC2	D	100	100	100	100	87.1	58.9	51.3	46.9	41.7	17	8.3	5.1	4.87	4.7	14.9					2.485	2.368	89.2			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.1	83	52.9	43.4	38.2	34.1	15.6	8.9	5.8	5.17	3.6	14.8					2.468	2.379	90			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.5	83.6	51.5	40.9	35.3	28.7	16.1	9.3	5.9	5.96	0.7	14.7					2.418	2.371	94.4			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.6	87.4	58.7	47.5	41.9	37.1	18.5	10.8	7.3	5.28	3.4	14					2.488	2.403	89.5			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.8	86.3	57.4	46.5	40.4	35.5	17.8	10.6	7.1	5.09	3.1	13.5					2.489	2.413	90.3			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	98.5	83.9	58.5	48.8	42.3	36.7	19.1	11.5	7.8	5.14	3.2	13.8					2.484	2.405	89.8			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.8	85.8	57.8	48.6	42.8	37.5	17.7	10.1	6.8	5.22	3.8	14.5					2.483	2.388	89.8			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.1	85.1	58.8	47.6	41.2	36.1	16.9	9.3	5.5	5.13	3.4	14					2.484	2.398	89.8			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	99.7	99.2	89.5	62.9	51.8	45.2	39.9	18.6	10.6	7	5.12	4.8	15.3					2.482	2.363	88.8			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	100	85.1	58.5	48.5	42.4	37.2	17.3	9.3	5.5	5.3	4.2	15.4					2.467	2.364	88.9			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.5	88.8	62.6	51.4	44.7	39.2	18.3	10	6	5.29	4	14.7					2.484	2.384	89.1			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.4	87.7	58.8	47.7	41.3	35.9	17.4	9.6	6.1	5.22	3.2	14					2.481	2.401	87.8			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.4	85.3	57.8	48.4	42.4	36.9	17.7	9.6	6.5	5.04	4.7	14.8					2.491	2.375	89.1			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.5	85.7	57.3	47.2	41.4	36.4	18.9	11.4	7.8	5.07	3	13.3					2.493	2.417	90.7			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.8	84.2	56.9	46.4	40.5	35.7	17.3	9.7	6.1	4.98	3.5	13.4					2.5	2.412	90			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	99.8	90.7	62.6	50.9	44	38.2	19.4	11.7	8.2	5.21	3.2	13.9					2.483	2.404	90.5			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2	D	100	100	100	100	85.5	54.8	45.2	30.9	19.6	12.4	8	5.2	5.16	3.7	15.7					2.715	2.615	87			100	100	100	96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		96.7	84.5	57.2	48.4	31.6	20.8	13.2	8.7	6.1	4.9	3	15.2	80.4	1.26			2.684	2.604	88.3	97		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		98.1	83.4	56.8	48.3	32	21.5	13.5	8.4	5.7	4.93	2.7	15.3	82.4	1.15			2.675	2.603	88.7	97.3		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		98.2	85.3	55.2	45.3	29	19.5	12.5	8.4	6	4.94	3	15	80	1.28			2.692	2.611	87.8	97		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		97.6	87.1	57.9	46.8	29.3	19.1	11.9	7.8	5.5	5.1	3.6	15.9	77.5	1.13			2.684	2.588	87.3	96.4		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		95.8	81.9	54.9	45.3	28.9	19.2	11.9	7.8	5.5	4.93	2.9	15.2	81.1	1.13			2.683	2.606	87.9	97.1		100	100		96.8	82.4	52.7	44.1	29.9	19.8	12.2	9.5	5.3	5	2.7	2.591
SP 12.5 FC2	D	100	100		100	90.1	53.8	40.1	31.2	24.1	14.6	6.9	3.4	4.86	3.5	15.9	78.1	0.72			2.797	2.7	90.1	96.5		100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100		99.5	86.5	49.1	33.4	26	20	11.8	5.1	2.7	4.79	3.5	14.3	75	0.68			2.849	2.748	89.3	96.5		100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100		99.3	89.2	51.3	37.9	30	20.4	13	5.9	2.5	4.69	4.2	15.7	73.1	0.57			2.82	2.701	89.5	95.8		100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100		99.3	90.9	52.7	40.6	31.9	25	15.7	8.2	4.6	4.79	3.5	15.4	77.4	1.03			2.811	2.713	89.2	96.5		100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100		99.7	89	51.1	35.4	26.9	20.5	12.4	6.3	3.3	4.79	3.9	15.2	74.6	0.78			2.828	2.719	89.8	96.1		100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704
SP 12.5 FC2	D	100	100		99.3	90.9	52.7	40.6	31.9	25	15.7	8.2	4.6	4.79	3.5	15.4	77.4	1.03			2.811	2.713	89.2	96.5		100	100		97.4	85.5	52.5	35	25.9	18.8	11.4	5.3	3.3	4.8	2.817	2.704

TABLE C-2

QUALITY ASSURANCE TEST RESULTS FOR 2011 CONSTRUCTION

Mix Type	Mix Category	Sample Results																								Job Mix Formula														
		25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	Air Voids	VMA	VFA	Dust	Stability	Flow	G_{mm}	G_{mb}	N_{ini}	N_{des}	N_{max}	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
SP 12.5 FC2 (WMA)	D	100	100	100	99.2	85.4	56	46.1	40.9	36.4	17.2	9.6	6.2	4.95	4.2	14					2.501	2.395	89.3			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2 (WMA)	D	100	100	100	100	85.8	57.5	46.1	40	35.3	17.6	10.4	6.5	5.18	2.3	13.3					2.478	2.421	91.2			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 12.5 FC2 (WMA)	D	100	100	100	99.8	88.5	58.3	46.8	40.5	35.9	17.5	9.8	6.2	5.15	3.5	14.1					2.484	2.398	90.2			100	100	100	97.5	82.8	54.3	43.3	38.2	33.4	14.5	8.2	6	5.2	2.469	2.371
SP 19.0	B	100	96.7		83.9	75	57.5	34.6	20.7	13.9	7.7	5.3	3.2	4.82	3.8	13.4	71.8	0.79			2.537	2.441	87	96.2		100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
SP 19.0	C	100	93.3	88.7	84.3	74.6	57.6	33.8	19.9	13.7	10.2	7.7	6	5.26	4.8	14.4					2.545	2.423	85.7	-	-	100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
SP 19.0	C	100	94.2	91.2	86.3	77.5	60.7	35.5	20.9	14.2	10.6	8.3	6.6	5.16	4.8	14.4					2.543	2.419	85.5			100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
SP 19.0	C	100	94.4	85.8	81.1	74.1	59	34.6	20.5	13.9	10.4	8	6.3	5.11	4.8	14					2.554	2.432	85.7			100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
SP 19.0	C	100	97.9	95	89.6	81	65.1	39.3	23.6	15.9	11.8	9.1	7.4	5.22	4.1	13.9					2.539	2.436	86.3			100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
SP 19.0	C	100	98.1	90.1	84.6	75.8	58.8	35.1	21	14.2	10.5	7.9	6.3	5.25	4.2	14.4					2.531	2.424	86.1			100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
SP 19.0	C	100	98.1	90.1	84.7	75.9	58.9	35.3	21.2	14.4	10.7	8.1	6.5	5.09	4.8	14.6					2.537	2.415	85.3			100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
SP 19.0	C	100	97.3	94.6	87.2	78.6	61.4	36.7	21.9	15.2	11.4	8.7	7	5.11	4.6	14.4					2.538	2.42	85.9			100	95.4		81.8	75.1	58.6	38.1	22.7	15.1	9.9	6.9	4.9	5	2.544	2.442
SP 19.0	C	100	98.7		85.1	75.9	57.8	46.1	25.9	15	11.6	5.2	3	4.68	3.8	13.9	72.4	0.72			2.557	2.46	88.4	96.2		100	98.4		86.4	74.3	55.5	43.9	29.8	18.8	9.9	5.9	3.9	4.8	2.563	2.461
SP 19.0	D	100	96.7		84.6	77.2	58.2	34.7	19.9	14.1	10.4	8.2	6.8	4.73	4.3	14	69.3	1.64			2.532	2.423	86	95.7		100	95.4		81.7	75	58.4	37.8	22.3	14.6	9.4	6.4	4.3	5	2.542	2.44
SP 19.0	D	100	98.3	88.9	82.7	66.3	52.2	45.1	29.5	17.2	9.7	6	3.6	4.97	3.9	14.2					2.568	2.469	88.5			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	99	94.1	87.5	77.9	62.3	52.1	32.4	19.4	12.4	8.7	5.5	4.61	3.5	13.4					2.572	2.483	88.2			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	96.6	91.7	86	72.9	55.5	45.7	29.9	19.1	12	8.2	5.2	4.98	2.2	13					2.56	2.504	89.6			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	97	90.5	83	71	56.1	46.9	31.2	20.2	12.4	8.4	5.1	4.6	3	12.9					2.576	2.498	89.1			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	98.4	93.1	87.8	75	56.9	47	30.1	18.4	11.4	7.6	4.8	4.89	3.1	13.7					2.56	2.482	88.7			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	100	93.4	84.8	69	52.5	44.3	27.6	16.7	10.5	7.3	4.5	4.78	3.2	13.3					2.571	2.49	88.6			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	96.4	88.2	81.9	71.3	53.8	44.3	29	18.6	11.7	7.9	4.8	4.5	4.6	13.3					2.603	2.482	87.7			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	98	93.5	89.2	77.8	60.3	49.8	31.3	18.8	11.8	8	5	4.22	6.7	15.4					2.589	2.415	85.5			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	95.4	90.8	86.7	75.7	58.4	45.4	27.6	17.3	11.5	8.2	5	4.92	3.2	13.4					2.574	2.491	87.9			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	98.5	92.4	86.8	74.6	59.6	49.3	31.7	20.2	13.6	9.8	6.3	4.87	2.4	12.7					2.571	2.509	89			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	94.7	87.4	83.6	72	56.8	46.5	29.5	18.2	11.9	8.4	5.1	4.63	3.4	13					2.581	2.494	88			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	99.1	92.7	86.9	76.3	59.4	48.2	30.6	19.3	12.8	9	5.6	4.72	3.2	13.1					2.577	2.495	88.4			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	95.9	87.6	80.8	66.9	52.3	43.7	31.7	20	11.3	7.2	4.4	4.4	3.4	13.1					2.574	2.487	88.2			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	99.3	94.8	89.9	78.1	61	51	32.2	20.1	13.3	9.5	6.2	4.81	3.3	13.5					2.572	2.486	88.3			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	96.7	88.1	80	70.1	55.3	45.2	29.1	18.2	11.8	8.2	5.1	4.41	4.2	13					2.597	2.489	87.8			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	98.4	93.2	90	80.6	64.7	53.4	32.7	19.3	12.1	8.4	5.4	4.69	4.8	13.9					2.596	2.471	87.1			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	98.4	92.8	88.7	78.3	63.7	53.1	32.8	19.4	12.5	9	6	4.59	4.6	14.1					2.581	2.463	87.3			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	97.9	92.9	87.1	76	61.8	51.5	31.3	18.3	11.6	8.2	5.4	4.81	3.8	13.4					2.586	2.487	88.3			100	98.3		85.7	73.9	54.7	45.2	28.6	17.8	10.5	6.6	4.3	4.8	2.567	2.465
SP 19.0	D	100	95.9	90.6	79.4	66.7	48.5	44.5	25	13	8	5.1	3.3	4.54	3.6	13.9	74.3	0.86			2.567	2.475	87.8			100	98.4		87.4	73.6	50.4	48.5	29.3	17.5	10.5	6.4	4	4.6	2.569	2.467
SP 19.0	D	100	99.7		89.1	73.5	53.2	49.5	33.5	22.8	14.9	10.1	5.2	4.79	3.6	13.6	73.9	1.25			2.583	2.491	89.4	96.4		100	98.4		87.4	73.6	50.4	48.5	29.3	17.5	10.5	6.4	4	4.6	2.569	2.467
SP 19.0	D	100	96.1		79.4	67.1	48.5	45.2	27	15.6	8.2	4.8	2.7	4.39	4.7	15.1	68.8	0.61			2.557	2.437	87.7	85.2		100	98.4		87.4	73.6	50.4	48.5	29.3	17.5	10.5	6.4	4	4.6	2.569	2.467
SP 9.5	C	100	100	100	100	99.3	83.1	50.1	34	23.3	15.2	10.2	7.3	5.75	4	15					2.558	2.455	86			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	98.9	81	48.9	33.3	23.2	15.1	10.1	6.9	5.74	3.2	14.4					2.552	2.471	87.5			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.1	82.8	50.2	34.4	23.5	14.9	9.6	6.4	5.8	3.1	14.6					2.546	2.467	87.7			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	98.9	82.9	51.6	35.5	24.5	15.9	10.7	7.6	5.96	3	14.2					2.56	2.483	87.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	97.4	70.4	33.6	21.1	14.5	10.6	7.9	6.2	6	8.5	18.9					2.52	2.306	80.9			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	100	99	74.6	36	21.9	14.7	10.8	8.3	6.7	6.01	7.9	18.3					2.523	2.323	80.9			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	99.7	97.7	72.1	34.6	21.4	14.2	10.2	7.7	6	6.15	7.8	18.2					2.526	2.328	81.1			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	100	97.4	70.4	33.5	21	14.4	10.5	7.8	6.2	6.1	6.1	16.9					2.518	2.365	83			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	99.5	97	70.5	34.7	21.6	14.6	10.7	8.2	6.5	6.17	8.1	18.2					2.536	2.33	81.2			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	99.2	98.1	68.2	39.2	24.2	16.1	11.5	8.6	6.7	6.19	5	15.8					2.525	2.399	84.8			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	100	99.2	72.5	41.9	25.3	16.8	11.9	8.8	6.8	6.39	4.8	16.1					2.516	2.394	84.9			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	100	97.8	66.6	36.6	22.6	15.1	10.9	8.1	6.5	5.93	6	16.6					2.522	2.37	83.4			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	100	98.7	71.4	35.4	22.2	15.1	11	8.3	6.5	5.97	5.7	16.5					2.516	2.373	83.7			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	99.8	98.3	74.1	36.8	22.7	15.4	11.3	8.7	6.9	5.97	7.3	17.7					2.52	2.338	81.9			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	100	98.6	72	40.9	25	16.7	11.7	8.6	6.9	6.19	4.7	16					2.511	2.394	85.1			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	100	98	73.1	44.9	28.5	18.8	12.9	9.3	7.4	6.23	4.3	15.4					2.518	2.41	85.5			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	100	98.5	71.2	40.7	25	16.8	11.7	8.6	7	6.23	4.4	15.9					2.509	2.398	85.2			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	99.5	99	72.8	44.2	28.3	18.9	13.1	9.4	7.5	6.06	4	15.2					2.512	2.412	86.2			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	100	98.9	71.2	44.6	28.5	18.9	12.9	9.1	7.2	6.17	3.4	15.3					2.498	2.412	86.5			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398
SP 9.5	C	100	100	100	98.7	96.5	64.6	38.4	24.7	17	12.2	9	7.1	6.16	4.5	15.4					2.524	2.41	85.2			100	100	100	100	98.8	69.7	40.7	27.6	18.8	12	8	6	6	2.498	2.398

TABLE C-2

QUALITY ASSURANCE TEST RESULTS FOR 2011 CONSTRUCTION

		Sample Results																								Job Mix Formula														
Mix Type	Mix Category	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	Air Voids	VMA	VFA	Dust	Stability	Flow	G_{mm}	G_{mb}	N_{ini}	N_{des}	N_{max}	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	G_{mm}	G_{mb}
SP 9.5	C	100	100	100	100	89.7	70.9	54	34.3	19.1	10.1	7.1	4.2	5.31	3.5	15.6	77.5	0.98			2.54	2.451	88.8			100	100	100	100	91.5	71.6	56.1	40	24	11.8	6.9	4.7	5.3	2.521	2.419
SP 9.5	C	100	100	99.3	98.7	89	71.3	56.7	38.6	22	11.5	6.9	4.4	5.12	5.9	17					2.526	2.377	87			100	100	100	100	91.5	71.6	56.1	40	24	11.8	6.9	4.7	5.3	2.521	2.419
SP 9.5	C	100	100	99.7	98.5	90.7	70.7	55.4	37.2	21.2	11.1	7	4.7	5.26	5.8	16.3					2.548	2.401	87			100	100	100	100	91.5	71.6	56.1	40	24	11.8	6.9	4.7	5.3	2.521	2.419
SP 9.5	C	100	100	100	98.3	85	62.8	49.9	36.9	23.9	14.1	9.3	6.3	5.37	2.1	13.7					2.529	2.477	90.4			100	100	100	100	91.5	71.6	56.1	40	24	11.8	6.9	4.7	5.3	2.521	2.419
SP 9.5	C	100	100	100	100	99.5	79.9	44.2	31.1	20.9	13.5	8.7	6.6	5.31	3.1	15.2	79.5	1.58			2.541	2.462	87.1			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.4	81.5	50.6	36.9	25.2	16.2	10	6.9	5.51	2.8	14.8	80.9	1.59			2.552	2.48	87.8			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99	78.8	43.3	31.2	20.9	12.9	7.7	5.4	5.47												100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	92.9	70.3	43.2	30.2	19.5	12.2	7.6	5.5	5.41												100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	97.5	77.3	42.7	30.6	21.5	14.7	9.7	7.4	5.63	2.4	14.9	83.6	1.64			2.541	2.479	88.1			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	98.7	78.6	47.2	32.9	22.5	14.6	9.6	7.3	5.62												100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	92.7	70.4	43.7	32.3	21.5	13.3	8.1	5.3	5.56	2.2	14.8	85.1	1.17			2.536	2.48	88.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.1	83.4	51.5	35.6	25.6	16.7	11.8	8.9	5.48	2.2	13.8	84.1	1.58			2.553	2.497	88.5			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	98.1	90.3	69.1	53.7	37	20.7	11.5	7	4.8	5.73	2.5	16.1	84.7	1.01			2.508	2.446	89.7			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	97.7	87.1	66.6	51.1	35	20.1	11.8	7.4	5	5.55												100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	99.1	90.1	69.6	53.3	35.1	18.6	9.9	6	4.4	5.75	2.2	16.4	86.8	0.93			2.493	2.439	89.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	97.9	90.1	68.7	52.7	35.3	19	10.3	6.2	4.3	5.79	3.3	16.7	80.4	0.93			2.514	2.432	88.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	99	91.2	68.7	55.3	38.2	205	11.1	6.5	4.1	5.7												100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	96.6	85.2	63.3	49.5	35.2	20.5	11	6.4	4.3	5.27	3.2	16.2	80.1	0.98			2.512	2.431	88.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	98.8	87.1	67.3	52.8	36.3	20.1	10.8	6	4.2	5.19	3.6	16	77.7	0.99			2.525	2.435	89			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	98.7	90.2	70.8	55.1	36.6	19.7	9.8	5.4	3.6	5.79	2	16.3	87.7	0.75			2.492	2.442	90.3			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	98.8	89.9	74.3	56.7	40.7	24.3	14.1	8.6	5.5	5.6	3	16.4	82	1.21			2.508	2.434	89.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	96.2	90.4	70.1	54	36	21.2	11.5	6.7	4.3	5.16	3.3	15.8	79.4	1.03			2.523	2.441	88.6			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	98.8	80.9	49.2	34.1	23.6	15.1	10.2	6.8	6.23	1.6	14					2.537	2.498	89			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	99.8	98.7	80.8	48.2	33.1	22.7	14.4	9.7	6.8	5.8	3.4	14.6					2.555	2.468	87.2			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99	80	48	33.3	23.3	14.8	9.8	6.9	5.93	2.4	14.1					2.547	2.487	88.3			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.3	84.9	54	37.8	26.1	15.6	9.6	6.5	6.14	2.2	14.7					2.531	2.475	88.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	98.5	79.5	47.4	33.4	23.4	14.4	9.1	6.4	6.19	1.7	14.5					2.524	2.481	88.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.4	79.8	46.7	33.2	23.9	15.1	9.7	6.9	5.93	3.4	14.2					2.571	2.482	87.4			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.3	82.9	50	35.1	24.8	15.5	9.8	6.9	6.1	2.3	14.4					2.539	2.481	88.4			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.2	84.1	50.5	35.1	24.3	15.5	10.2	7.1	5.92	2.6	14.3					2.544	2.479	88			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.9	83.1	48.1	31.6	20.7	13.2	8.8	6	5.6	5.7	16					2.57	2.423	84.7			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.3	84	51.2	35.2	24.3	15.6	10.5	7.4	5.95	2.8	14.6					2.542	2.471	87.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	99	98.5	96.2	80.4	49.4	34	23.5	15	9.9	6.8	6.19	2	14.4					2.533	2.482	88.7			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.2	82.4	49.9	34.3	23.3	14.6	9.7	7	5.84	3.3	14.8					2.546	2.462	87.6			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.4	81.9	48.5	33.5	22.9	14.3	9.5	6.8	5.63	3.2	14.6					2.545	2.464	87.5			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	98.1	79.7	49.6	34.8	24.3	15.5	10.3	7.5	5.79	2.3	13.9					2.546	2.488	88.7			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	98.8	80.1	46.8	33	23.5	15.2	10.1	7.5	5.87	2.6	14.2					2.546	2.48	88.2			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.5	80.5	45.6	31.1	21.4	13.9	9.7	7.2	5.91	3.3	15.1					2.542	2.457	86.7			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.4	82.2	47.8	32.4	22.1	13.9	9.3	6.9	5.99	3.8	15.4					2.546	2.451	86.8			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.4	83.3	49.9	33.8	23	14.7	10.2	7.5	5.89	3.8	15.3					2.546	2.449	86.5			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	99.8	99.5	92.9	48.7	33.3	23.3	15.3	10.7	7.9	6.16	2.4	14.8					2.532	2.471	87.7			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	99.8	98.8	82.2	49.1	34.2	23.7	15.2	10.1	7.1	5.93	2.9	13.7					2.569	2.496	87.7			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.4	81.6	49.2	34.2	23.8	15.2	10.1	7.2	5.84	2.4	13.5					2.563	2.501	88.1			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.5	83.9	51.3	34.6	23.8	15.8	10.9	7.7	5.75	3.1	14.4					2.553	2.473	87.5			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.5	85.2	51.8	34.6	23.9	15.9	11	7.6	5.84	3.2	14.2					2.561	2.479	87.4			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	99.7	98.8	81.1	49.2	34	23.5	15	9.8	6.9	5.79	3.2	14.6					2.547	2.466	87.7			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.5	84.2	51.6	35.3	24.3	16	11	7.9	5.74	3.3	14.3					2.559	2.475	87.4			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	98.9	83.2	51.2	35.3	24.4	15.8	10.6	7.2	5.67	3.3	14.2					2.558	2.475	87.4			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	99.4	97.6	82.3	51.1	34.6	23.9	15.9	11.4	8.6	6.26	1.7	14.4					2.528	2.485	88.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.2	84.2	50.6	34	23.5	15.9	11.1	8.1	5.79	2.3	14.2					2.537	2.479	88.1			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.3	83.1	50.1	34	23.3	15.2	10.2	7.3	5.75	4	15					2.558	2.455	86			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	98.9	81	48.9	33.3	23.2	15.1	10.1	6.9	5.74	3.2	14.4					2.552	2.471	87.5			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	99.1	82.8	50.2	34.4	23.5	14.9	9.6	6.4	5.8	3.1	14.6					2.546	2.467	87.7			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5	C	100	100	100	100	98.9	82.9	51.6	35.5	24.5	15.9	10.7	7.6	5.96	3	14.2					2.56	2.483	87.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432

TABLE C-2
QUALITY ASSURANCE TEST RESULTS FOR 2011 CONSTRUCTION

		Sample Results																								Job Mix Formula														
Mix Type	Mix Category	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Content	Air Voids	VMA	VFA	Dust	Stability	Flow	G_{mm}	G_{mb}	N_{ini}	N_{des}	N_{max}	25.0 mm	19.0 mm	16.0 mm	12.5 mm	9.5 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm	AC Conten	G_{mm}	G_{mb}
SP 9.5 (WMA)	C	100	100	100	99.5	98.9	80.7	47.8	34.3	23.7	15.3	10	7.1	5.51												100	100	100	100	91.5	71.1	56.6	46.1	32.5	15.4	7	4.2	5.3		
SP 9.5 (WMA)	C	100	100	100	100	99.4	79.7	47.1	33.6	23.9	15.9	11.1	7.5	6.03	1.9	14.2					2.534	2.486	88.8			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5 (WMA)	C	100	100	100	100	99.4	80.9	48.5	34.1	24.2	16.1	11.3	8.3	5.89	3.2	14.8					2.544	2.463	87.6			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5 (WMA)	C	100	100	100	100	99.6	86.4	51	34.8	24.1	15.2	10.5	7.5	6.29	2.7	15.2					2.531	2.462	88			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5 (WMA)	C	100	100	100	100	99.2	85.1	50.8	35.2	24.9	16.5	11.8	8.9	5.96	2.3	14.5					2.533	2.475	88.2			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5 (WMA)	C	100	100	100	100	98	80.1	45.9	31	21	13.3	8.9	6.5	5.71	4.5	16					2.539	2.426	86			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5 (WMA)	C	100	100	100	100	99.4	84	50.1	33.2	21.8	13.3	8.6	6.3	5.96	4.8	16.4					2.542	2.419	85.8			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5 (WMA)	C	100	100	100	100	99.6	81	49.3	35.9	26.2	17.7	12.4	8.7	6.05	1.9	14					2.539	2.491	89.2			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5 (WMA)	C	100	100	100	100	99.3	81.2	47.4	33.4	23.7	15.7	11.5	8.3	5.93	2.1	14.2					2.536	2.481	88.4			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5 (WMA)	C	100	100	100	100	99.7	85	50.2	34.8	24.5	16	11.3	8.5	6.02	3	14.7					2.549	2.472	87.6			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5 (WMA)	C	100	100	100	100	98.8	81.2	48.5	33.7	23.8	15.6	10.8	8.1	5.87	2.8	14.4					2.547	2.476	87.9			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432
SP 9.5 (WMA)	C	100	100	100	100	98.5	82.1	50.2	35.6	25.1	16.5	11.6	8.3	6.08	2.1	14.2					2.539	2.486	88.8			100	100	100	100	100	80.6	42.1	27.5	19.1	12.8	9.8	8	5.8	2.533	2.432

APPENDIX D

Quality Assurance Compaction Results

TABLE D-1
QUALITY ASSURANCE COMPACTION RESULTS FOR 2010 CONSTRUCTION

Mix Type	Mix Category	Specified Compaction		Compaction (%)																														
		Lower Limit	Upper Limit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Additional Test Results
HL 8 HS		91	97.5	95	93	93	95	94	94	95	94	93	94	93	94	94	95	94	93	95	93	95	94	93	94	93	93	93	93	93	93	95	94	
HL 8 HS		92	97.5	94.6	95.8	96.5	97.3	95.7	96.3	96.6	95.4	92.3	95.7	94.4	95.1	96.4	94.4	94.7	92.8	94.5	94.9	94.5	94.6	97	93.4	95.8	97.7	95.4	92.9	96.2	94.1	95.8		
HL 8 HS		92	97.5	94.6	93.9	97	94.2	96.1	92	94.9	93	92.5	95.1	93.4	92.3	93.4	93	94	96.1	94.9	93	95.3	92.5											
HM 3 HD		92	97.5	93.7	92	92	92.4	95.2	92	91.8																								
SP 12.5	B	92	97.5	96	97	96	95	95	97	96	96	95	95	96	94	93	96																	
SP 12.5	B	92	97.5	93	94	93	93	97	94	94	95	95	95	93	94	93	96	94	94	95	92	93	96	93	94	93	94	93	95	92	93	94	94	95, 93, 93, 93
SP 12.5	B	92	97.5	92																														
SP 12.5	B	92	97.5	94	94	92	95	92	92																									
SP 12.5	B	92	97.5	95	93																													
SP 12.5	B	92	97.5	92	92																													
SP 12.5	B	92	97.5	96	96	95	96	94	95	95	95	94	93																					
SP 12.5	B	92	97.5	93	94	93	92	96	93	92	94	92	96	92	93	93	95	92	94	92	95	92	93											
SP 12.5 FC2	C			97.6	95.2	97.1	97	98	96.5	97.3	96.7	93.1	96.5	96.5	97	94.1	95.7	96.6	96.5	94	94.7	96.5	96	95.3	98.4	95	97.4	97.3	95.4	97.7				
SP 12.5 FC2	D	92	98.5	93	94	93	95	94	96	94	93	99	96	95	96																			
SP 12.5 FC2	D	92	98.5	93	95	94	94	94	95	97	98	96	95	95	95	97	95																	
SP 12.5 FC2	D	92	98.5	93	96	94	93	93	94	94	94	93	97	96	97																			
SP 12.5 FC2	D	91	97.5	93	94	93	92	92	92	94	94	94	94	93	94	96	93	94	93	94	94	93												
SP 12.5 FC2	D	91	97.5	94	93	92	93	95	92	93	94	93	94	92	92	93	92	92	92	94	93	94	92	94	93	93	94	95	94	93	92	93	91	93, 92, 92, 93, 94, 92, 94, 93, 93, 94, 92, 94
SP 12.5 FC2	D	91	97.5	93	94	91	93	92	93	93	92	93	95	92	93	94	94																	
SP 12.5 FC2	D	92	98.5	95	97	95	93	91	94	94	96	94	93	92	94	93	93	93	93	93	93	93	93	94	92	95	92	94	94	93	92	92	92	94, 92, 94, 93, 92, 92, 93, 91, 88, 87, 88
SP 12.5 FC2	D	92	98.5	96	98	95	94	92	92	92	95	94	94	97	97	94	94	94	94	94	94	94	95	94	96	95	96	93	94	97	96	95	93	92, 93, 92, 93
SP 12.5 FC2	D	92	97.5	94.6	94.8	93.7	93.4	93.4	94.5	94.2	94.3	95.3	94.2	95.4	97.6	95	96.4	95.9	94.2															
SP 12.5 FC2	D			92.3	93.7	95.8	92.8	96.1	97.5	93.5	95.7	92.7	96.9	94.5	92.9	97.4	95.5																	
SP 12.5 FC2	D			95.3	96.5	94.1	96.8	92.7	97.6	95.2																								
SP 12.5 FC2	D			95.2	96.2	94.1	95.9	94.6	94.6	95.2	95.1	94.9	95	94.1	97.3	96.8	96.3	94.6	92	92.6	86.8	93.2	94.5	95.9	96.3	94.2	94.6	93.6	94.8	92.8	88.8	93.5	97	95.4, 94.8, 93.4, 93.7, 94.5, 96, 94.6, 95.8, 93.4, 97.3
SP 12.5 FC2	D	92	97.5	94.3	94.8	94.6	94.8	94.8	95.1	94.6	95.1	95.2	94.3	94.8	94.6	94.9	94.6	94.3	97.1	94.6	94.8	94.8	94.6	94.6	94.8	94.9	94.6	94.8	95.1	95.5	94.3	94.8	94.9	94.6, 95.8, 95.2, 94.3, 94.6, 94.6, 94.8, 95.5, 97.1, 94.9, 95.1, 95.5, 95.1, 95.8, 94.3, 94.8, 94.9, 95.1, 94.3
SP 12.5 FC2	D	92	97.5	93.9	94.4	94.4	93.7	93.9	94.2	94.7	96.1	93.9	94.5	95.8	95.8	94.7	95																	
SP 12.5 FC2	D	92	97.5	94.2	94.8	93.7	94.5	94.3	94.7	93.9	95	93.7	97.5	93.9	95.1	96.6	95.5	94.8																
SP 12.5 FC2	D	92	97.5	94.5	94.1	94.2	96.7	94.2	95.4	93.9	93.7	95.1	96.2	95.3	97	96	94.3	95.5	92.5	93.7	93.9	96.2	96.1	92.3	94.5	94.6	94.6	94.3	94.5					
SP 12.5 FC2	D	92	98.5	96	94	94	93	94	93	92	92	91	92	93	93	93	91	91	91	94	93	94	94	93										
SP 12.5 FC2	D	92	98.5	93	92	92	93	92	94	92	92	92	91	93	94																			
SP 12.5 FC2	D			92	93	95	99	98	96	96	95	95	97	99	95	91	96	95	96	97	99	99	100	95	94	92	93	94	95	94	96	93	93	96, 98, 95, 92, 96, 94, 96, 96, 94, 96, 95, 94, 93, 97, 95, 95, 94
SP 12.5 FC2	D			90	93	96	95	95	95	97	96	94	97	93	97	96	96	95	97	94	95	98	93	94	99	96	96	97	98	92	95	96	97	96, 97, 96
SP 12.5 FC2	D			94	92	97	93	93	98	94	98	98	96	95	97	94	95	96	93	95	97	96	99	92	97	93	92	92	97	97	93	100	94	97, 94, 98, 93
SP 19.0	B	92	97.5	95	95	93	97	94	95	93	93																							
SP 19.0	B	92	97.5	95	92	93	92	93	92	92	92	93	93	93	93	91	94	95	93	91	93	91	93	93	93	93	93	93	92					
SP 19.0	C	-	-	96	94.2	93.6	94.7	93																										
SP 19.0	C	92	97.5	93	97	95																												
SP 19.0	C	92	97.5	96	97	93	96	94	96	96	95	96	97	95	97	94	94	96	95	94	94	94	96	94	94	95	94	94	97	96	98	95	94	95, 94, 95, 96, 94, 96, 94, 96, 95, 95
SP 19.0	C	92	97.5	93	97	95	94	95	97	96	96	94	94	97	93	96	92	94	93	95	93	98	96	98	97	97	97	93	93	95	96	93		
SP 19.0	C	92	97.5	94	96	93	96	92	93	95	94	92	95	93	94	93	93																	
SP 19.0	C			93.9	93.1	94	94	94.4	94	93.6	95.9	94.2	93.9	94.2	93.9	93.2	94.6	93.7	94.9	93.2	93.5	93	95.8	94.7	94.5	94.3	93.4	93.6	95.9	94.6	94.9	93.4	93.8	94.5, 94.1, 93.8, 93.8, 96.5, 94.1, 93.9, 94.7
SP 19.0	C			94.2	93.4	96.2	93.9	93.6	93.8	93	93.9	95.3	94.9	92.9	93.4	96.6	93.5	94.3	93.3	94.4	94	92.7	94.7											
SP 19.0	D	92	97.5	95	94	93	95	92	94	92	96																							
SP 19.0	D	92	97.5	93	92	93	92																											
SP 19.0	D	92	-	93	95	93	95	94	93	94	94																							

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TABLE D-1
QUALITY ASSURANCE COMPACTION RESULTS FOR 2010 CONSTRUCTION

Mix Type	Mix Category	Specified Compaction		Compaction (%)																														
		Lower Limit	Upper Limit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Additional Test Results
SP 19.0	D	92	-	93	95	94	96	97	94	95	93	93	93	95	96	97	95	93																
SP 19.0	D	92	-	97	96	95	95	94	94																									
SP 19.0	D	92	97.5	92.4	92.6	92.6	92.4	92.9	92.4	93.5	93.6	92.7	92.5	93.9	94.9	93.2	93.3	93.9	93.2	92.5	93.8	94.4	93.3	94.6	92.5	93.9	94.4	93	93.8	93	94.2	94.2	92.7	94.6
SP 19.0	D			95.7	92.4	95.5	93.5	96.4	92.1	93.6	91	95.4	93.7	91.1	94.2	95	95.7	94.1	95.3															
SP 19.0	D			93	91	93.7	92.5	96.3	91.5	94.4	92.3	92.6	94	99.4	93.4	91.5	94.9	93.1	93.1	94.6	95.4													
SP 19.0	D	92	97.5	92.3	92.9	92.8	92.1	92.7	93	92.5	92.2	92.5	92.4	92.3	92.2	92.7	93.9	94.2	93.6	92.6														
SP 19.0	D	92	97.5	92.5	93.5	92.1	93.2	93.6																										
SP 19.0	D	92	97.5	91.8	95.3	92.5	92	92.5	93.6	90.7	92.1	91.7	93	91.4	92.9	91.9	94	91.7	92.2	93.3	93.9	91.5	92.4	92.6	92.7	94.1	94.5	93.2	91.6	94.1	94.5	93.2	91.6	93.9, 92.6, 92.5, 92.2, 92.1, 94, 93.6, 91.7, 93.7, 92.5, 95.5, 92.7, 93.5
SP 19.0	D	92	97.5	96.9	92.6	94	92.3	92.7	93.7	92.8	92.5	93.1	93.4	94.1	94	92.8	92.9	94.5	92	93.5	92.5	92.9	92.2	91.6	92.1	94.3	92.3	92.2	94.9	91.8	91.9	92.1	91.6	92.9, 93.9, 93.6, 94, 92.3, 92.2, 93
SP 19.0	D	92	97.5	92.8	91.9	88.4	89.4	91.1	92	91.6	92.5	91.8	92.1	95.3	91.4	91.2	91.5	91.4	93.1	92.6	92	91.4												
SP 19.0	D	92	97.5	94	96	93	94	96	95	95	96	96	98	95	95	96	96	97	99	96	94	96	96	97	97	95	96	96	93	93	93			
SP 19.0	D	92	97.5	93	93	91	93	93	93	92	92	92	92	92	94	93	92	92	93	93	93	93	93	93	93	92	94	94	96	94	93	94	93	91, 94, 92, 92, 92, 92, 93, 93, 94, 92, 93, 92, 92, 94, 93, 93, 93, 93, 94, 93
SP 19.0	D	92	97.5	93	94	93	93	94	92	97	94	93	97	95	93	93	95	95	93	94	93	95	94	95	93	94	96	94	95	94	95	94		
SP12.5	B	92	97.5	96	97	97	96	94	96	96	97	95	94	94	92																			
SP12.5 FC2	C			97	93.8	92.9	93	95.2	94.4	92.7	93.3	94	94.2	93.8	93.6	93.8	95.2	94.6																
SP12.5 FC2	C			91.7	93.3	94.1	94.4	92.6	93.6	94.4	92.4	93.1	92.6	94.1	92.6	94.8	93.4	93.4	93.7	93.9	92.9	94												
SP12.5 FC2	C	92	97.5	96.6	94.6	92.2	92.3	92.7	93.1	92.7	93.1	92.7	92.8	92.5	93.1	92.7	92.5	93.8	93.1	94.4	92.7	94.1	93.3	92.8	93.1	93.3								
SP12.5 FC2	C	92	97.5	92.3	92.3	92.8	92.6	93.6	93.6	92.6	94.5	92.3	94.5	92.8	94	92.3	94.8	95.6	93.6	93.1	92.3	92.6	92.3	92.3	93.1	92.9	92.8	92.6	93.7	92.5	92.6	93.1	92.6	94.5, 92.6, 92.5, 92.6, 92.6
SP12.5 FC2	D	92	98.5	95	96	94	96	95	96	96	96	97	97	96	96	96	96	95	97	95	97	96	96	96	95	94	95	97	95	96	96	97	96	94, 96
SP12.5 FC2	D			94.7	93.1	96.2	95.5	93.8	97	97.2	94.2	95.9	92.9	91.6	92.6	93.9																		
SP12.5 FC2	D			95.3	97.3	96.2	96	95.1																										

TABLE D-2

QUALITY ASSURANCE COMPACTION RESULTS FOR 2011 CONSTRUCTION

Mix Type	Mix Category	Specified Compaction		Percent Compaction																													
		Lower Limit	Upper Limit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Additional Test Results
HL 8		92	97.5	94	94	94	93	94	93	95	95	96	95	94	93	94	94	93	93	95	94												
HL 8		92	97.5	95	96	96	95	96	93	95	93	95	94	94	95	96	96	95	99	96	100	95	95	93	93	96	95	96	94	95	95	97	96, 97, 95, 96, 94, 96, 93, 92, 95, 97, 96, 96, 97
HL 8		92	97.5	94	94	93	92	94	93	92	94	96	94	94	94	95	95	92	93	93	94	93	95	96	94	94	94	95	95				
SP 12.5	B	-	-	90	91	90	91	91	90	91	90	91	91																				
SP 12.5	B	92	97.5	96	93	93	93	93	93	95	94	93	95	92	93	92	94	92	94	93	94	95	95	95	94	93	94	95	93	93	96	93	94, 93, 93, 92, 95, 94, 93, 94, 93, 92, 94, 94, 95
SP 12.5	D	92	97.5	94	93	95	95	95	94	93	94	96	95	94	94	94	94	95	93	94	93	96	94	94	93	96							
SP 12.5	D	-	-	92.5	92.5	92.5	92	93.2	93.3	92.9	94.2	92.9	94	94	92.2	92.2	92	94.1	92	93.9	93.2	93.1	93.7	92.2	92.4	92.9	92	93.7	92	92	92.1	94.1	93.9, 92.8, 94.1, 92.3, 92.4, 92.7, 93.9, 93, 92.6, 92.2, 92.6, 92.1, 92.2, 93.7, 92.4, 93.9, 93.7, 92.7, 93.2, 92, 94.2, 93.3, 92.7, 94.1, 94.1, 92.9, 92.2
SP 12.5 (WMA)	D	-	-	94	92	92	93	93	93	93	93	92	92	92	92	92																	
SP 12.5 (WMA)	D	-	-	93	94	95	95	95	93	95	93	93	94	93	93	94	94	93	94	92	93	93	92										
SP 12.5 FC 2	D	-	-	94	97.3	92	93.1	95.9	97.2	96	93.8	93.6	95.2	97	97.9	94.3	94.7	92.5	96.5	94.2	95.7	95.3	94.8	92.2	97.1	94.2	97.6	94	95.3	95.5	94.1	94.2	
SP 12.5 FC1	D	-	-	93.7	94.9	94.5	95.3	94.7	94.9	94	94	94.5	94	94.6	95	94.5	94.1	94.3	94.5	94.7	94.4	95.1	94.9	95	94	94.6	94	94.3	94	94.3	94.2	94.5	93.7, 94.3, 93.8, 94.2, 93.8, 93.9, 93.8, 94.7, 93.8, 95, 93.9, 95.2, 94, 95, 94.1, 95, 94.2, 95.3
SP 12.5 FC2	D	92	97.5	94	92	93	91	92	94	91	92	91	91	100+	92	91	92	93	92	92	94	95	96	95	95	96	95	94	95	93	92	98	93, 93, 95, 94, 95, 94, 96, 93, 92, 92, 95, 95, 95, 98, 93, 93, 96, 96, 96, 95, 94, 95, 93, 93, 95, 94, 94, 92, 95, 97, 93, 94
SP 12.5 FC2	D	92	97.5	95	95	94	94	95	95	96	96	93	96	94	93	94	94	95	95	95	97	96	97	94	96	95	96	96	95	94	95	94	
SP 12.5 FC2	D	92	97.5	94	97	93	96	95	95	96	96	95	94	94	96	94	95	94	95	95	94	96	94	95	94	96	96						
SP 12.5 FC2	D	92	97.5	93	92	92	93	94	93	95	94	94	96	94	93	92	92	94	94	92	92	93	93	94	93	93	93	92	94	93	93	92	93, 93, 92, 94, 92, 95, 93, 93, 93, 93, 93, 93, 93, 94, 93, 93, 93, 94, 94, 93, 92, 92, 92, 93, 92, 94, 92, 92
SP 12.5 FC2	D	92	97.5	94	93	94	95	94	94	95	94	95	95	94	95	94	95	95	94	95	93	94	95	94	95	93	94	95	94	94			
SP 12.5 FC2	D	92	97.5	92	91	94	96	93	92	92	94	93	94	93	95	93	93	95	93	95	94	95	94	93	95	93	95	95	95	95	93	93	94, 94, 94, 95, 95, 93, 94, 93, 94, 94, 94, 94, 93, 93, 93, 94, 94, 95, 94, 93, 94, 93, 94, 93, 94, 95, 93, 94, 97, 95, 93, 94, 93, 94, 93, 94, 94
SP 12.5 FC2	D	-	-	98	92.5	94.6	96.6	94	95.7	95.3	95.3	96.3	94.8	99.4	96	94.3	96.4	96.7	92.4														
SP 12.5 FC2	D	-	-	93.3	95.5	92.2	96.1	92.2	94.7	93.6	96.2	94	95.3	94.2	95.7	93.9	93.1	93	95.1	95.7	93.2	94.2	96.5	94.9	94.8	94.7	96.4	96	95.7	96.1	93.3	94.4	94.3, 93, 93.8, 94.2, 95.4, 93.5, 93.9, 92.9, 94.6, 94.3, 96.2, 93.2, 93.8, 95.2, 93.6, 92.5, 95, 93.3, 92.9, 95.3, 94.4, 92.9, 95.4, 94.1, 94, 95, 93.2, 94, 96.3, 94, 93, 96.4, 96.2, 95.6, 94, 96, 96.3, 96.1, 96.3, 93
SP 12.5 FC2	D	-	-	93.7	93.6	93.6	94.5	94	96.1	93.8	96.2	93.2	95.7	93.9	95.9	93.5	94.8	95.5	93.8	93.8	95.6	95.8	96.4	96	95.5	94.4	95.5	94.2	95	95.7	93.7	93.5	96.2, 94.1, 94.2, 95, 94, 93.3, 93.2, 93.3, 92.5, 92.5, 92.1
SP 12.5 FC2	D	-	-	92	92	93	94	94	93	93	93	94	96	95	92	92	92	94	92	95	92	92	96	93	95	95	95	95	95	93	92	92	93, 92, 92, 92, 95
SP 12.5 FC2	D	-	-	93	92	93	92	93	93	94	92	93	93	92	92	93	93	93	93	93	93	92	93	92	92	92	93	94	93	92	93	94	94, 94, 92, 97, 93, 92, 93, 92, 92
SP 12.5 FC2	D	-	-	93	95	93	93	93	94	95	92	93	92	95	94	92	92	93	93	95	94	94	94	95	93	96	92	93	92	97	92	92	93, 94, 93, 93, 92, 93, 93, 92, 94, 92, 92, 92, 92, 93
SP 12.5 FC2	D	-	-	92	92	92	92	93	93	92	92	94	92	92	92	95	92	92	92	92	92	92	92	93	92	93	94	92	93	92	92	92	92, 92, 92, 92, 92, 92, 93, 94, 92, 92, 92, 92, 93, 92, 92, 93, 92, 92, 93, 94, 94, 92, 92, 92, 92, 92, 95, 92, 92
SP 12.5 FC2	D	-	-	92	92	94	93	92	93	95	93	93	94	94	93	92	93	93	93	93	92	92	93	93	95	93	93	93	94	94	94	94	94, 93, 92, 93, 93, 92, 92, 92, 93, 92, 92, 94, 93, 93, 92, 93, 92, 92
SP 12.5 FC2 (WMA)	D	92	97.5	95	94	94	94	93	93	94	94	94	93	95	95	95	95	95	93	93	96	96	94	94	93	93	95	93	95	93	95	93	95, 94, 93, 93, 94, 93, 94, 95, 94, 96, 95, 94, 95, 93, 96, 94, 93, 94, 95, 93, 95, 94, 95
SP 19.0	B	-	-	93	93	93	93	93	93																								
SP 19.0	C	92	97.5	94	95	94	95	94	95	95	96	95	95	95	95	94	96	96	97	94	95	94	93	94	94	94	95						

TABLE D-2
QUALITY ASSURANCE COMPACTION RESULTS FOR 2011 CONSTRUCTION

Mix Type	Mix Category	Specified Compaction		Percent Compaction																													
		Lower Limit	Upper Limit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Additional Test Results
SP 19.0	C	92	97.5	94	95	95	95	94	95	96	95	95	95	95	95	98	94	95	96	95	95	96	95	95	95	96	94	95	94	95	94	95	95, 95, 96, 94, 94, 94, 95, 94, 94, 97, 94, 94, 95, 95, 94, 94, 95, 97, 94
SP 19.0	C	92	97.5	95	94	96	96	94	95	95	96																						
SP 19.0	C	92	97.5	97	95	97	94	94	93	95	94	96	95	95	92	93	93	94	94	93	93	94	94	93	94	94	93	92	91	91	91	92	92, 91, 91, 91, 91, 90, 89, 87, 88, 85, 86
SP 19.0	C	92	97.5	90	90	88	87	87	90	92	92	92	87	86																			
SP 19.0	C	-	-	92	93	94	94	93	93	95	94	94	93	97	95	94	94	94	95	94	94	94	94	94	95	93	94	95	94	93	94	95	93, 94, 94, 94, 93, 93, 95, 95, 93, 93, 94, 94, 95
SP 19.0	D	-	-	94	95	93	94	94	94	94	93																						
SP 19.0	D	-	-	94	94	94	93	94	94	94	94																						
SP 19.0	D	92	97.5	94	93	95	95	95	94	93	95	95	93	96	94	94	94	95	95	94	95	59	95	94	93	97	94	93	9	495	95	94	94, 95, 95, 95, 94, 94, 95, 94, 93, 94, 94, 95, 95, 93, 93, 94, 94, 93, 95, 94, 93, 94
SP 19.0	D	92	97.5	94	96	94	95	95	94	95	95	94	94	94	95	95	93	93	94	95	93	93		94	95	93	93	94	93	94	93	92	94, 94, 94, 93, 92, 96, 94, 93
SP 19.0	D	92	97.5	93	93	93	94	95	93	93	96	92	94	93	94	93	94	93		94	93	95	93	96	93	94	93	94	94	94	93	95	93, 95, 94, 95
SP 19.0	D	92	97.5	96	95	94	94																										
SP 19.0	D	92	97.5	95	93	97	94	97	94	95	93	93	94	95	94	97	95	93	94	95	94	97	95	93	93	94	97	94	94	94	93	94	100+, 95, 95, 94, 93, 94, 96, 93, 93, 93, 93, 96, 93, 95, 94, 96, 94, 99, 92
SP 19.0	D	92	97.5	93	94	95	94	96	95	93	94	94	94	93	95	93	95	94	92														
SP 19.0	D	-	-	93	95	100	93	93	92	93	90	93	93	89	93	93	91	97	87	94	93	93	93	91	94	92	93	99	93	96	93	93	93, 97, 95, 93, 93, 93, 93, 93, 93, 93, 92, 93, 93, 92, 94, 93, 93, 93, 92, 93, 93, 93, 89, 93, 93, 93, 93, 93, 93, 93, 93, 94, 94, 97, 93, 93, 93, 93, 93, 93
SP 19.0	D	-	-	93	93	93	94	94	95	96	93	94	94	94	94	95	95	96	93	94	95	96	94	94	94	95	96	95	96	93	95	96	93, 94, 95, 95, 94, 93, 94, 95, 94
SP 19.0	D	-	-	93	92	92	92	92	92	93	93	92	92																				
SP 9.5	C	92	97.5	94	95	94	94	94	94	93	94	94	94	94	93	94	94	93	94	94	93	94	94	93	94	95	94						
SP 9.5	C	92	97.5	93	95	93	95	95	95	93	93	94	92	93	93	94	96	93	94														
SP 9.5	C	92	97.5	94	96	94	100	93	96																								
SP 9.5	C	92	97.5	94	93	94	95	96	94	97	94	100+	95	93	95	95	96																
SP 9.5	C	92	97.5	92	94	93	93	92	92	92	93	92	94	94	92	93	95	94	93														
SP 9.5	C	92	97.5	94	95	93	93	94	93	94	95																						
SP 9.5	C	92	97.5	92	93	93	93	94	93	92	95																						
SP 9.5	C	92	97.5	95	95	94	95	96	96	96	94	94	95	94	93	93	93	92	93	94	93	93	94	93	93	93	96	94	95	93	93	94	92, 93, 92
SP 9.5	C	92	97.5	95	93	94	95	94	96	94	93	93	94	93	94	94	93	93	93	94	93	93	94										
SP 9.5	C	92	97.5	93	94	94	93	94	93	93	93	94	93	93	94																		
SP 9.5	C	92	97.5	93	93	94	94	92	93	93	92	93	93	94	93	93	93	93	93														
SP 9.5	C	92	97.5	94	94	94	93	94	93	94	95	93	94																				
SP 9.5	C	92	97.5	94	95	94	95	95	96	94	94	93	95	93																			
SP 9.5	C	92	97.5	94	93	94	94	92																									
SP 9.5	C	92	97.5	95	94	94	94	95	93	94	93	94	93	93	93	93	93	93	94	94	93	94											
SP 9.5	C	92	97.5	92	92	92	92	93	92	91	93	93	93	92	94	95	95	94	95	95	93	93	93	93	93								
SP 9.5	C	92	97.5	94	95	94	93	93	92	94	93	93	93																				
SP 9.5	C	-	-	92	93	95	92	93	92	92	93	92	92	92	92	92	92	92	93	94	92	92	92	92	92	92	92	92	92	92	92	92	93
SP 9.5	C	-	-	94	92	93	92	93	93	94	92	94	94	94	92	93	93	92	92	92	92	92	92	92	92	92	93	93	93				
SP 9.5	C	92	97.5	92	91	91	92	92	92	92	93	93	93	93	92	93	92	92	93	93	92	93	93	93	92	92	92						
SP 9.5	C	92	97.5	92	94	92	94	92	92	93	92	92	94	93	92	92	92	93	93														
SP 9.5	C	92	97.5	94	95	95	94	96	94	94	95																						

QUALITY ASSURANCE COMPACTION RESULTS FOR 2011 CONSTRUCTION

Mix Type	Mix Category	Specified Compaction		Percent Compaction																													
		Lower Limit	Upper Limit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Additional Test Results
SP 9.5	C	92	97.5	97	93	92	93	95	93	94	96	94	95	95	96	94	93	94	93														
SP 9.5	C	92	97.5	94	93	93	94	93	93	94	94	94	95																				
SP 9.5	C	92	97.5	94	94	94	95	93	93	94	94	95	93	93	94	93	93	93	93														
SP 9.5	C	92	97.5	93	93	94	93	93	95	94	94	94	94	94	94	94	95	93	93	94													
SP 9.5	C	-	-	96	93	94	92	93	93	92	94																						
SP 9.5	C	-	-	93	92	92	96	95	92	92	94																						
SP 9.5	C	-	-	92	93	92	95	92	92	92	95																						
SP 9.5	C	-	-	93	92	95	97	94	93	97	95																						
SP 9.5	C	-	-	92	93	96	96	92	95																								
SP 9.5	C	-	-	92	94	94	95	93	92	92	92	94	93	92	92	95	92																
SP 9.5	C	-	-	93	96	92	93	93	92																								
SP 9.5	C	-	-	95	94	93	94	92	94	92	92																						
SP 9.5	C	-	-	92	94	94	93	95	92																								
SP 9.5	C	-	-	94	93	92	92	92	92	92	92	92	92	92	92																		
SP 9.5	C	-	-	93	93	93	93	93	93	93	92	92	93	92	92																		
SP 9.5	C	-	-	92	92	92	92	92	92	92	92	92	92	92																			
SP 9.5	C	-	-	92	92	93	92	92	93	92	92	92	92	92	92	92																	
SP 9.5	C	-	-	94	94	94	93	93	94	92	92	97	93	92	93	92	94	94	93	94	94	94	94	93	94	94	94	94	93	96	93	94	95, 94, 93, 93, 95, 94, 93
SP 9.5	C	-	-	95	95	93	94	95	93	93	93																						
SP 9.5	C	-	-	95	97	94	96	96	94	96	94	94	96	94	96	94	96	97	94	97	94	93	94	95	92	93	94	93	93	92	92	96	95, 93, 97, 94, 97, 95, 93, 96, 93, 92, 94, 93, 95, 94, 95, 92, 94, 92, 93, 93, 94, 93, 93, 97, 94, 95, 96, 93, 94, 94, 93, 96, 95, 93
SP 9.5	C	-	-	94	93	92	93	93	92																								
SP 9.5	C	-	-	94	92	92	94	93	92																								
SP 9.5	C	-	-	93	92	93																											
SP 9.5	C	-	-	95	93	94	93	95	94	93	93	93	93	94	95	95	93	95	95	93	94	93	93	93	93	94	94						
SP 9.5	C	-	-	93	93	93	93	93	93																								
SP 9.5	C	-	-	93	94	93	92	93	93																								
SP 9.5	C	-	-	92	93	92	39	94	92																								
SP 9.5	C	-	-	96	92	93	94	95	94																								
SP 9.5	C	-	-	92	93	93	94	93	94																								
SP 9.5	C	-	-	93	93	92	93	92	95																								
SP 9.5	C	-	-	94	93	92	94	93	93																								
SP 9.5	C	92	97.5	95	95	95	93	96	95	94	95	95	95	96	96	95	94	94	94	94	94	94	93	93	95	94	94	94	94	93			
SP 9.5	C	92	97.5	92	92	92	92	93	94	95	92	95	93	95	94	95	95	93	93	96	94	95	96	95	94	95	96						
SP 9.5	C	92	97.5	94	93	95	94	93	95	93	94	95	94	96	96	94	93	93	93	96	95	94	95	93	95	93	95	94	95	94	93	95	95, 95, 94, 97, 92, 96
SP 9.5	C	92	97.5	92	93	92	94	92	93	95	92																						
SP 9.5	C	92	97.5	93	94	92	92	93	93	93	93																						
SP 9.5	C	92	97.5	93	94	93	94	92	93	93	93																						
SP 9.5	C	92	97.5	94	96	94	95	96	92	94	93	94	94																				
SP 9.5	C	92	97.5	93	94	94	94																										
SP 9.5	C	92	97.5	95	94	94	95	93	94	93	94	95	96	95	97	94	93	94	96														

TABLE D-2
QUALITY ASSURANCE COMPACTION RESULTS FOR 2011 CONSTRUCTION

Mix Type	Mix Category	Specified Compaction		Percent Compaction																													
		Lower Limit	Upper Limit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Additional Test Results
SP 9.5	C	92	97.5	95	95	95	97	93	96	92	92																						
SP 9.5	C	92	97.5	94	94	94	95	94	93	94	94																						
SP 9.5	C	92	97.5	93	92	95	94	93	93	93	92	95	94	94	95	93	94	93	93	92	93	93	93	93	92	93	94						
SP 9.5	C	92	97.5	92	92	96	95	92	93	94	93																						
SP 9.5	C	92	97.5	86	83	84	81	86	84	87	93	85	85	85	87	84	83	86	83														
SP 9.5	C	92	97.5	92	93	94	94	94	94	94	94	94	93	93	92	94	94	94	93	94	93	93	93	93	93	95	93	93	95	93	93	94	93, 94
SP 9.5	C	92	97.5	93	93	94	91	93	94	93																							
SP 9.5	C	92	97.5	93	93	92	92	94	94	93	94																						
SP 9.5	C	92	97.5	94	95	94	94	94	94	93	94	94	94	94	93	94	94	93	94	94	93	94	94	93	94	95	94						
SP 9.5	C	92	97.5	93	95	93	95	95	95	93	93	94	92	93	93	94	96	93	94														
SP 9.5 (WMA)	C	-	-	94	94	94	94	94	94	94	95	94	94	94	95	95	95	94	95														
SP 9.5 (WMA)	C	-	-	94	94	95	95	95	94	94	95	94	94																				
SP 9.5 (WMA)	C	-	-	94	94	94	95	94	95	94	95	94	95	95	94																		
SP 9.5 (WMA)	C	-	-	94	94	95	95	95	94	95	95	95	95	94	94	94	95																
SP 9.5 (WMA)	C	-	-	94	94	94	94	94	94	95	94	94	94	94	94	93	93	93	94	94	94	94	94										
SP 9.5 (WMA)	C	92	97.5	97	94	95	96																										
SP 9.5 (WMA)	C	92	97.5	94	93	94	95	96																									
SP 9.5 (WMA)	C	92	97.5	97	93	94	93	93	93	93																							
SP 9.5 (WMA)	C	92	97.5	93	92	94	95	95	95	94	94	93	95	92	96	97	94	94	95	94	95	94	96										
SP 9.5 (WMA)	C	92	97.5	93	94	96	95	94	96	93	96																						
SP 9.5 (WMA)	C	92	97.5	94	94	94	94	94	95	93	95																						
SP 9.5 (WMA)	C	92	97.5	93	93	96	92																										
SP 9.5 (WMA)	C	92	97.5	95	98	94	93	95	93	95	96	96	97	96	96	96	97	99															
SP 9.5 (WMA)	C	92	97.5	93	93	93	94	93	94	93	94	92	93	94	94	93	94	92	93	95	92	95	93	94									
SP 9.5 (WMA)	C	92	97.5	95	94	94	92	93	93	94	94	93	94	93	94	94	95	93	92	100+													
SP 9.5 (WMA)	C	92	97.5	94	94	95	93	96	93	95	94	94	94	94	94	94	95	92	95	94	94	95	93	94	93								

APPENDIX E

Special Provision- Hot Mix Asphalt Paving

TABLE E-1

PAVING SPECIFICATION REFERENCE GUIDE

Subject	Specifications/ Special Provisions	Specification Title/Special Provision Title
Granular Layers	OPSS 1010	Material Specification for Aggregtaes - Base, Subbase, Select Subgrade, and Backfill Material
	OPSS 314	Construction Specification for Untreated Granular, Subbase, Base, Surface Shoulder, and Stockpiling
Hot Mix Asphalt Mix Design	OPSS.MUNI 1151/SP1151	Material Specification for Superpave and Stone Mastic Asphalt Mixtures/ Special Provision for Superpave and Stone Mastic Asphalt Mixes
	OPSS.MUNI 1101/SP1101	Material Specification for Performance Graded Asphalt Cement/ Special Provision for Performance Graded Asphalt Cement
	OPSS 1001	Material Specification for Aggregates - General
	OPSS 1003/ SP1003	Material Specification for Aggregates - Hot Mix Apshalt/ Special Provision for Material Specification for Agrgeagtes - Hot Mix Asphalt
	SP1	Special Provision for Warm Mix Asphalt - Process Selection
	SP2	Special Provision for Warm Mix Asphalt - Mix Design
	SP3	Special Provision for Engine Oil Residue (EOR)
Hot Mix Asphalt Construction/ Segregation/ Smoothness	OPSS 310/ SP310	Construction Specification for Hot Mix Asphalt/ Special Provision for Construction Specification for Hot Mix Asphalt

SPECIAL PROVISION FOR ENGINE OIL RESIDUE (EOR)

3.01 SCOPE

This Special Provision does not allow the use of Engine Oil Residue (EOR) in paving projects in the City of Hamilton.

3.02 ENGINE OIL RESIDUE

EOR is considered by the City to be a harmful additive to the asphalt cement and its use is strictly prohibited in any of the City's paving projects.

3.03 TESTING

As part of the Quality Control (QC) and Quality Assurance (QA) procedures samples of the asphalt cement will be obtained from the asphalt plant from asphalt tank(s) during asphalt production. One sample will be taken for the Contractor, one for the City of Hamilton and one for referee testing. The samples shall be 1 litre each and stored in glass containers.

If there is any concern about the quality of the asphalt cement in the mix, the samples of the asphalt cement will be tested in Gas Chromatography Mass Spectrometer (GCMS) for the presence of deleterious components not anticipated in good quality asphalt cement.

SPECIAL PROVISION FOR CONSTRUCTION SPECIFICATION FOR HOT MIX ASPHALT

This Special Provision amends the requirements of OPSS. 310, Construction Specification for Hot Mix Asphalt, April 2011.

AMMENDMENTS TO OPSS 310

310.07.07 Use of Paving Equipment

Clause 310.07.07 of OPSS 310 is amended by the addition of 310.07.07.01, 310.07.07.02 and 310.07.07.03, which are the following:

310.07.07.01 Paving in Echelon

When feasible and required in pavement design, placement of the surface and binder course asphalt in echelon is mandatory. The pavers shall be operated at the same time and maintain a distance of not more than 50 m of each other so that a hot joint is obtained between the lanes of mixtures being placed. The Contractor shall supply sufficient personnel to adequately control both spreading operations simultaneously.

310.07.07.02 Asphalt Material Transfer Vehicle

A Shuttle Buggy® Asphalt Material Transfer Vehicle (AMTV) is required for all paving operations, including paving using only one paver. The use of an AMTV will be paid for by the tonne.

310.07.07.03 Re-Heating and Compaction of Longitudinal Joints

For surface course, the Contractor shall use an approved method of re-heating, re-working and compacting all centerline longitudinal cold joints. Pricing shall be based on an infra-red heating system capable of maintaining a minimum temperature of 93° C to produce a welded joint, without scorching or burning the mix.

All re-heating methods shall be approved prior to the start of any asphalt placement.

The density of the mix at any longitudinal joint shall be within 1.5 percent of the mainline mat density. Compaction of longitudinal joint shall be measured within 0.3 m from the joint.

310.11 ASPHALT LAYERS SEGREGATION

OPSS 310 is amended by the addition of 310.11, which is the following:

Segregation consists of areas with comparatively coarser texture than that of the surrounding pavement. All segregation is deemed to be deficient materials and/or workmanship, regardless of the type, location, cause or severity. The Contractor shall provide traffic control, as required, to conduct all segregation assessments.

310.11.01 Types of Segregation

GOL0007440

Two main types of segregation are recognized:

Mid-lane Segregation: consists of any continuous or semi-continuous longitudinal mark or "streak", typically no greater than 300 mm in width. Such segregation is often found in the middle of the lane, in the vicinity of a paver's gearbox, but may be located anywhere across the width of the lane.

Other Segregation: consists of discrete areas or patches of regular, irregular or chevron shape.

310.11.02 Severity of Segregation

The severity of segregation is categorized as follows:

Slight Segregation: The pavement matrix is in place between the coarse aggregate particles; however there are slightly more coarse aggregate particles in comparison with the surrounding acceptable mix.

Medium Segregation: The pavement has significantly more coarse aggregate particles than the surrounding acceptable mat and usually exhibits some lack of surface matrix.

Severe Segregation: The pavement appears very coarse, with coarse aggregate particle against coarse aggregate particle and the pavement has little or no matrix.

310.11.03 Paving Segregation

If the Contractor fails to prevent slight segregation in paving, the Project Manager will issue a written warning and request the Contractor to address the problem. The contractor may be allowed to continue paving at the discretion of the Project Manager. If medium segregation is observed, the paving operation will be stopped. The Contractor shall prove to the satisfaction of the Project Manager that the paving can be continued without any medium segregation.

310.11.04 Correction of Segregation

If the Contractor's actions fail to prevent continued slight to medium segregation from any source, the Project Manager may instruct the Contractor to cease paving until the problem has been corrected and the City shall not be held responsible for any additional costs that the Contractor may incur as a result.

From the time that the Contractor receives notification of mid-lane segregation, the Contractor will be allowed a maximum of 100 tonnes of mix to be placed on the Contract, in order to demonstrate the effectiveness of any repairs and/or adjustments that have been made to a defective paver.

The Contractor shall demonstrate the repairs and/or adjustments to the paver, which is acceptable to the Project Manager. If the Contractor is unable to eliminate segregation to the satisfaction of the Project Manager, by making repairs or adjustments to the paver within the allowable 100 tonnes of hot mix, then the Contractor shall discontinue the use of that machine.

310.11.04.01 Mid-Lane Segregation

Medium to severe mid-lane segregation shall be repaired by removal and replacement at no cost to the City. Slight mid-lane segregation will be accepted into the work with no payment reduction.

310.11.04.02 Other Segregation

The disposition of Other Segregation shall be as follows:

Slight Segregation: Slightly segregated mix will be accepted into the work with no payment reduction.

Medium Segregation: Medium segregation in all HMA lifts shall be repaired at the direction of the Project Manager at no cost to the City.

Severe Segregation: All severely segregated mix shall be repaired by removal and replacement at no cost to the City.

Leveling or padding courses with a total thickness which is less than that is normally placed in a lift of hot mix (i.e., usually 40 mm), that is not machine-laid and any areas of "handwork" shall not be assessed on the basis of segregation but on the basis of other workmanship-related problems. However, if they deteriorate prior to being overlaid by another pavement course, the Project Manager will assess the causes of the deterioration before determining responsibility for the cost of repairs.

310.11.05 Repairs

All repairs shall be subjected to the approval by the Project Manager.

Repairs shall consist of removal and replacement with new hot mix or a hot mix overlay, where permitted.

Repairs for segregated hot mix shall be full lane or shoulder width. However, localized repairs may be permissible for mid-lane segregation in binder courses provided hot joints are used or the mat is still hot.

A paver shall be used for all repairs except those where localized repairs are allowed.

Where localized repairs are allowed for mid-lane segregation in binder courses, these repairs shall be:

- Less than or equal to 300 mm in width;
- To the full depth of the subject lift; and
- Entirely tack-coated.

Hot mix used in all repairs shall meet the requirements specified for the tender item in the Contract. All repairs shall be done in a workmanlike manner complying with all requirements for placing hot mix stated in the Contract. All repaired areas must be entirely tack-coated and all transverse joints in surface course repairs must butt up to a vertical face.

310.11.06 Basis of Payment

For surface and binder courses, all repairs for remedial work due to visually defective mix, including pavement removal and replacement, overlays where permitted, additional shouldering, traffic control and any other work which has to be redone such as line painting shall be made entirely at the Contractor's expense.

310.12 SMOOTHNESS

OPSS. 310 is amended by the addition of 310.12, which is the following:

This specification covers all surface smoothness requirements for hot mix asphalt on major paving projects

310.12.01 References

Ministry of Transportation Publications:

LS-296 Method of Test for Calibrating, Correlating and Conducting Surface Smoothness Measurements Using an Inertial Profiler
SP-024 Manual for Condition Rating of Flexible Pavements – Distress Manifestations

American Association of State Highway and Transportation Officials:

AASHTO MP 11-08 – Standard Equipment Specification for Inertial Profiler
AASHTO PP 49-08 – Standard Practice for Certification of Inertial Profiling Systems
AASHTO PP 50-07 – Standard Practice for Operating Inertial Profilers & Evaluating Pavement Profiles

American Society for Testing and Materials (ASTM):

ASTM E 950 - 98 - Standard Test Method for Measuring the Longitudinal Profile of Travelled Surfaces with an Accelerometer Established Inertial Profiling Reference.

310.12.02 Definitions

DMD (or Distance Measuring Device) is a device for measuring longitudinal distance along a profile measured by an Inertial Profiler.

Existing Surface means the original pavement surface prior to construction under the Contract.

Expanded Asphalt Mix (EAM) means "Full Depth Reclamation with Expanded Asphalt Stabilization" which is a mixture of reclaimed existing asphalt pavement, granular base, corrective aggregate if required, and expanded asphalt.

Final Measurements means the set of three measurements used for acceptance purposes.

Incident of Localized Roughness means a location where localized roughness with similar +ve or –ve deviation in mm has been identified at stations that are within ± 2 m of one another in at least two of the three runs that were measured by the applicable inertial profilers. Its station and average deviation shall respectively be considered to be the average station and the average deviation for the individual localized roughness locations that were identified in the 2 or 3 applicable runs.

Initial Measurements means the first set of three measurements taken by an Inertial Profiler on a given pavement section.

International Roughness Index (IRI) is a specific mathematical transform of a true profile in which a low pass filter (usually consisting of a moving average with a 250 mm base length) followed by a "Quarter Car Filter" are applied to the true profile then the absolute values of the vertical vibration of the "Quarter Car Filter" are accumulated and divided by the sublot length. It's expressed in units of m/km.

Localized Roughness is based on the difference (i.e. deviation in mm) between the average profile for the left and right wheel paths, which has had both a high pass Butterworth filter and a low pass moving average filter applied to it, and the same filtered average profile which has had a 7.62 m moving average filter applied to it..

Profiler Operator means any person who can provide a written statement to the Ministry by the manufacturer of an inertial profiler that that person has been adequately trained in that inertial profiler's operation and that person has also taken the Ministry's own training in the use of Transtec's ®ProVAL software.

Pulverized Grade means a grade that has undergone "In-place Full Depth Reclamation of Bituminous Pavement and Underlying Granular".

QA Profiler means an inertial profiler operated by on behalf of the Owner for acceptance purposes.

Quarter Car Filter calculates the suspension deflection of a simulated mechanical system with a response similar to one corner (a quarter) of a passenger car travelling at 80 km/hr.

Sublot means a continuous traffic lane of pavement; excluding the shoulder, which has been measured by inertial profiler for purposes of repairs/payment adjustments and normally having a length of 100 m, measured horizontally for highway survey purposes.

Subsequent Measurements means any measurements by an inertial profiler taken after the initial measurements.

Tolerance(s) means measurements of deviations which are taken using a rigid metal straight edge.

Total Allowable Repair Area Limit means the limit for all surface smoothness-related repairs which is equal to 5% of the area represented by all measured sublots of surface course constructed within the same construction season.

Unfiltered Data File means a data file from an inertial profiler representing the profile of a pavement surface determined from the raw measurements taken by the laser sensors after being adjusted by the measurements taken by the accelerometer(s) and the "smoothing-out" of any electrical "noise" but before any user-controlled data filter factors are applied.

Wheel paths mean 0.9 m on each side of the centreline of the actual trafficked lane. The trafficked lane does not include adjacent paved areas such as paved shoulders or tapers.

310.12.03 Equipment

310.12.03.01 Smoothness Measuring Device

All smoothness measuring devices used for surface smoothness measurements shall consist of inertial profilers conforming to the minimum requirements of an ASTM Class 1 Profilometer Standard/Specification (ASTM Standards, Vol. 04.03 Designation: E 950-98) and meeting the additional requirements stated in LS-293, AASHTO MP 11-03 and this Specification.

All inertial profilers to be used on the Contract site will be correlated at one or more Correlation Site(s) on *a yearly basis*. In addition, all inertial profilers will be properly calibrated before taking any measurements each day, in accordance with the requirements of LS-296.

All inertial profilers used for acceptance will be operated under the direct supervision of a Ministry-approved profiler Operator at a minimum speed of 60 km/hr and no more than the speed which is required to exceed a sampling interval of 25.4 mm.

310.12.04 Construction

310.12.04.01 Smoothness Correction of Pavement Surface(s) Beneath Surface Courses

At no additional cost to the Owner, unless otherwise specified in the Contract, the Contractor may place hot mix padding on the existing pavement or any other pavement(s) underlying the surface course, in order to meet the surface smoothness requirements specified for the surface course. The Contractor shall obtain Contract Administrator's approval on the mix type used for padding. Diamond grinding or micromilling will also be allowed for such corrections on existing pavements or any other pavements underlying the surface course, but only if the thickness of those pavements after grinding or micromilling is not reduced by more than 5 mm below the general profile of the surrounding unground or unmilled pavement surface.

310.12.05 Measurements

310.12.05.01 Surface Smoothness

The Owner will measure all through lane pavement surfaces using an approved QA profiler, as specified in the Contract Documents, with the following exceptions:

- .01 Lanes less than 400 m in length;
- .02 Curves with a centerline radius of less than 300 m and pavement within the superelevation transition, i.e. slope changes, of such curves; and
- .03 Additionally noted stations, roadways and major intersections.

310.12.05.02 Sublots To Be Measured

Within 5 Business Days after the pre-pave meeting, the Contract Administrator will provide a sketch to the Contractor showing the proposed details for the numbering and stations of each sublot.

In addition, at any time up until surface smoothness measurements of any particular sublot begin, the Contract Administrator will have the right to make additional changes to the sketch which affect that sublot as long as the Contract Administrator notifies the Contractor before the measurements of that sublot are taken. In all cases, the Contract Administrator will have final decision regarding the sketch.

At least 48 hours prior to beginning the construction of the surface course, the Contractor may propose changes to the sketch or any areas for consideration by the Contract Administrator which the Contractor wants exempted from the surface smoothness-related payment adjustment or repair requirements. The decision of the Contract Administrator regarding such areas will be binding and no additional areas will be exempted from such requirements, except for "Damaged Areas" excluded by the Contract Administrator in accordance with clause 310.12.06.02.02 of this special provision.

310.12.05.03 Inertial Profiler Measurements

The Contractor shall notify the Contract Administrator, in writing, when the surface course is ready for QA profiler acceptance testing. QA profiler acceptance measurements will only be performed when, regardless of the number of surface course tender items involved, the surface course has been completed to one of the following milestones:

.01 50% completed; or
.02 Once with a given calendar year; or
.03 Surface course completed.

The Contractor shall clearly mark out the sublot number and the station at the beginning of at least each 5 sublots, the beginning and ending of any sublots that are shorter than or longer than 100 m as well as any additional sublot(s) that mark the beginning of an abrupt change in chainage, in a way that remains visible to the Profiler Operator until the final measurements are completed and accepted.

The QA profiler will begin to carry out surface smoothness testing within 10 Business Days of the Contract Administrator receiving the Contractor's written notification that QA testing can begin and the Contract Administrator is fully satisfied that the locations of the sublots, that are to be measured, have been properly marked out by the Contractor.

Stations, areas that will not be measured, areas that will be measured but not payment-reduced and all distances from such areas will be referenced from the centreline of the inertial profiler's laser sensors.

Upon finishing the last complete sublot in any lane, if the remaining portion of the lane is greater than or equal to 50 m in length, then that remaining portion of the lane will be considered to be the last sublot in the lane. However, if the portion of the lane is less than 50 m in length, then it will be added to the previous sublot in the lane. In either case, the IRI of the affected sublot will be averaged over the increased/reduced sublot length and the sublot will be considered equally with all other sublots when calculating the overall payment factor.

An inertial profiler will be required to do three runs of any particular pavement section. However, when the Profiler Operator deems that the results for one or more sublots within a particular run are invalid, due to technical difficulties or other reasons, then the Profiler Operator, after consultation with the Contract Administrator, will be allowed to repeat that run and the data file for the repeated run will be used to calculate the IRI for all of the sublots and all of the localized roughness that are identified within that run.

For each profile run of each sublot that is measured by an inertial profiler, the Profiler Operator will run all of the applicable unfiltered data files through the ®ProVAL *version 2.73.0033* software, in accordance with the procedures specified in LS-296 to determine, as a minimum, the:

- Average left wheel path IRI, the average right wheel path IRI, the average IRI for both wheel paths, for each sublot, as well as the
- Locations and values of all localized roughness.

After the measurements by the QA profiler are analyzed, all areas to be repaired due to rejectable sublots and/or incidents of localized roughness shall be marked on the pavement surface by the Contractor at the direction of the Contract Administrator and prior to the Contractor doing any corrective work.

Within 5 Business Days After the surface smoothness measurements have been completed to any of the milestones listed at the beginning of this clause, the Contract Administrator will provide copies of the following on CD's or DVD's or via e-mail for use by IBM-compatible PC's to the Contractor:

- All of the unfiltered data files from the final measurements that are generated by the Inertial Profiler in ppf or erd format for each profile run;
- A summary of the longitudinal reference lines and offsets that were used for each profile run;
- A summary of all "lead-in" distances that the inertial profiler required, prior to the start of the first sublot being measured in every profile run;
- Summaries of all IRI measurements and the locations and values of all localized roughness in both wheel paths for each run of each sublot, as determined by the ®ProVal *version 2.73.0033* software in accordance with LS-296, in Microsoft® Excel spreadsheet file(s).

310.12.06 Quality Assurance

310.12.06.01 Surface Tolerances

The Contractor shall provide all traffic control, as required, for the Owner to conduct surface tolerance measurements. All tolerance-related repairs shall be carried out in accordance with Clause 310.12.06.02.03.

310.12.06.02 Acceptance Criteria for Surface Smoothness

310.12.06.02.01 Lot Size

A lot for surface smoothness shall consist of the total pavement quantity in a given surface course contract item that was measured by the QA profiler. Each lot will generally be divided into 100 metre single lane sublots.

Lot acceptance for surface smoothness shall be based on measurements of IRI and incident(s) of localized roughness.

310.12.06.02.02 Damage to Existing Pavement Surface after Preparation or Damage to Surface Course Prior to Smoothness Measurements

The Contractor shall provide written documentation to the Contract Administrator within 1 Business Day of the Contractor becoming aware of the damage to areas of:

- Existing pavement surfaces underlying a sublot, which have been milled and/or padded; or
- Surface course within a sublot;

When such damage was due to circumstances beyond the Contractor's control and occurred prior to measurement for surface smoothness.

The Contract Administrator will evaluate the Contractor's submission and may exclude all or part of the affected area from the final calculation for the payment factor.

310.12.06.02.03 Repairs and Redecisioning

Repairs shall not exceed the Total Allowable Repair Area Limit.

Any incident of localized roughness will either be repaired or receive a penalty in accordance with the requirements given in Table B. However, if one or more of these incident(s) of localized roughness are located within a rejected sublot, then at least a portion of the sublot containing the incident(s) of localized roughness shall be repaired, subject to the Total Allowable Repair Area Limit.

For any sublot with an IRI which is greater than 1.25 m/km, the sublot is rejected and the Contractor shall repair at least a portion of the sublot, subject to the Total Allowable Repair Area Limit.

Where surface smoothness-related repairs are not permitted because such repairs will exceed the Total Allowable Repair Area Limit, then penalties shall be assessed in lieu of repairs, in accordance with Tables A and B.

All repairs shall be made in accordance with clause 310.12.06.02.03.01 of this special provision. Redecisioning shall be in accordance with clause 3 of this special provision.

All repairs and the redecisioning of all sublots which are constructed in a given construction season shall be completed within 30 Days of the Contractor receiving written notice from the Contract Administrator that the last set of measurements had indicated repairs for those sublots. However, if such repairs cannot be made, due to rapid changes in weather or other issues that are no fault of the

Contractor, then, at the discretion of the Contract Administrator, the Contractor may be requested to delay those repairs until the beginning of the next construction season, at no additional cost to the Owner.

The Contractor shall inform the Contract Administrator, in writing, when the repaired sublots are ready for QA profiler acceptance re-testing.

310.12.06.02.03.01 Repairs

General:

At least 5 Business Days prior to beginning any surface smoothness-related or tolerance-related repairs, the Contractor shall submit a written proposal to the Contract Administrator with the sublot and repair locations including the appropriate stations, length of each repair area, distance between the ends of the repair areas on the same lane that are within 100 m of each other, and the method(s) of repair that the Contractor intends to use for each repair area. The Contractor shall not start repairs unless the Contract Administrator has given written permission. If permission is denied, then the Contract Administrator will provide the Contractor with the reason(s) in writing.

Surface smoothness-related or tolerance-related repairs shall consist of one or more of the following corrective measures:

1. Diamond Grinding
2. A hot mix overlay, where permitted;
3. Remove and Replace; and/or
4. Other methods of repair, if approved by the Contract Administrator, in consultation with the Ministry.

Diamond Grinding:

Subject to the Total Allowable Repair Area Limit, diamond grinding will not be allowed in any area of the surface course where that area:

a) Consists of a single lift of hot mix placed on a granular surface, Expanded Asphalt Mix (EAM) base or on pulverized grade; or

b) Will be reduced by more than 5 mm below the general profile of the surrounding pavement surface after the repair.

A sublot shall be limited to no more than 3 separate diamond ground repair areas representing a total combined area not exceeding 20 percent of that sublot.

If the Contractor wishes to grind more than 5 mm below the general profile of the surrounding pavement surface, the Contractor shall, at the Contract Administrator's request, prove by coring that the design thickness of the surface course will not be reduced by more than 5 mm after the repair.

Diamond grinding shall be performed parallel to the lane with each pass overlapping the previous one by at least 25 mm. The elevation difference between abutting edges of adjacent lanes shall not exceed 3 mm after grinding and the pavement cross slope shall be maintained throughout the repaired area. The pavement after repair shall be of uniform surface texture. The slurry produced from diamond grinding shall be removed from the site by the Contractor and managed as specified in the Contract Documents.

Hot Mix Overlay / Remove and Replace

As long as the Total Allowable Repair Area Limit is not exceeded, overlays on traffic lanes beneath structures may be allowed, if clearances between the pavement surface and the underside of the structure after overlay meet the established minimum requirements. Overlays on traffic lanes adjacent to curb-and-gutter or on bridge decks shall not be permitted. If an overlay is constructed, it shall be re-tested. If the overlay does not meet the tolerances and/or surface smoothness requirements specified in the Contract, a second overlay will not be permitted.

The transverse joints for an overlay shall be a butt-joint constructed by removing the existing surface course to a minimum depth of 40 mm to form a straight vertical face and for a longitudinal distance of not less than 3 m.

A paver shall be used wherever corrective measures include removal and replacement or the construction of a hot mix overlay. Hot mix used in such repairs shall meet all of the requirements specified for the item in the Contract. Hot-in-place recycling may only be used to repair hot-in-place contract items. Where there is an integral overlay, the integral overlay must be replaced with a new integral overlay of the same specified thickness as the original integral overlay.

The minimum width of all repairs by "remove and replace" or a hot mix overlay shall be the width of the lane being repaired, i.e. between longitudinal joints, and including any pavement markings that may be present. Also, for such repairs, there shall be no more than one repair area in an individual sublot and all individual repair areas shall be at least 50 m apart.

310.12.06.02.03.02 Redecisioning

When repairs are made to all or part(s) of any sublot for the pavement courses defined by clause 310.12.06.02.03.01 of this special provision for any reason, then the entire sublot will be re-tested by the QA profiler as specified in the Contract. Re-testing by inertial profiler will include at least 15 m on either side of the repaired area. If this requirement extends the testing onto an adjacent sublot, then the adjacent sublot will also be re-tested. After such repairs to the sublot, subsequent measurements will be used in the final calculations for the payment adjustment to the lot.

After a sublot is repaired/overlaid due to high initial IRI's or incident(s) of localized roughness, then the subsequent measurements of the sublot shall have no incident(s) of localized roughness and its IRI shall be less than or equal to 1.25 m/km.

310.12.07 Basis of Payment

310.12.07.01 Payment Adjustment for Surface Smoothness

310.12.07.01.01 Smoothness Correction of Pavement Surface(s) Beneath Surface Courses

No additional payment will be made to the Contractor for the smoothness corrections described in clause 310.12.04.01.

310.12.07.01.02 IRI

A sublot's payment factor for smoothness will be based on the initial QA IRI measurements, unless that sublot has been repaired or the initial QA IRI has been substituted or adjusted as a result of Referee testing or carry-over. Where a sublot has been repaired, the subsequent measurements taken after the repair will be used in the calculation for the payment adjustment to that sublot.

Subsequent measurements of IRI shall not be used to increase a payment factor, unless the sublot has been repaired.

No sublot that has been repaired for any reason shall receive a payment factor greater than 1.0.

For any sublot with an initial average IRI measurement for the three runs that is greater than 1.00 m/km but less than or equal to 1.250 m/km, the Contractor may either accept the inclusion of its payment factor in the calculation for the lot or the Contractor may choose to repair at least a portion of the sublot, subject to the Total Allowable Repair Area Limit.

The individual payment factors for each sublot will be determined by the Contract Administrator by substituting the IRI's into the applicable formulae shown in Table A and rounding to 3 decimal places, in accordance with LS 100.

The payment factor for the entire lot will be the average of the individual payment factors for all measured sublots of surface course within the lot, rounded to 3 decimal places, in accordance with LS 100, up to a maximum 1.050 times the Contract price of the hot mix surface course tender item.

If the average payment factor for the lot is equal to 1.000, the payment adjustment will be zero.

If the average payment factor for the lot is greater than 1.000, the payment adjustment will be:

(PFS - 1.000) x Price x Lot Quantity

If the average payment factor for the lot is less than 1.000, the payment reduction will be:

(1.000 - PFS) x Price x Lot Quantity

where: PFS = the average payment factor for smoothness for the lot

The term "Price" means the Contract price of the hot mix surface course tender item. However, when the Contract specifies that the contract price will be adjusted due to a change in asphalt cement content from that specified for bidding purposes, then "Price" means the contract price after adjustment for the change in asphalt cement content, if applicable.

Where the unit of measure is by tonnes:

For the "Lot Quantity", the Contract Administrator will calculate the theoretical tonnage of surface course in the lot using the length of pavement on which the inertial profiler measurements were made, design widths and lift thickness of the finished lane; excluding any paved shoulder and the mean lot average bulk relative density calculated from all of the values obtained from compaction acceptance testing of core samples for the applicable surface course. The bulk relative density values will be the same as those used in calculating the final compaction payment factors, as specified elsewhere in the Contract Documents.

Where the unit of measure is by square metres:

For the "Lot Quantity", the Contract Administrator will calculate the theoretical area of surface course in the lot using the length of pavement on which the inertial profiler measurements were made and the design widths of the finished lane; excluding any paved shoulder.

TABLE A – Payment Factors

Average IRI for a Sublot from a set of 3 Measurements Taken by an Inertial Profiler is Each Sublot (m/km)	Payment Factors
≤ 1.000	1.000
> 1.000 to 1.250	1.40 – (0.4 x IRI) (subject to Note 2 given below)
> 1.250	REJECTED (Requires repairs – subject to Notes 2 and 3 given below)

Notes

1. The payment factor will be equal to 1.000 for subsequent IRI measurements which are taken after repairs regardless of the reason for the repairs.
2. Sublots, with IRI's between 1.000 and 1.350 m/km and located in areas of hot-in-place recycling being used as a surface course (including hot-in-place with an integral overlay and hot-in-place recycled premium mix), will receive a payment factor of 1.000. sublots with IRI's greater than 1.350 m/km and located in areas of hot-in-place recycling being used as a surface course (including hot-in-place with an integral overlay and hot-in-place recycled premium mix) shall be required if within the Total Allowable Area Limit.
3. Repairs to a sublot will only be permitted up to the Total Allowable Repair Area Limit. Any rejectable sublot that is not allowed to be repaired because the Total Allowable Repair Area Limit is exceeded will receive a payment factor of 0.500, in addition to any other penalities assessed for incidents of localized roughness within that sublot that are also not allowed to be repaired.

310.12.07.01.03 Incident(s) of Localized Roughness

The Contractor will either be given penalties or required to repair all incidents of localized roughness in accordance with Table B.

However, where two or more incidents of localized roughness with the same +ve or –ve deviation are found to be within 3 m of one another and they are left unrepaired, then the localized roughness at those locations will be respectively treated as a single incident of localized roughness and the deviation of that single incident of localized roughness will be considered to be the average deviation for all of the individual incidents of localized roughness within that 3 m for penalty assessment purposes.

The payment adjustment for any sublot which includes any unrepaired incidents of localized roughness will be unaffected by any penalties given for such incidents of localized roughness.

TABLE B – Penalties/Repairs for Localized Roughness

Incidents of Localized Roughness (determined from three sets of measurements taken by an Inertial Profiler, run through ProVAL version 2.73.0033 and rounded to the nearest 0.05 mm)	Penalty
3.00 to 3.50	The Contractor shall receive a penalty (subject to Notes **1** and **2**) of $1,500 for each incident of localized roughness located in multi-lane freeways, and $1250 for each incident of localized roughness located in all other highway types. Repairs will be allowed for any incident of localized roughness in this amplitude range subject to Note **2**.
3.55 to 4.70	The Contractor shall receive a penalty (subject to Notes **1** and **2**) of $3,000 for each incident of localized roughness located in multi-lane freeways and $2500, for each incident of localized roughness located in all other highway types. Repairs will be allowed for any incident of localized roughness in this amplitude range subject to Note **2**.
> 4.70	All incidents of localized roughness shall be repaired in this range (subject to Note **2**). For any additional incident of localized roughness that is not allowed to be repaired because the Total Allowable Repair Area Limit has been exceeded, the Contractor shall receive a penalty of $3000 if it is located in a multi-lane freeway and $2500 if it is located in any other highway type.

Notes

1. Incidents of localized roughness with a deviation between 3.00 and 4.70 mm which are located in areas where hot-in-place recycling is used as a surface course (including hot-in-place recycling with an integral overlay and hot in-place recycled premium mix), will receive no penalties.
2. As long as the total area for all surface smoothness-related repairs has not exceeded the Total Allowable Repair Area Limit and subject to the restrictions on repairs stated in clause 313.08.01.05.04.01 entitled “Repairs”, the Contractor may repair an incident of localized roughness with a deviation greater than 3.00 mm. If the repair removes that incident of localized roughness, then the penalty for that incident of localized roughness will be waived. Any additional incident of localized roughness that is not allowed to be repaired because the Total Allowable Repair Area Limit has been exceeded shall receive the above specified penalty.

TABLE 7 **TOLERANCES FOR THE JOB-MIX FORMULA AGGREGATE GRADATION AND ASPHALT CEMENT**

CONTENT

Table 7 in OPSS. 310 should be revised such that the asphalt cement content for all mixes has the following tolerances on the job-mix formula:

- Acceptable < 0.20
- Borderline 0.20 to 0.30
- Rejectable > 0.30

SPECIAL PROVISION FOR MATERIAL SPECIFICATION FOR AGGREGATES – HOT MIX ASPHALT

This Special Provision amends the requirements of OPSS.MUNI 1003, Material Specification for Aggregates – Hot Mix Asphalt, November 2006.

AMMENDMENTS TO OPSS.MUNI 1003

1003.05.04 Reclaimed Asphalt Pavement

Clause 1003.05.04 of OPSS.MUNI 1003 is amended by the addition of the following:
Coarse and fine RAP to be used on City of Hamilton's paving projects should be from certified stockpiles. For a RAP stockpile to be certified the following requirements should be met:

- The source of RAP shall be clearly identified;
- The age of RAP shall be identified or at least the year the RAP material was obtained; and
- Quality assurance testing should be as for other asphalt aggregates.

SPECIAL PROVISION FOR PERFORMANCE GRADED ASPHALT CEMENT

This Special Provision amends the requirements of OPSS.MUNI 1101, Material Specification for Performance Graded Asphalt Cement, November 2002.

AMMENDMENTS TO OPSS.MUNI 1101

1101.05 MATERIALS

Clause 1101.05 of OPSS.MUNI 1101 is amended by the addition of the following:
The basic grade of asphalt cement in the City of Hamilton is PG 58 – 28.

Clause 1101.05 of OPSS.MUNI 1101 is amended by the addition of the following two sections: 1101.05.03; and 1101.05.04.

1101.05.03 PG Grade Bumping

The asphalt cements bumped by 1 or 2 grades, i.e. from PG 58-28 to PG 64-28 or to PG 70-28 shall by polymer modified and their designation shall be PG 64-28 PM and PG 70-28 PM, accordingly.

1101.05.04 Engine Oil Residue (EOR)

The addition of Engine Oil Residue (EOR) to any asphalt cement is not allowed on any projects in the City of Hamilton as covered in the City of Hamilton Special Provision SP3, January 2012.

SPECIAL PROVISION FOR SUPERPAVE AND STONE MASTIC ASPHALT MIXES

This Special Provision amends the requirements of OPSS.MUNI 1151, Material Specification for Superpave and Stone Mastic Asphalt Mixtures, November 2006.

AMMENDMENTS TO OPSS.MUNI 1151

1151.04 SUBMISSION AND DESIGN REQUIREMENTS

1151.04.01 Mix Requirements for Design Purposes

Clause 1151.04.01 of OPSS.MUNI 1151 is amended by the addition of the following:
Asphalt cement content shall be as described in OPSS.MUNI 1101, November 2002 and City of Hamilton Special Provision SP1101, April 2012.
Superpave and SMA mixes must be verified as described in Section SP1151.10 of this City of Hamilton Special Provision.
For major paving projects, as determined by the City of Hamilton, performance properties of asphalt mixes should be tested in as described in Section 1151.11 of this City of Hamilton Special Provision and submitted as part of the mix design procedure.

Clause 1151.04.01 of OPSS.MUNI 1151 is amended by the addition of Clause 1151.04.01.02.

1151.04.01.02 Steel Slag

Steel slag can be used in Superpave 12.5 FC1 Mixes as described in City of Hamilton Special Provision SP1151.05.02.02.

1151.05 MATERIALS

1151.05.01 Asphalt Cement

Clause 1151.05.01of OPSS.MUNI 1151 is amended by the addition of the following:
Asphalt cement shall be performance graded asphalt cement as described in the City of Hamilton Special Provision SP1101, April 2012.

1151.05.02 Aggregates

Clause 1151.05.02 of OPSS.MUNI 1151 is amended by the addition of the following:
Aggregates shall be according to the City of Hamilton Special Provision SP1003, April 2012.

1151.05.02.01 Reclaimed Asphalt Pavement

Clause 1151.05.02.01 of OPSS.MUNI 1151 is amended by the addition of the following:
RAP shall meet the requirements of the City of Hamilton Special Provision SP1003, April 2012.

RAP with steel slag shall not be used in HMA, foamed asphalt and emulsion stabilized layers since the steel slag can still be active and cause cracking. RAP with steel slag can only be used as granular material providing it meets all OPSS requirements for granular materials. However, it shall not be used as a backfill material on water main projects.

1151.05.02.02 Steal Slag

Clause 1151.05.02 of OPSS.MUNI 1151 is amended by the addition of 1151.05.02.02, which is the following:
The Contractor shall have the option of supplying either Superpave 12.5 FC1 (OPSS) or Superpave 12.5 FC1 Steel Slag.
In the event that the Contractor chooses to supply Steel Slag asphalt mix, the following criteria shall apply:

.01 Designated source for coarse aggregates shall be Dofasco's K.O.B.M. Processed Course Steel Slag Aggregate.
.02 F.O.B. Heckett Multiserve Facilities at Dofasco's Bay Front Operations.
.03 The Contractor is required to submit the proposed mix design, fine aggregate sources and asphalt cement supplier to the City of Hamilton for review and approval.
.04 In the event that the above steel slag aggregate is not available at the time of construction, the Contractor shall not be entitled to any financial compensation for the supply of an approved substitute aggregate.

1151.09 PAYMENT ADJUSTMENT FOR VARIATIONS IN ASPHALT CEMENT IN HMA (BID AC)

OPSS.MUNI 1151 is amended by the addition of 1151.09 which is the following:

1151.09.01 Bidding Requirements

The asphalt cement content of mix designs for bidding purposes shall be those shown in the table below. The asphalt cement content of the JMF must be equivalent to or greater than those shown in the following table.

Mix Type	Asphalt Cement Content for Bid Purposes	Minimum Asphalt Cement Content for JMF
Superpave 9.5	5.5	5.3
Superpave 12.5	5.0	4.8
Superpave 19 mm	4.8	4.6
Superpave 25 mm or greater	4.6	4.4

1151.09.02 Price Adjustments

The Contractor shall submit to the Project Manager, a request for payment adjustment based on the criteria set forth in this SP. The Price used to calculate the payment adjustment shall be based on the mix design % AC and the applicable AC bid % provided in above table. There will be no adjustment for the use of RAP.

The City of Hamilton will use the Asphalt Price Index issued the month prior to tender close to determine the adjustment, if any:

Payment adjustment* = HMA Qty x (Actual AC – Bid AC) x AC Price
*Negative value indicates payment to City

The price correction shall be deemed to include all costs excluding taxes associated with the difference in AC content between the bid and actual mix design. Contractor shall submit all required documentation upon request.

Example 1 – Approved Mix Design AC higher than Bid AC
HMA Specified = Superpave 12.5mm PG 58-28
HMA Qty = 10,000 tonnes
Approved Mix Design % AC = 4.9 %
Bid AC for Superpave 12.5 = 4.7 %
Applicable Price Index = $312/ tonne (Price Index in effect the month prior to tender closing)

Price Adjustment = [10,000 x (0.049 – 0.047)] x 312 = $ 6240
(Payment adjustment to be paid to the Contractor)

Example 2 – Approved Mix Design AC lower than Bid AC
HMA Specified = Superpave 12.5mm PG 58-28
HMA Qty = 10,000 tonnes
Approved Mix Design % AC = 4.4 %
Bid AC for Superpave 12.5 = 4.7 %
Applicable Price Index = $312/ tonne (Price Index in effect the month prior to tender closing)

Price Adjustment = [10,000 x (0.044 – 0.047)] x 312 = $ 9360
(Credit to City)

Notes:

- Contractors should bid the hot mix asphalt item using the cost of the PGAC specified. The AC Price Index is only a tool for qualifying hot mix prices and is not intended as a standard AC price to be incorporated into the contract bid.
- The payment adjustment calculated using this formula is full compensation for any and all PGAC grades specified.
- Asphalt payment adjustment will only be considered on items where the measurement for payment quantity specified in the Schedule of Quantities and Price is the tonne.

1151.09.03 Payment Adjustment for Changes in the "Asphalt Cement Price Index"

The price index will be based on the price, excluding taxes, FOB the depots in the Hamilton area, of asphalt cement grade PG 58-28 or equivalent. One index will be used to establish and calculate the payment adjustment for all grades. As of July 2006 the price index for each month will reflect the average of the same month's prices and be published on the last day of the month and be retroactively applied to HMA laid in the same month.

The City of Hamilton will use the Asphalt Price Index issued the month prior to tender close to determine the adjustment, if any:

A payment adjustment per tonne of asphalt cement will be established for each month in which paving occurs when the price index for the month differs by more than $15.00/tonne from the price index for the month prior to tender close. When the price index differential is less than $15.00/tonne, there will be no payment adjustment for that month. Payment adjustments due to changes in the price index are independent of any other payment adjustments made to the hot mix tender items.

The payment adjustment per tonne will apply to the quantity of asphalt cement in the hot mix accepted into the Work during the month for which it is established. The payment adjustment for the month will be calculated by the following means:

.01 **When AC Prices are Rising** by more than a $15.00/tonne difference: the payment adjustment to be paid to the Contractor is the result of subtracting the price index in effect when the tender was submitted from the price index in effect when paving took place, minus the $15.00 float, multiplied by the number of tonnes of PGAC incorporated in the mix(s) as determined from the average of samples taken during paving operations. If the answer is negative, no adjustment is made.
.02 **When AC Prices are Falling** by more than $15.00/tonne difference: the payment adjustment made in favour of the Owner is the result of subtracting the price index in effect when paving took place, plus $15.00 from the price index when the tender was submitted, multiplied by the number of tonnes of PGAC incorporated in the mix(s) as determined from the average of samples taken during paving operations.

The quantity of new asphalt cement includes all grades of asphalt cement supplied by the Contractor with and without polymer modifiers. For each month in which a payment adjustment has been established, the quantity will be calculated using the hot mix quantity accepted into the Work and its corresponding asphalt cement content as determined from the average of samples taken during paving operations.

For mixes which contain reclaimed asphalt pavement, the increase due the Contractor or the rebate due the owner will be calculated as if virgin hot mix asphalt has been supplied. This fairly reflects the increasing value of the Contractor's RAP pile when AC prices are increasing and the opposite when they are declining.

Example 1 – AC Prices Increasing

- PGAC 64-28 specified, 3,000 tonnes of HL3 @ 5.2% AC (156.0 tonnes AC)
- The Price index on April 5th, 2006 on tender closing is $332.90*(actual)*/tonne
- (PG 58-28)
- The applicable Price Index as published on August 31st effective for the August 17th-24th, 2006 actual paving dates is $475*(fictional)*/tonne (PG 58-28)
- Payment adjustment to be paid to the Contractor:
- [($475 - $15) - $332.90] x 156 tonnes AC = $19,827.60

Example 2 – AC Prices Decreasing

- PGAC 58-28 specified, 4,500 tonnes of HL8 @ 4.6% AC (207.0 tonnes AC)
- The Price index on July 5th, 2006 on tender closing is $500*(fictional)*/tonne
- (PG 58-28)
- The applicable Price Index as published on October 31st effective for the October 11th-18th, 2006 actual paving dates is $470*(fictional)*/tonne (PG 58-28)

- Payment for hot mix items reduced by:
- [$500 – ($470+ $15)] x 207 tonnes AC = $3,105.00

Example 3 – Year to Year Carryover Work

- PGAC 58-22 specified 11,000 tonnes of Superpave 12.5 @ 4.9% AC
- (539.0 tonnes AC)
- The Price index on July 19th, 2005 on tender closing is $285.50*(actual)*/tonne, PG 58-28
- The applicable Price Index for June 3rd to 14th, 2006 the actual paving dates is $433.80 (actual)/tonne PG 58-28
- Payment adjustment to be paid to the Contractor:
- [($433.80 - $15)] - $285.50 x 539 tonnes AC = $71,848.70

Notes:

- Contractors should bid the hot mix asphalt item using the cost of the PGAC specified. The AC Price Index is only a tool for qualifying hot mix prices and is not intended as a standard AC price to be incorporated into the contract bid.
- The payment adjustment calculated using this formula is full compensation for any and all PGAC grades specified.
- If the AC index has not changed more than $15.00 per tonne up or down, no adjustment is required. Only the amount of the change that is greater than $15.00 is used to calculate payment adjustments.
- Asphalt payment adjustment will only be considered on items where the measurement for payment quantity specified in the Schedule of Quantities and Price is the tonne.

1151.10 SUPERPAVE AND SMA MIX VERIFICATION

Clause 1151.04.02.02 of OPSS.MUNI 1151 is amended by adding the following, 1151.10:
After receiving the asphalt mix design from the Contractor or asphalt supplier, the Contractor shall provide asphalt mix verification test results in accordance with the following criteria:

.01 The tests must be performed by a laboratory independent from the firm producing the asphalt mix design.

.02 The laboratory performing verification testing must have a valid "Certificate of Conformance" issued by the Canadian Council of Independent Laboratories (CCIL) Asphalt Laboratory Certification Program and be qualified under the following categories:

.01 Asphalt Mix Design– Marshall and Superpave Methods (Type A)

.02 Asphalt Mix Compliance – Marshall and Superpave Methods (Type B)

All verification testing must be reviewed and accepted by the City of Hamilton prior to the start of any paving operations.

The mix design shall be submitted for acceptance at least two weeks before construction. The mix design has to be reviewed and approved by the Engineer. Before construction, a trial batch shall be submitted to the Project manager for verification and approval.

The submitted mix design shall include, besides JMF, the documents listed in Section 1151.04.05 of the OPS 1151 MUNI specification. The mix design that does not include the required documents will not be reviewed and accepted.

A sample of Performance Graded asphalt cement specified for the subject project shall be submitted with the mix design for future testing, if required.

1151.11 ASPHALT MIX PERFORMANCE REQUIREMENTS

OPSS.MUNI 1151 is amended by the addition of 1151.11, the following:
On selected major paving projects prior to construction, as part of the mix design procedure, dynamic modulus, rutting resistance and fatigue endurance of the asphalt mix and complex shear modulus (G*) and phase angle (δ) of asphalt cement used must be tested and results submitted to the Contract Administrator for mix characteristics verification and mix approval a minimum of 15 working days prior to the start of the paving operation. The requirements are as follows:

1151.11.01 Resilient Modulus Testing

The resilient modulus of the RBM mix shall be tested in accordance with the AASHTO TP62-03 "Standard Method of Test for Determining Dynamic Modulus of Hot-Mix Asphalt Concrete Mixtures".

1151.11.02 PGAC Testing

Complex shear modulus (G*) and phase angle (δ) of asphalt cement shall be tested on the Rolling Thin Film Oven (RTFO) residue in accordance with the Asphalt Institute "Superpave Performance Graded Asphalt Binder Specification and Testing" Superpave Series SP-1.

1151.11.03 Rutting Resistance Testing

Rutting resistance of the RBM mix shall be tested by one of the following methods:

.01 Using the Asphalt Pavement Analyzer (APA) in accordance with AASHTO TP-63-03 "Standard Test Method for Determining Rutting Susceptibility of Asphalt Paving Mixtures Using the Asphalt Pavement Analyzer (APA)". The mix shall be tested at a temperature of 58ºC. The rut depth at 8,000 cycles shall not exceed 5.0 mm; or

.02 Using the Hamburg Wheel Rut Tester (HWRT) in accordance with the Colorado L 5112 "Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Bituminous Mixtures". The mix shall be tested at a temperature of 58ºC. The rut depth shall not exceed 4.0 mm at 10,000 wheel passes and 10.0 mm at 20,000 wheel passes.

1151.11.04 Fatigue Endurance

Fatigue endurance of the RBM mix shall be tested in accordance with AASHTO TP8-94 standard "Standard Test Method for Determining the Fatigue Life of Compacted Hot Mix Asphalt (HMA) Subjected to Repeated Flexural Bending". The minimum requirement in terms of repetitions to failure will be set up by the designer for a particular mix.

APPENDIX F

WMA Special Provisions
NCHRP 691 Appendix A

SPECIAL PROVISION FOR WARM MIX ASPHALT – PROCESS SELECTION

This Special Provision determines the Warm Mix Asphalt (WMA) process selection to be used in the City of Hamilton .

1.01 WMA Technologies

There are currently more than 30 WMA technologies available. They can be grouped as follows:

.01 Organic additives such as wax which allow significantly lower mixing and compaction temperature due to reduced viscosity of the asphalt cement. An example of the technology using this process is Sasobit. Wax based technologies have been used in Ontario including the City of Hamilton;

.02 Chemical additives which improve the ability of the asphalt cement to coat the aggregate particles at lower mixing temperatures without significantly lowering the viscosity of the asphalt cement. They often also include antistripping additives. Examples of this process are Evotherm and Hyper Therm. They have been used in Ontario including the City of Hamilton;

.03 Foaming additives including zeolites which release water from within their crystal structure when added to the mix causing the asphalt cement to foam. The workability improves and the aggregate particles can be coated at lower mixing temperatures. An example of such technology is Advera. Advera has been used in Ontario including the City of Hamilton; and

.04 Foaming process where a small amount of water is added to hot asphalt cement. The asphalt cement expands for a short period of time and the viscosity is significantly reduced. An example of this process is the double barrel Green. This process has not been used in Ontario yet; however due to its low cost is popular in the U.S.

1.02 WMA Process Selection

The City of Hamilton is developing a "List of Approved WMA Technologies" that can be used on its asphalt paving projects. The current list is based on successful use of WMA in the City. If a Contractor wants to use a process that is not on the approved WMA technologies list, it will have to prove that the subject technology has been successfully used on other similar projects in Canada or the U.S. The contractor should submit the following information:

.01 Name of process, manufacturer, type of process and the technology group;

.02 Manufacture's recommendations including

- .01 Process description
- .02 Mix design recommendations
- .03 Required plant modification
- .04 Hauling recommendations
- .05 Mixing and compaction temperatures
- .06 Construction aspects, if any differences from conventional HMA paving besides temperatures; and

.03 Projects where the process has been used including

- .01 Location
- .02 Client including contact information (telephone, email)
- .03 Mix designs
- .04 Construction
- .05 Date of construction
- .06 To date performance.

The provided information will be reviewed by the City of Hamilton. The product has to be approved and placed on the "List of Approved WMA Technologies" in order to used on the City of Hamilton's paving projects. The provided information will be verified against mix design, construction and performance criteria described in the relevant City of Hamilton's WMA special provisions.

SPECIAL PROVISION FOR WARM MIX ASPHALT – MIX DESIGN

This Special Provision describes the Warm Mix Asphalt (WMA) mix design requirements to be used in the City of Hamilton (the City).

2.01 WMA MIX DESIGN

The currently used "permissive WMA mix design" used in Ontario is considered insufficient and requires modifications. The permissive methodology has a number of shortcomings that have to be addressed in order to successfully use WMA technologies. This is particularly important now that the number of WMA technologies on the market is consistently increasing and the Hot Mix Asphalt (HMA) core mix design of the permissive methodology does not address the aspects relevant to WMA.

The WMA mix design process required on the City of Hamilton's projects is generally based on the National Cooperative Highway Research Program (NCHRP) Report 691, "Mix Design Practices for Warm Mix Asphalt" prepared for the Transportation Research Board (TRB) in 2011. The recommended procedure is described in NCHRP Report 691, Appendix A, "Draft Appendix to AASHTO R 35: Special Mixture Design Considerations and Methods for Warm Mix Asphalt (WMA)". A copy of the draft Appendix to AASHTO R 35 is attached to this report in Appendix E.

2.02 MAJOR STEPS IN WMA MIX DESIGN PROCEDURE

The major steps in the WMA mix design shall be:

- .01 Materials selection
  - .01 WMA process selection – described in the City of Hamilton's Special Provision SP1
  - .02 Gradation – specified in OPSS.MUNI 1151 as amended by City of Hamilton SP1151
  - .03 Aggregate – specified in OPSS 1003
  - .04 Binder selection – specified in OPSS.MUNI 1101 as amended by City of Hamilton SP1101
  - .05 RAP in WMA mixes – generally specified in OPSS.MUNI 1151 as amended by City of Hamilton SP1151
- .02 Volumetric design
  - .01 Mixing and compaction temperatures – based on material coating and compatibility as described in Draft Appendix to ASSHTO R 35
  - .02 Specimen preparation – process specific as described in Draft Appendix to ASSHTO R 35

.03 Optimum binder content – specified in OPSS.MUNI 1151 as amended by City of Hamilton SP1151

.04 Volumetric criteria – specified in OPSS.MUNI 1151 as amended by City of Hamilton SP1151

.03 Mixture evaluation

.01 Coating and compatibility – as described in Draft Appendix to ASSHTO R 35

.02 Moisture sensitivity – specified in OPSS.MUNI 1151 as amended by City of Hamilton SP1151

.03 Rutting resistance – testing in Asphalt Pavement Analyzer (APA). Hamburg Wheel Rut Tester (HWRT), French Laboratory Rutting Resistance Tester (FLRRT), Flow Number Test.

2.03 ASPECTS OF PARTICULAR CONCERNS FOR WMA

There are aspects of WMA mix design that differ from the conventional hot-mix asphalt (HMA) mix design procedure. They are as follows:

.01 Binder grade selection – generally the procedure of PG selection described in OPSS.MUNI 1101 as amended by City of Hamilton SP1101 should be followed. However, WMA processes with very low production temperatures where the initial oxidation at the plant is very low and asphalt mix rutting can be of concern may require the increase in high temperature grade of the asphalt cement to meet rutting resistance requirements. Change in rutting resistance of mixes using WMA technologies is process specific and some processes, such as Sasobit, are known to provide improved rutting resistance with the same binder grade as equivalent HMA.

.02 RAP in WMA – it is generally assumed that RAP binder and new binder do mix at WMA process temperatures, although the amount of blending is unknown. However, it is appropriate to design WMA mixes containing RAP in the same way as HMA, accounting for the contribution of the RAP binder to the total binder content of the mix. RAP and new binder continue to blend while the mix is held at elevated temperature. To ensure that this blending occurs, a limit should be placed on the maximum stiffness of the RAP binder for WMA. The RAP binder should have a high temperature grade that is less than the planned field compaction temperature for the WMA.

.03 Specimen preparation – is specific to the WMA process which governs whether the additives are added to the binder, to the mix or to the wet aggregate. In order to ensure sufficient blending between RAP binder and new binder at the mix design stage, a 2-hour conditioning time at the compaction temperature should be used in the laboratory.

.04 Evaluation of coating and compatibility – the evaluation should be done at the optimum asphalt cement content. The evaluation of **coating** shall be carried out using AASHTO T195, "Determining Degree of Particle Coating of Bituminous-Aggregate Mixtures" which is a measure of the percentage of fully coated coarse aggregate particles in the mixture. The evaluation is done at the planned mixture production temperature. Coating is evaluated in lieu of the viscosity based mixing temperature for HMA. **Compatibility** is evaluated in WMA instead of the viscosity based compaction temperature. It is evaluated by compacting specimens to N_{design} at the planned field compaction temperature and again at 30ºC below the planned field temperature. The number of gyrations to reach 92% relative density is calculated from the height data. The ratio of the gyrations to 92% relative density at the lower temperature to the higher temperature should be less than 1.25.

.05 Moisture sensitivity – is one of the major concerns for the WMA technologies. It should be evaluated in accordance with OPSS.MUNI 1151 as amended by City of Hamilton SP1151. The criteria are the same as for HMA, i.e. the Tensile Strength Ratio (TSR) shall not be lower than 0.8. Since it has been reported that the moisture sensitivity of WMA mixes in the field have been lower than those of laboratory prepared mixes, the TSR of field mixes should be tested.

.06 Rutting resistance of WMA mixes shall be evaluated using Asphalt Pavement Analyzer (APA). Hamburg Wheel Rut Tester (HWRT), French Laboratory Rutting Resistance Tester (FLRRT), Flow Number Test. The criteria will be developed by the City of Hamilton. If a mix does not meet the rutting criteria, mix adjustment will be required as described in Draft Appendix to ASSHTO R 35. One of the methods is to increase the PG high temperature grade.

APPENDIX A

Draft Appendix to AASHTO R 35: Special Mixture Design Considerations and Methods for Warm Mix Asphalt (WMA)

Draft Appendix to AASHTO R 35

Appendix: Special Mixture Design Considerations and Methods for Warm Mix Asphalt (WMA)

1. PURPOSE

1.1. This appendix presents special mixture design considerations and methods for designing warm mix asphalt (WMA) using AASHTO R 35. WMA refers to asphalt concrete mixtures that are produced at temperatures approximately 50 °F (28 °C) or more cooler than typically used in the production of HMA. The goal with WMA is to produce mixtures with similar strength, durability, and performance characteristics as HMA using substantially reduced production temperatures.

1.2. The methods in this appendix are applicable to a wide range of WMA processes including:

- WMA additives that are added to the asphalt binder,
- WMA additives that are added to the mixture during production,
- Wet aggregate mixtures, and
- Plant foaming processes.

1.3. The information in this appendix supplements the standard procedures contained in AASHTO R 35. This appendix assumes the user is proficient with the standard procedures contained in AASHTO R 35.

2. SUMMARY

2.1. This appendix includes separate sections addressing the following aspects of WMA mixture design:

- Equipment for Designing WMA,
- WMA Process Selection,
- Binder Grade Selection,
- RAP in WMA,
- Process Specific Specimen Fabrication Procedures,
- Evaluation of Coating
- Evaluation of Compactability,
- Evaluation of Moisture Sensitivity,
- Evaluation of Rutting Resistance, and
- Adjusting the Mixture to Meet Specification Requirements.

2.2. In each section, reference is made to the applicable section of AASHTO R 35.

3. ADDITIONAL LABORATORY EQUIPMENT

3.1. All WMA Processes:

3.1.1. **Mechanical mixer**. A planetary mixer with wire whip having a capacity of 20 qt. or a 5 gal. bucket mixer.

Note 1 – The mixing times in this appendix were developed using a planetary mixer with wire whip, Blakeslee Model B-20 or equivalent. Appropriate mixing times for bucket mixers should be established by evaluating coating of HMA mixtures prepared at the viscosity based mixing temperatures specified in Section 8.2.1 of AASHTO T 312.

3.2. Binder Additive WMA Processes:

3.2.1. **Low shear mechanical stirrer.** A low shear mechanical stirrer with appropriate impeller to homogeneously blend the additive in the binder.

3.3. Plant Foaming Processes:

3.3.1. **Laboratory foamed asphalt plant.** A laboratory scale foamed asphalt plant capable of producing consistent foamed asphalt at the water content used in field production. The device should be capable of producing foamed asphalt for laboratory batches ranging from approximately 10 to 20 kg.

4. WMA PROCESS SELECTION

4.1. There are over 20 WMA processes being marketed in the United States. Select the WMA process that will be used in consultation with the specifying agency and technical assistance personnel from the WMA technology providers. Consideration should be given to a number of factors including: (1) available performance data, (2) the cost of the warm mix additives, (3) planned production and compaction temperatures, (4) planned production rates, (5) plant capabilities, and (6) modifications required to successfully use the WMA process with available field and laboratory equipment.

4.2. Determine the planned production and planned field compaction temperatures.

5. BINDER GRADE SELECTION

5.1. Use the same grade of binder normally used with HMA. Select the performance grade of the binder in accordance with Section 5 of AASHTO M 323 considering the environment and traffic at the project site.

Note 2 – For WMA processes having production temperatures that are 100 °F (56 °C) or more lower than HMA production temperatures, it may be necessary to increase the high temperature performance grade of the binder one grade level to meet the rutting resistance requirements included in this appendix.

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6. RAP IN WMA

6.1. For WMA mixtures incorporating RAP, the planned field compaction temperature shall be greater than the as-recovered high temperature grade of the RAP binder.

Note 3 – This requirement is included to ensure that there is mixing of the new and recycled binders. Laboratory studies showed that new and recycled binders do mix at WMA process temperatures provided this requirement is met and the mixture remains at or above the planned compaction temperature for at least 2 hours. Plant mixing should be verified through an evaluation of volumetric or stiffness properties of plant produced mixtures.

6.2. Select RAP materials in accordance with Section 6 of AASHTO M 323.

6.3. For blending chart analyses, the intermediate and low temperature properties of the virgin binder may be improved using Table 1.

Note 4 – The intermediate and low temperature grade improvements given in Table 1 will allow additional RAP to be used in WMA mixtures when blending chart analyses are used. An approximately 0.6 °C improvement in the low temperature properties will allow approximately 10 percent additional RAP binder to be added to the mixture based on blended binder grade requirements.

Table 1. Recommended Improvement in Virgin Binder Low Temperature Continuous Grade for RAP Blending Chart Analysis for WMA Production Temperatures.

Virgin Binder PG Grade	58-28	58-22	64-22	64-16	67-22
Average HMA Production Temperature, °F	285	285	292	292	300
Rate of Improvement of Virgin Binder Low Temperature Grade per °C Reduction in Plant Temperature	0.035	0.025	0.025	0.012	0.025
WMA Production Temperature, °F	Recommended Improvement in Virgin Binder Low Temperature Continuous Grade for RAP Blending Chart Analysis, °C				
300	NA	NA	NA	NA	0.0
295	NA	NA	NA	NA	0.1
290	NA	NA	0.0	0.0	0.1
285	0.0	0.0	0.1	0.0	0.2
280	0.1	0.1	0.2	0.1	0.3
275	0.2	0.1	0.2	0.1	0.3
270	0.3	0.2	0.3	0.1	0.4
265	0.4	0.3	0.4	0.2	0.5
260	0.5	0.3	0.4	0.2	0.6
255	0.6	0.4	0.5	0.2	0.6
250	0.7	0.5	0.6	0.3	0.7
245	0.8	0.6	0.7	0.3	0.8
240	0.9	0.6	0.7	0.3	0.8
235	1.0	0.7	0.8	0.4	0.9
230	1.1	0.8	0.9	0.4	1.0
225	1.2	0.8	0.9	0.4	1.0
220	1.3	0.9	1.0	0.5	1.1
215	1.4	1.0	1.1	0.5	1.2
210	1.5	1.0	1.1	0.5	1.3

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7. PROCESS SPECIFIC SPECIMEN FABRICATION PROCEDURES

7.1. Batching

7.1.1. Determine the number and size of specimens that are required. Table 2 summarizes approximate specimen sizes for WMA mixture design.

Note 5 – The mass of mixture required for the various specimens depends on the specific gravity of the aggregate and the air void content of the specimen. Trial specimens may be required to determine appropriate batch weights for the AASHTO T 283 and flow number testing.

Table 2. Specimen Requirements.

Specimen Type	Gyratory Specimen Size	Approximate Specimen Mass	Number Required
Maximum Specific Gravity	NA	500 to 6,000 g depending on maximum aggregate size	2 per trial blend plus 8 to determine design binder content plus 1 at design binder content for compactability evaluation
Volumetric Design	150 mm diameter by 115 mm high	4,700 g	2 per trial blend plus 8 to determine design binder content
Coating	NA	500 to 6,000 g depending on maximum aggregate size	1 at the design binder content
Compactability	150 mm diameter by 115 mm high	4,700 g	4 at the design binder content
AASHTO T 283	150 mm diameter by 95 mm high	3,800 g	6 at the design binder content
Flow Number	150 mm diameter by 175 mm high	7,000 g	4 at the design binder content

7.1.2. Prepare a batch sheet showing the batch weight of each aggregate fraction, RAP, and the asphalt binder.

7.1.3. Weigh into a pan the weight of each aggregate fraction.

Note 6 – For WMA processes that use wet aggregate, weigh the portion of the aggregate that will be heated into one pan and weigh the portion of the aggregate that will be wetted into a second pan.

7.1.4. Weigh into a separate pan, the weight of RAP.

7.2. **Heating**

7.2.1. Place the aggregate in an oven set at approximately 15 °C higher than the planned production temperature.

Note 7 – The aggregate will require 2 to 4 hours to reach the temperature of the oven. Aggregates may be placed in the oven overnight.

7.2.2. Heat the RAP in the oven with the aggregates, but limit the heating time for the RAP to 2 hours.

7.2.3. Heat the binder to the planned production temperature.

7.2.4. Heat mixing bowls and other tools to the planned production temperature.

7.2.5. Preheat a forced draft oven and necessary pans to the planned field compaction temperature for use in short-term conditioning the mixture.

7.3. **Preparation of WMA Mixtures With WMA Additives Added to the Binder**

Note 8 – If specific mixing and storage instructions are provided by the WMA additive supplier, follow the supplier's instructions.

7.3.1. Adding WMA Additive to Binder

7.3.1.1. Weigh the required amount of the additive into a small container.

Note 9 – The additive is typically specified as a percent by weight of binder. For mixtures containing RAP, determine the weight of additive based on the total binder content of the mixture.

7.3.1.2. Heat the asphalt binder in a covered container in an oven set at 135 °C until the binder is sufficiently fluid to pour. During heating occasionally stir the binder manually to ensure homogeneity.

7.3.1.3. Add the required amount of additive to the binder and stir with a mechanical stirrer until the additive is totally dispersed in the binder.

7.3.1.4. Store the binder with WMA additive at room temperature in a covered container until needed for use in the mixture design.

7.3.2. Preparing WMA Specimens

7.3.2.1. Heat the mixing tools, aggregate, RAP, and binder in accordance with Section 7.2.

7.3.2.2. If a liquid anti-strip is required, add it to the binder per the manufacturer's instructions.

7.3.2.3. Place the hot mixing bowl on a scale and zero the scale.

7.3.2.4. Charge the mixing bowl with the heated aggregates and RAP and dry mix thoroughly.

7.3.2.5. Form a crater in the blended aggregate and weigh the required amount of asphalt binder into the mixture to achieve the desired batch weight.

Note 10 – If the aggregates and RAP have been stored for an extended period of time in a humid environment, then it may be necessary to adjust the weight of binder based on the oven dry weight of the aggregates and RAP as follows:

1. Record the oven dry weight of the aggregates and RAP, w_i
2. Determine the target total weight of the mixture

$$w_t = \frac{w_i}{\left(1 - \frac{p_{b_{new}}}{100}\right)}$$

where:

w_t = target total weight

w_i = oven dry weight from step 1

$p_{b\,new}$ = percent by weight of total mix of new binder in the mixture

3. Add new binder to the bowl to reach w_t

7.3.2.6. Remove the mixing bowl from the scale and mix with a mechanical mixer for 90 sec.

7.3.2.7. Place the mixture in a flat shallow pan at an even thickness of 25 to 50 mm and place the pan in the forced draft oven at the planned field compaction temperature for 2 hours. Stir the mixture once after the first hour.

7.4. **Preparation of WMA Mixtures With WMA Additive Added to the Mixture**

Note 11 – If specific mixing and storage instructions are provided by the WMA additive supplier follow the supplier's instructions.

7.4.1. Weigh the required amount of the additive into a small container.

Note 12 – The quantity of additive may be specified as a percent by weight of binder or a percent by weight of total mixture.

7.4.2. If a liquid anti-strip is required, add it to the binder per the manufacturer's instructions.

7.4.3. Heat the mixing tools, aggregate, RAP, and binder in accordance with Section 7.2.

7.4.4. Place the hot mixing bowl on a scale and zero the scale.

7.4.5. Charge the mixing bowl with the heated aggregates and RAP and dry mix thoroughly.

7.4.6. Form a crater in the blended aggregate and weigh the required amount of asphalt binder into the mixture to achieve the desired batch weight.

Note 13 – If the aggregates and RAP have been stored for an extended period of time in a humid environment, then it may be necessary to adjust the weight of binder based on the oven dry weight of the aggregates and RAP as follows:

1. Record the oven dry weight of the aggregates and RAP, w_i
2. Determine the target total weight of the mixture

$$w_t = \frac{w_i}{\left(1 - \frac{p_{b_{new}}}{100}\right)}$$

where:

w_t = target total weight

w_i = oven dry weight from step 1

$p_{b\,new}$ = percent by weight of total mix of new binder in the mixture

3. Add new binder to the bowl to reach w_t

7.4.7. Pour the WMA additive into the pool of new asphalt binder.

7.4.8. Remove the mixing bowl from the scale and mix with a mechanical mixer for 90 sec.

7.4.9. Place the mixture in a flat shallow pan at an even thickness of 25 to 50 mm and place the pan in the forced draft oven at the planned field compaction temperature for 2 hours. Stir the mixture once after the first hour.

7.5. **Preparation of WMA Mixtures With A Wet Fraction of Aggregate**

Note 14 – Consult the WMA process supplier for appropriate additive dosage rates, mixing temperatures, percentage of wet aggregate and wet aggregate moisture content.

7.5.1. Adding WMA Additive to Binder

7.5.1.1. Weigh the required amount of the additive into a small container.

Note 15 – The additive is typically specified as a percent by weight of binder. For mixtures containing RAP, determine the weight of additive based on the total binder content of the mixture.

7.5.1.2. Heat the asphalt binder in a covered container in an oven set at 135 °C until the binder is sufficiently fluid to pour. During heating occasionally stir the binder manually to ensure homogeneity.

7.5.1.3. Add the required amount of additive to the binder and stir with a mechanical stirrer until the additive is totally dispersed in the binder.

7.5.2. Preparing WMA Specimens

7.5.2.1. Add the required moisture to the wet fraction of the aggregate, mix thoroughly, then cover and let stand for at least 2 hours before mixing with the heated fraction.

7.5.2.2. Heat the mixing tools, dry aggregate portion, and dry RAP portion to the initial mixing temperature in accordance with Section 7.2.

7.5.2.3. Place the hot mixing bowl on a scale and zero the scale.

7.5.2.4. Charge the mixing bowl with the heated aggregates and RAP and dry mix thoroughly.

7.5.2.5. Form a crater in the blended aggregate and weigh the required amount of asphalt binder into the mixture to achieve the desired batch weight.

Note 16 – If the aggregates and RAP have been stored for an extended period of time in a humid environment, then it may be necessary to adjust the weight of binder based on the oven dry weight of the aggregates and RAP as follows:

1. Record the oven dry weight of the heated aggregates and RAP, w_i
2. Determine the target total weight of the mixture:

$$w_t = \frac{\left(w_i + w_{dwf}\right)}{\left(1 - \frac{p_{b_{new}}}{100}\right)}$$

where:

w_t = target total weight
w_i = oven dry weight from step 1
w_{dwf} = oven dry weight of the wet fraction from the batch sheet
$p_{b\,new}$ = percent by weight of total mix of new binder in the mixture

3. Determine the target weight of the heated mixture:

$$w_{thm} = w_t - w_{dwf}$$

where:

w_{thm} = target weight of the heated mixture
w_t = target total weight
w_{dwf} = oven dry weight of the wet fraction from the batch sheet

4. Add new binder to the bowl to reach w_{thm}

7.5.2.6. Add the additive to the binder immediately before mixing with the heated fraction of the aggregate per Section 7.5.1.

7.5.2.7. Remove the mixing bowl from the scale and mix with a mechanical mixer for 30 sec.

7.5.2.8. Stop the mixer and immediately add the wet fraction.

7.5.2.9. Restart the mixer and continue to mix for 60 sec.

7.5.2.10. Place the mixture in a flat shallow pan at an even thickness of 25 to 50 mm.

7.5.2.11. Check the temperature of the mixture in the pan. It shall be between 90 and 100 °C.

7.5.2.12. Place the pan in the forced draft oven at the planned field compaction temperature for 2 hours. Stir the mixture once after the first hour.

7.6. **Preparation of Foamed Asphalt Mixtures**

7.6.1. The preparation of foamed asphalt mixtures requires special asphalt binder foaming equipment that can produce foamed asphalt using the amount of moisture that will be used in field production.

7.6.2. Prepare the asphalt binder foaming equipment and load it with binder per the manufacturer's instructions.

7.6.3. If a liquid anti-strip is required, add it to the binder in the foaming equipment per the manufacturer's instructions.

7.6.4. Heat the mixing tools, aggregate, and RAP in accordance with Section 7.2.

7.6.5. Prepare the foamed asphalt binder per the instructions for the foaming equipment.

7.6.6. Place the hot mixing bowl on a scale and zero the scale.

7.6.7. Charge the mixing bowl with the heated aggregates and RAP and dry mix thoroughly.

7.6.8. Form a crater in the blended aggregate and add the required amount of foamed asphalt into the mixture to achieve the desired batch weight.

Note 17 – The laboratory foaming equipment uses a timer to control the amount of foamed asphalt provided. Make sure the batch size is large enough that the required amount of foamed asphalt is within the calibrated range of the foaming device. This may require producing one batch for the two gyratory specimens and the two maximum specific gravity specimens at each asphalt content then splitting the larger batch into individual samples.

Note 18 – If the aggregates and RAP have been stored for an extended period of time in a humid environment, then it may be necessary to adjust the weight of binder based on the oven dry weight of the aggregates and RAP as follows:

1. Record the oven dry weight of the aggregates and RAP, w_i
2. Determine the target total weight of the mixture

$$w_t = \frac{w_i}{\left(1 - \frac{p_{b_{new}}}{100}\right)}$$

where:

w_t = target total weight
w_i = oven dry weight from step 1
$p_{b\,new}$ = percent by weight of total mix of new binder in the mixture

3. Add foamed binder to the bowl to reach w_t

7.6.9. Remove the mixing bowl from the scale and mix with a mechanical mixer for 90 sec.

7.6.10. Place the mixture in a flat shallow pan at an even thickness of 25 to 50 mm and place the pan in the forced draft oven at the planned field compaction temperature for 2 hours. Stir the mixture once after the first hour.

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8. WMA MIXTURE EVALUATIONS

8.1. At the optimum binder content determined in accordance with Section 10 of AASHTO R 35, prepare WMA mixtures in accordance with the appropriate procedure from Section 7 of this appendix for the following evaluations:

- Coating
- Compactability
- Moisture sensitivity
- Rutting resistance

8.2. **Coating**

8.2.1. Prepare sufficient mixture at the design binder content to perform AASHTO T 195 using the appropriate WMA fabrication procedure from Section 7 of this appendix. Do not short-term condition the mixture.

8.2.2. Evaluate the coating in accordance with AASHTO T 195.

8.2.3. The recommended coating criterion is at least 95 percent of the coarse aggregate particles fully coated.

8.3. **Compactability**

8.3.1. Prepare sufficient mixture at the design binder content for 4 gyratory specimens and one maximum specific gravity measurement using the appropriate WMA fabrication procedure from Section 7 of this Appendix including short-term conditioning for 2 hours at the planned compaction temperature.

8.3.2. Determine the theoretical maximum specific gravity (G_{mm}) according to AASHTO T 209.

8.3.3. Compact duplicate specimens at the planned field compaction temperature to N_{design} gyrations in accordance with AASHTO T 312. Record the specimen height for each gyration.

8.3.4. Determine the bulk specific gravity of each specimen in accordance with AASHTO T 166.

8.3.5. Allow the mixture to cool to 30 °C below the planned field compaction temperature. Compact duplicate specimens to N_{design} gyrations in accordance with AASHTO T 312. Record the specimen height for each gyration

8.3.6. Determine the bulk specific gravity of each specimen in accordance with AASHTO T 166.

8.3.7. For each specimen determine the corrected specimen relative densities for each gyration using Equation 1.

$$\%G_{mm_N} = 100 \times \left(\frac{G_{mb} \times h_d}{G_{mm} \times h_N} \right) \qquad (1)$$

where:

$\%G_{mm_N}$ = relative density at N gyrations;

G_{mb} = bulk specific gravity of specimen compacted to N_{design} gyrations;

h_d = height of the specimen after N_{design} gyrations, from the Superpave gyratory compactor, mm; and
h_N = height of the specimen after N gyrations, from the Superpave gyratory compactor, mm

8.3.8. For each specimen, determine the number of gyrations to reach 92 percent relative density.

8.3.9. Determine the average number of gyrations to reach 92 percent relative density at the planned field compaction temperature.

8.3.10. Determine the average number of gyrations to reach 92 percent relative density at 30 °C below the planned field compaction temperature.

8.3.11. Determine the gyration ratio using Equation 2.

$$Ratio = \frac{(N_{92})_{T-30}}{(N_{92})_T} \qquad (2)$$

where:
Ratio = gyration ratio
$(N_{92})_{T-30}$ = gyrations to 92 percent relative density at 30 °C below the planned field compaction temperature
$(N_{92})_T$ = gyrations to 92 percent relative density at the planned field compaction temperature

8.3.12. The recommended compactability criterion is the gyration ratio should be less than or equal to 1.25.

Note 18 – The compactability criterion limits the temperature sensitivity of WMA to that for a typical HMA mixture. The criterion is based on limited research conducted in NCHRP 9-43. The criterion should be considered tentative and subject to change as additional data on WMA mixtures are collected.

8.4. **Evaluating Moisture Sensitivity**

8.4.1. Prepare sufficient mixture at the design binder content for 6 gyratory specimens using the appropriate WMA fabrication procedure from Section 7 of this appendix including short-term conditioning.

8.4.2. Compact test specimens to 7.0 ± 0.5 percent air voids in accordance with AASHTO T 312.

8.4.3. Group, condition and test the specimens in accordance with AASHTO T 283.

8.4.4. The recommended moisture sensitivity criteria are the tensile strength ratio should be greater than 0.80 and there should not be any visual evidence of stripping.

8.5. **Evaluating Rutting Resistance**

8.5.1. Evaluate rutting using the flow number test in AASHTO TP 79.

8.5.2. Prepare sufficient mixture at the design binder content for four flow number test specimens using the appropriate WMA fabrication procedure from Section 7 of this appendix including short-term conditioning.

8.5.3. The test is conducted on 100 mm diameter by 150 mm high test specimens that are sawed and cored from larger gyratory specimens that are 150 mm diameter by at least 175 mm high. Refer to AASHTO PP 60 for detailed procedures for test specimen fabrication procedures. The short-term conditioning for WMA specimens is 2 hours at the compaction temperature.

8.5.4. Prepare the flow number test specimens to 7.0 ± 1.0 percent air voids.

8.5.5. Perform the flow number test at the design temperature at 50 % reliability as determined using LTPP Bind Version 3.1. The temperature is computed at 20 mm for surface courses, and the top of the pavement layer for intermediate and base courses.

8.5.6. Perform the flow number test unconfined using repeated deviatoric stress of 600 kPa with a contact deviatoric stress of 30 kPa.

8.5.7. Determine the flow number for each specimen, then average the results. Compare the average flow number with the criteria given in Table 3.

Table 3. Minimum Flow Number Requirements

Traffic Level, Million ESALs	Minimum Flow Number
<3	NA
3 to < 10	30
10 to < 30	105
≥ 30	415

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9. ADJUSTING THE MIXTURE TO MEET SPECIFICATION PROPERTIES

9.1. This section provides guidance for adjusting the mixture to meet the evaluation criteria contained in Section 8 of this appendix. For WMA mixtures, this section augments Section 12 in AASHTO R 35.

9.2. **Improving Coating**- Most WMA processes involve complex chemical reactions and/or thermodynamic processes. Consult the WMA additive supplier for methods to improve coating.

9.3. **Improving Compactability**- Most WMA processes involve complex chemical reactions and/or thermodynamic processes. Consult the WMA additive supplier for methods to improve compactability.

9.4. **Improving the Tensile Strength Ratio** – Some WMA processes include adhesion promoters to improve resistance to moisture damage. Consult the WMA additive supplier for methods to improve the tensile strength ratio.

9.5. **Improving Rutting Resistance**- The rutting resistance of WMA can be improved through changes in binder grade and volumetric properties. The following rules of thumb can be used to identify mixture adjustments to improve rutting resistance.

- Increasing the high temperature performance grade one grade level improves rutting resistance by a factor of 2.
- Adding 25 to 30 percent RAP will increase the high temperature performance grade approximately one grade level.
- Increasing the fineness modulus (sum of the percent passing the .075, 0.150, and 0.300 mm sieves) by 50 improves rutting resistance by a factor of 2.
- Decreasing the design VMA by 1 percent will improve rutting resistance by a factor of 1.2.
- Increasing N_{design} by one level will improve rutting resistance by factor of 1.2.

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10. ADDITIONAL REPORTING REQUIREMENTS FOR WMA

10.1. For WMA mixtures, report the following information in addition to that required in Section 13 of AASHTO R 35.

10.1.1. WMA process description.

10.1.2. Planned production temperature.

10.1.3. Planned field compaction temperature.

10.1.4. High temperature grade of the binder in the RAP for mixtures incorporating RAP.

10.1.5. Coating at the design binder content.

10.1.6. Gyrations to 92 percent relative density for the design binder content at the planned field compaction temperature and 30 °C below the planned field compaction temperature

10.1.7. Gyration ratio.

10.1.8. Dry tensile strength, tensile strength ratio, and observed stripping at the design binder content.

10.1.9. Flow number test temperature and the flow number at the design binder content.

APPENDIX G

Field Visit Photos

Figure G1 - Stonechurch (Upper James to Upper Wellington)

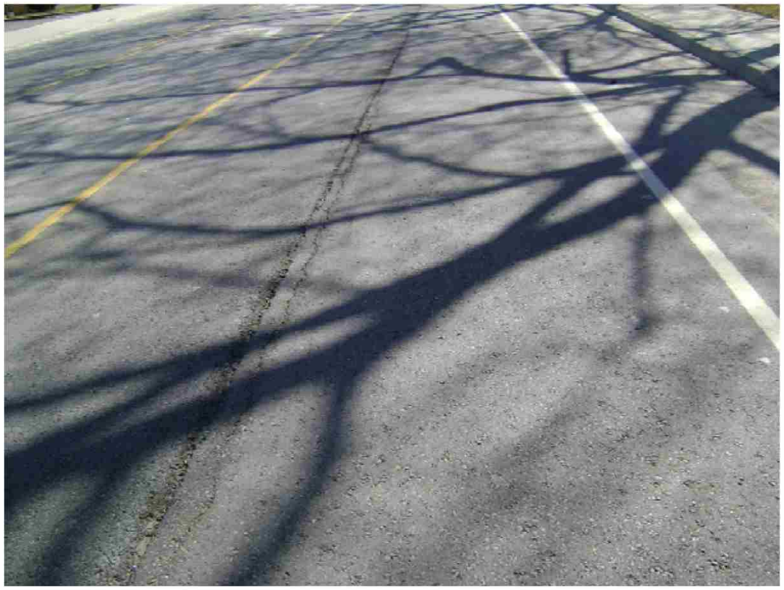

Figure G1 - Stonechurch (Upper James to Upper Wellington)

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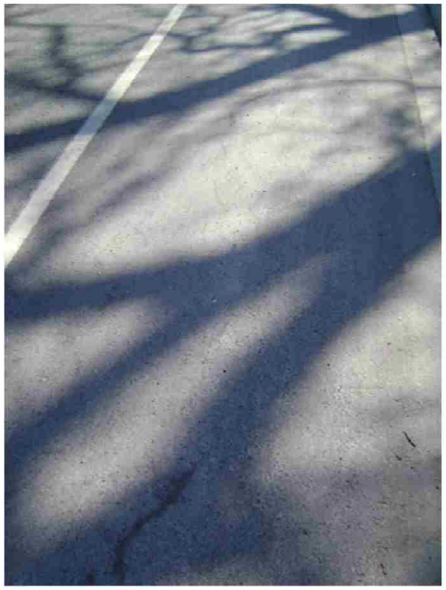

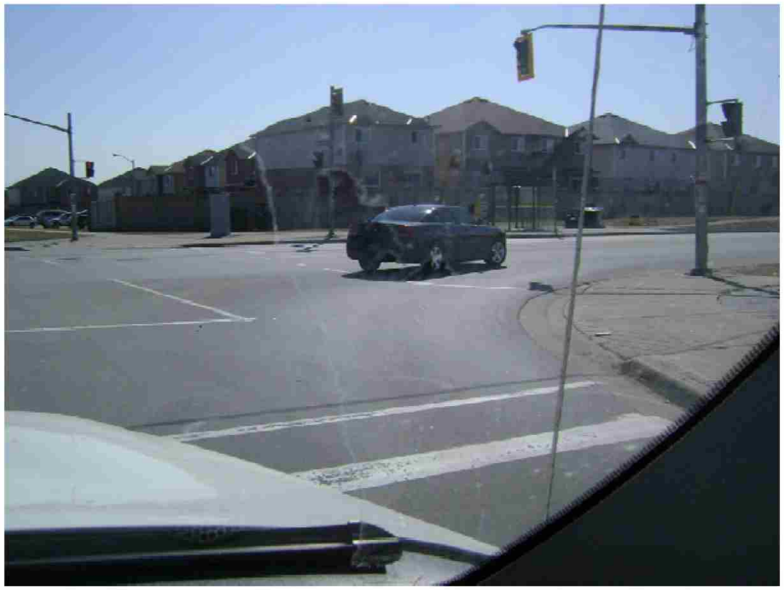


Figure G1 - Stonechurch (Upper James to Upper Wellington)

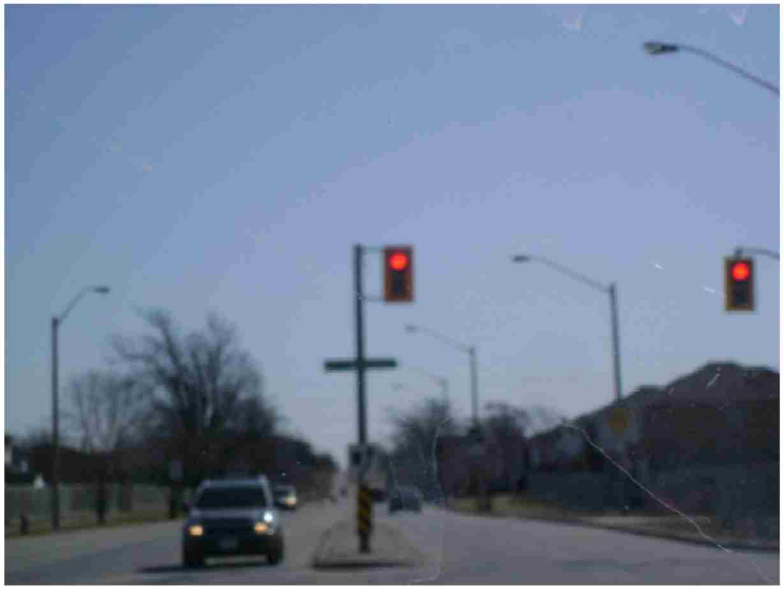

Figure G2 - Upper Wellington (Mohawk to Fennell)

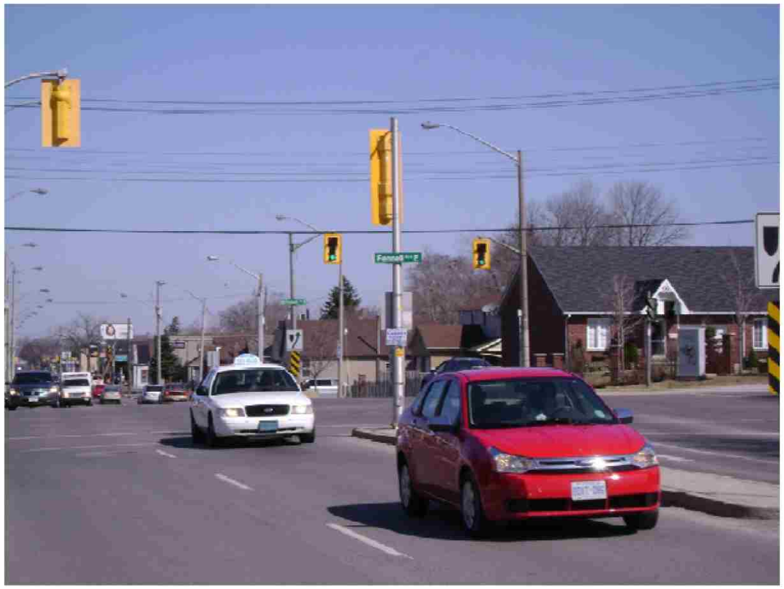

Figure G2 - Upper Wellington (Mohawk to Fennell)

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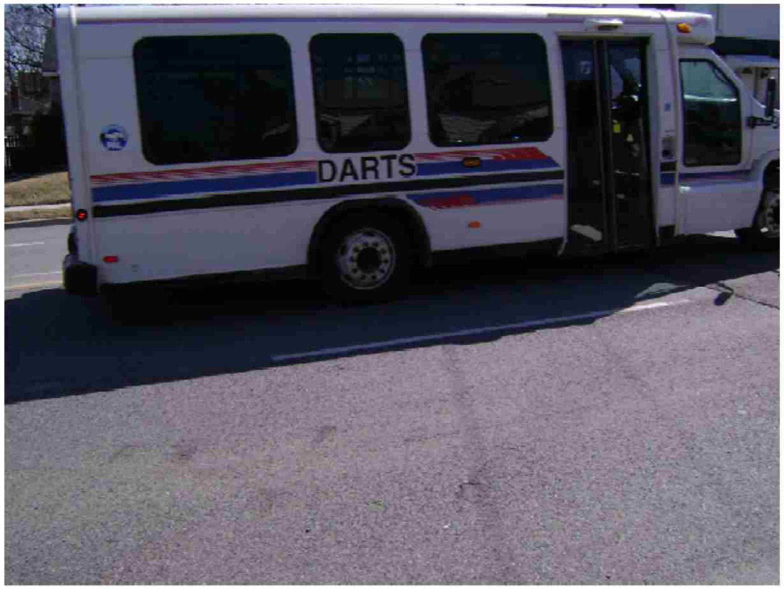
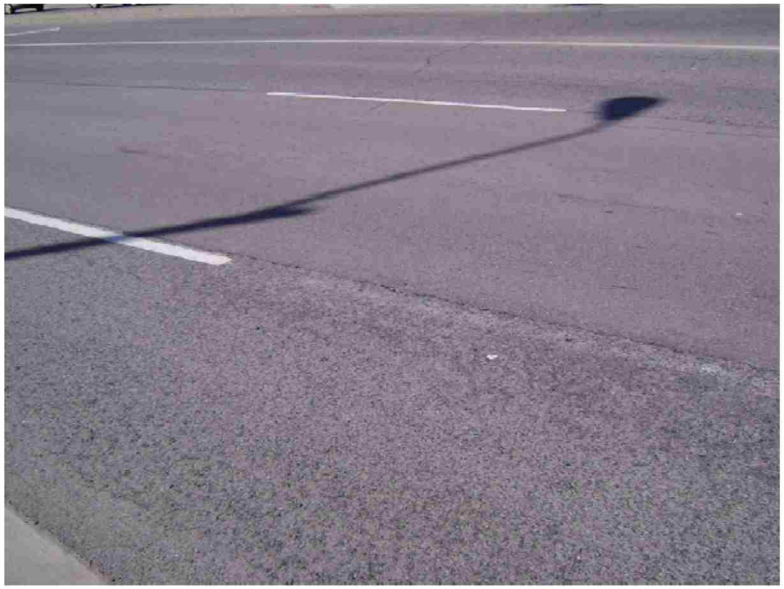


Figure G3 - Upper Wentworth (Linc Mohawk)



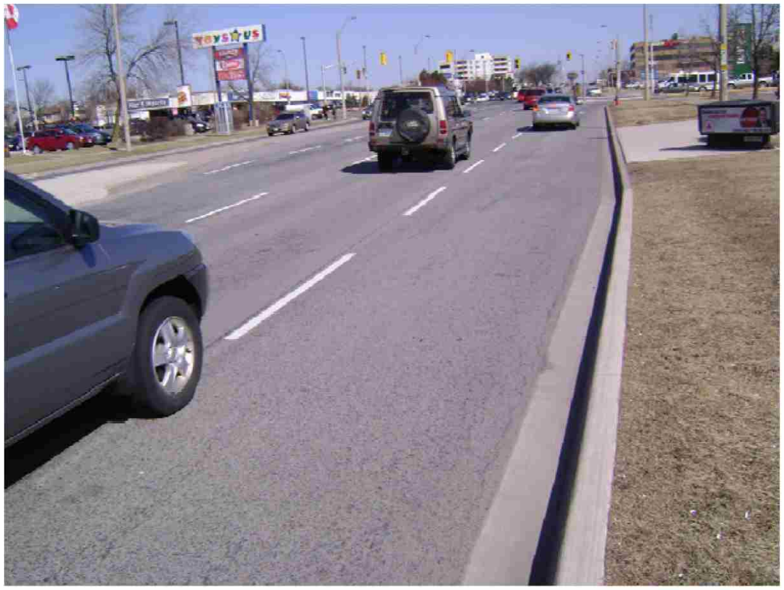
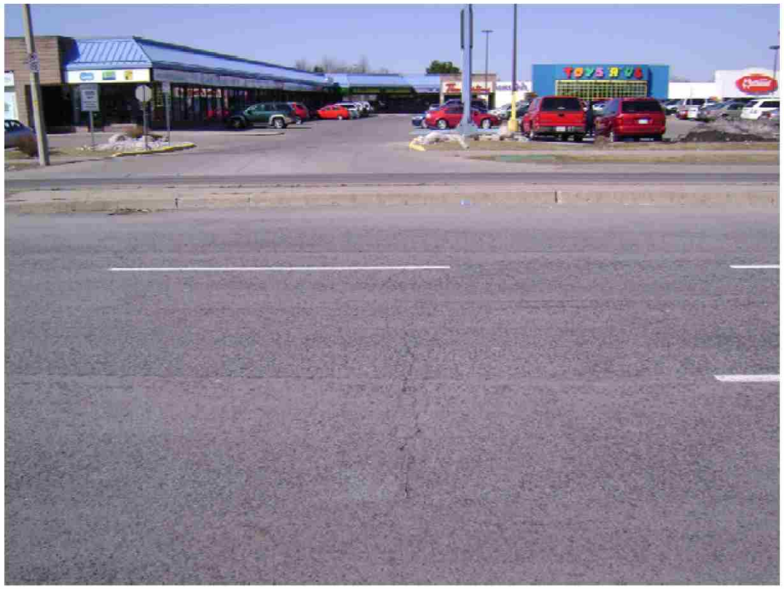


Figure G3 - Upper Wentworth (Linc Mohawk)



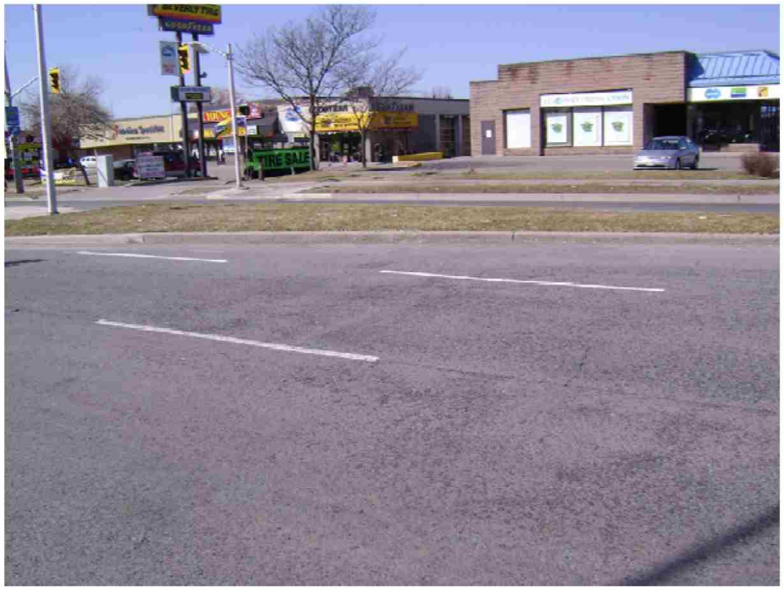


Figure G3 - Upper Wentworth (Linc Mohawk)

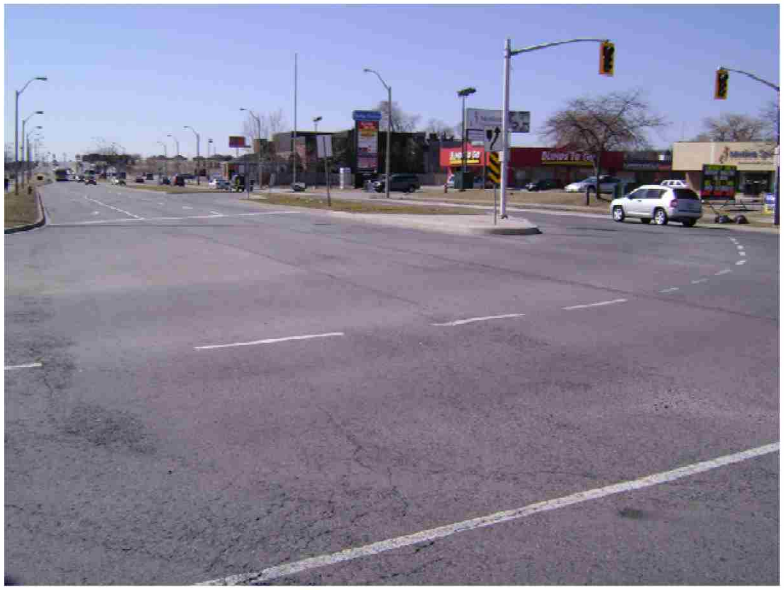
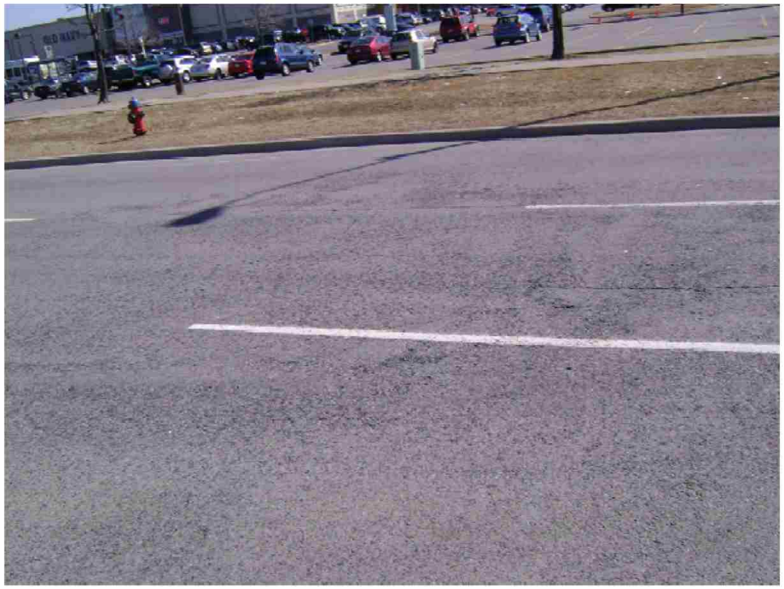


Figure G3 - Upper Wentworth (Linc Mohawk)



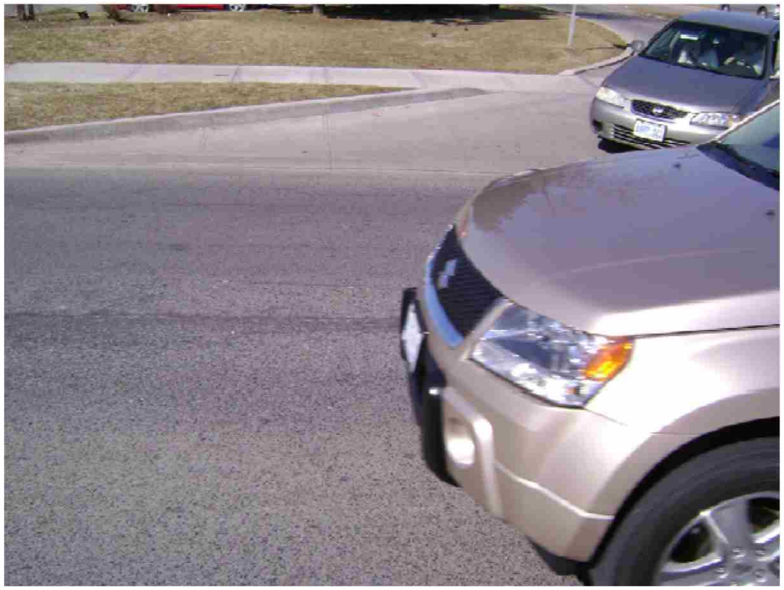
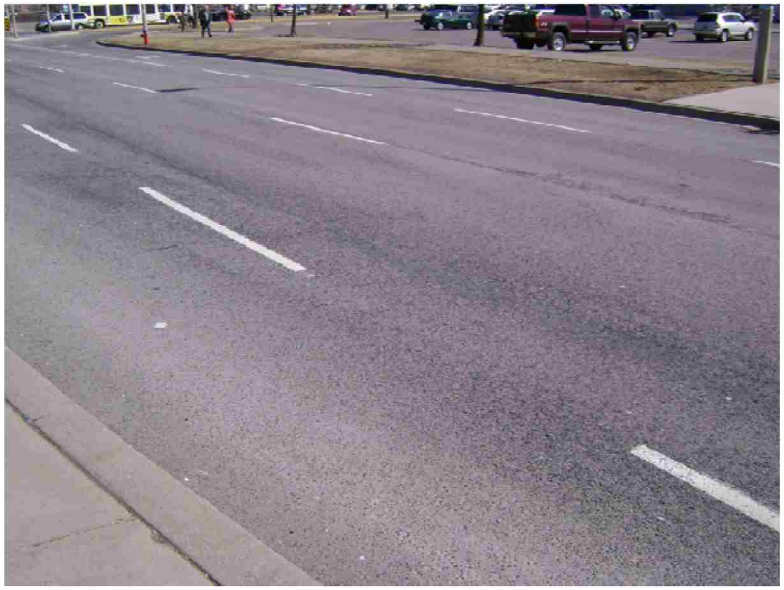


Figure G3 - Upper Wentworth (Linc Mohawk)



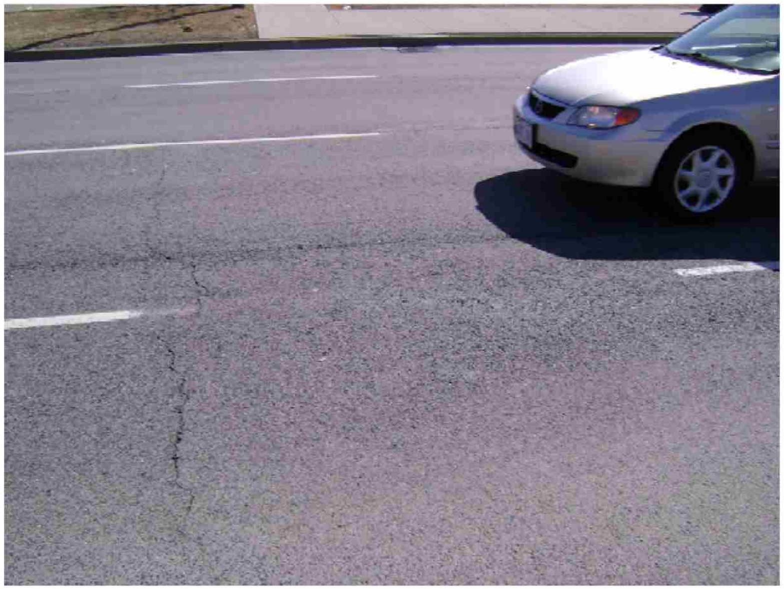
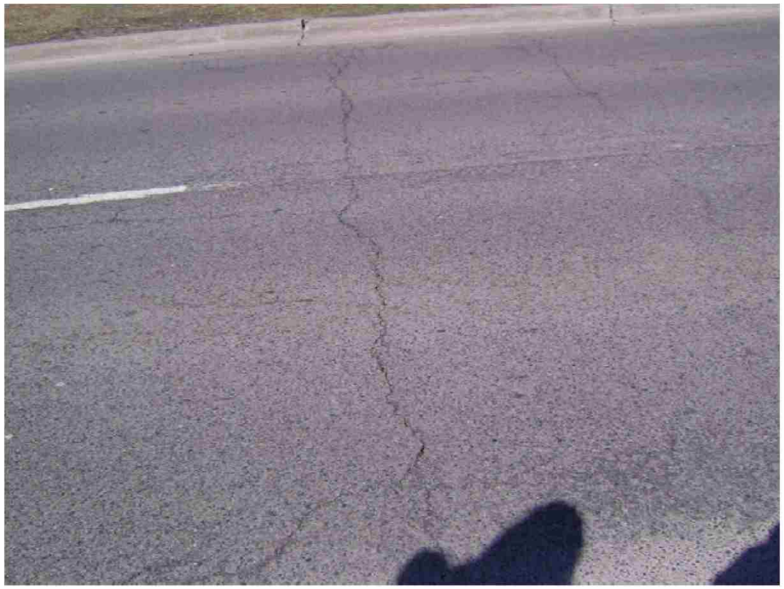
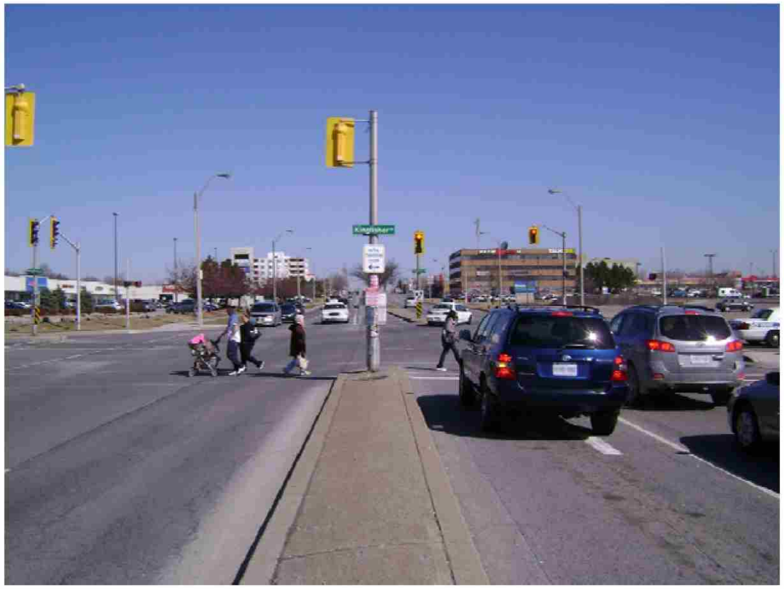


Figure G3 - Upper Wentworth (Linc Mohawk)





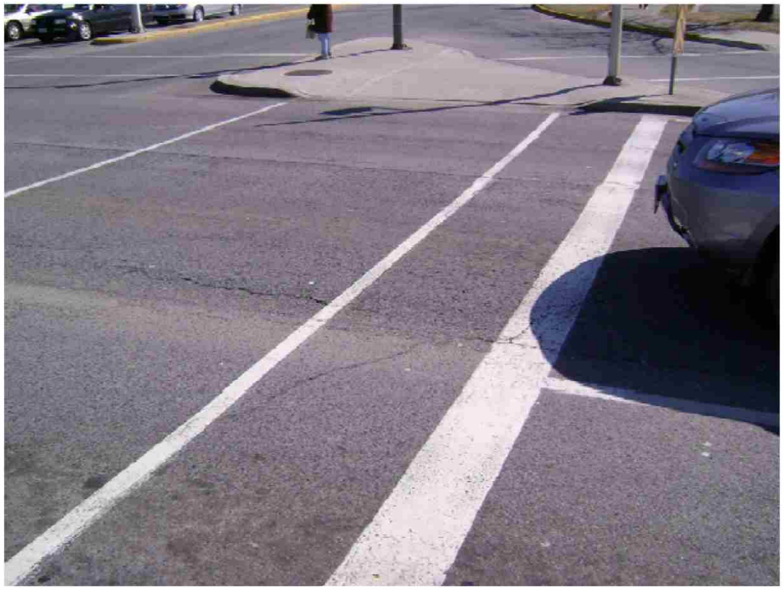
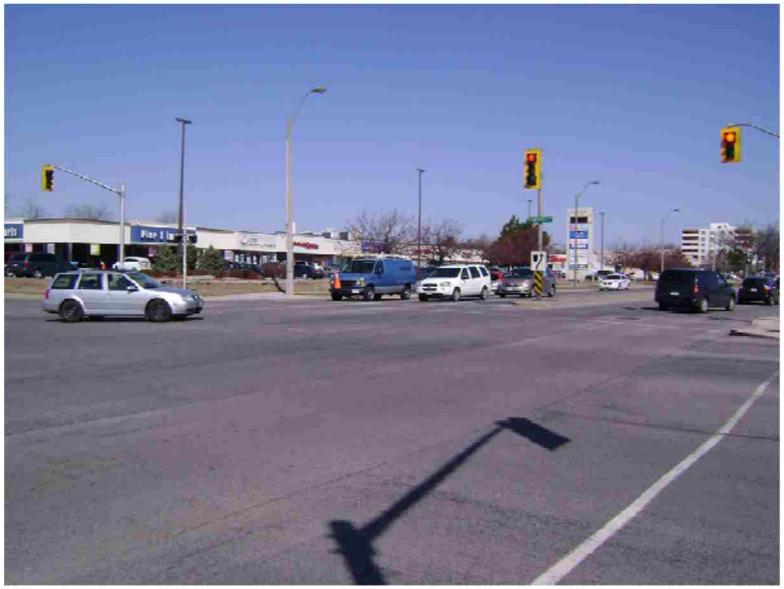
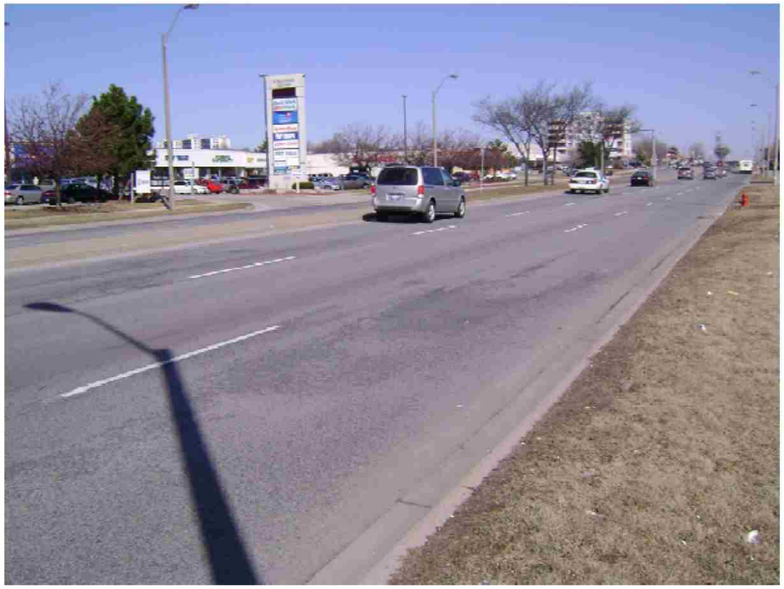


Figure G3 - Upper Wentworth (Linc Mohawk)





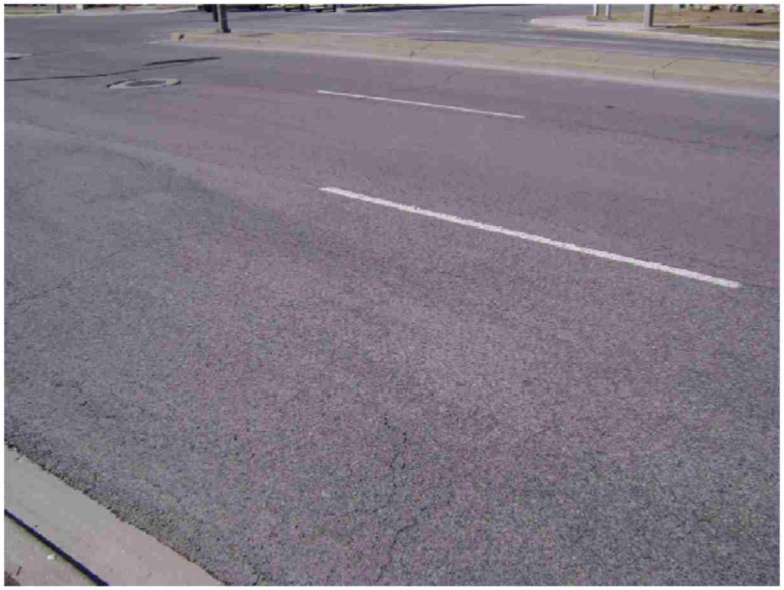
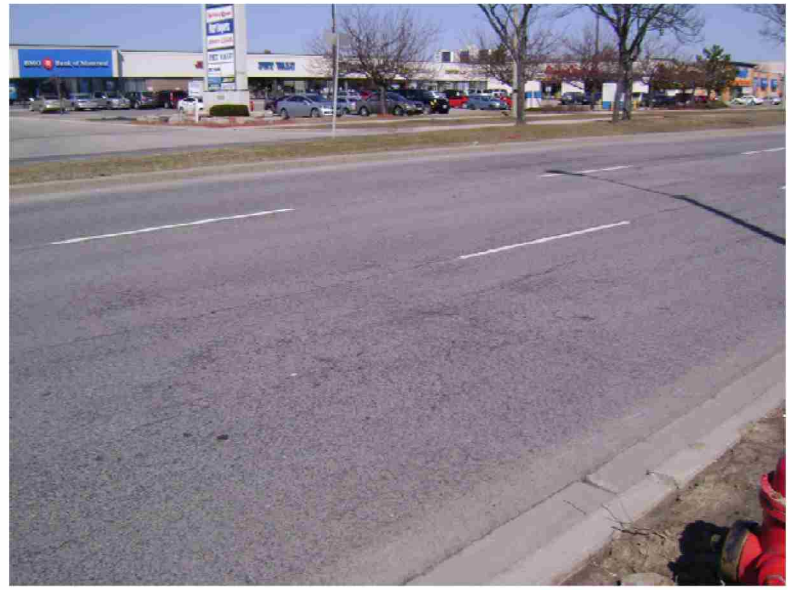


Figure G3 - Upper Wentworth (Linc Mohawk)



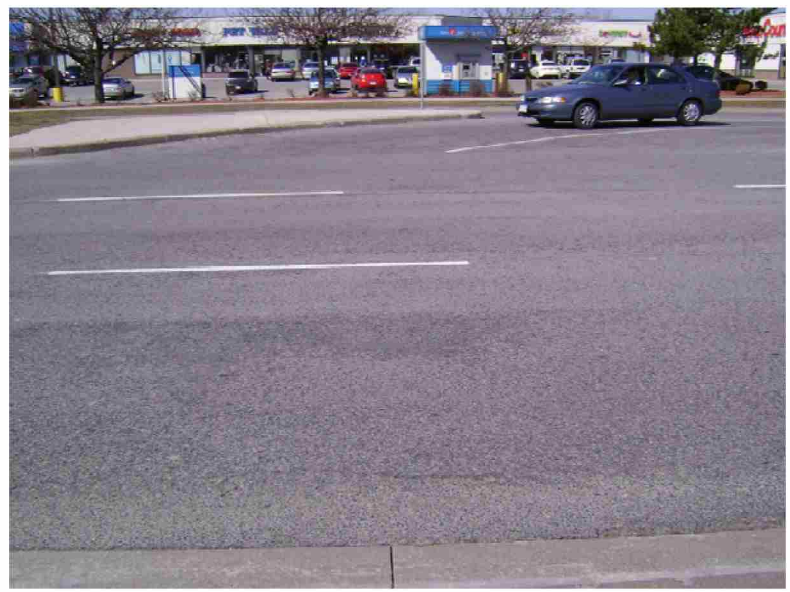
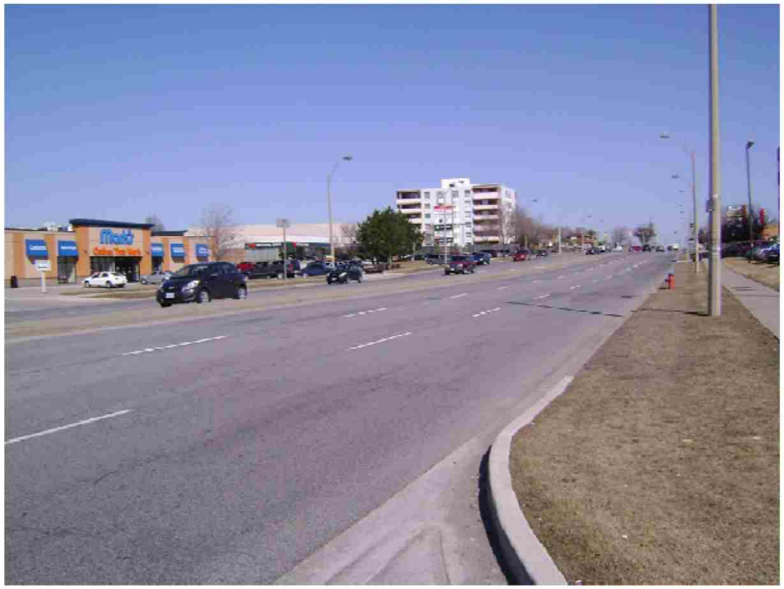
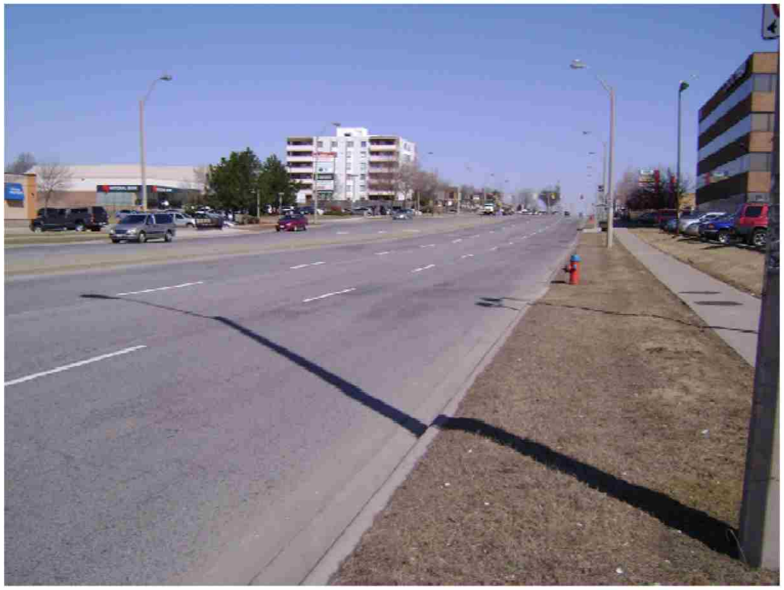


Figure G3 - Upper Wentworth (Linc Mohawk)





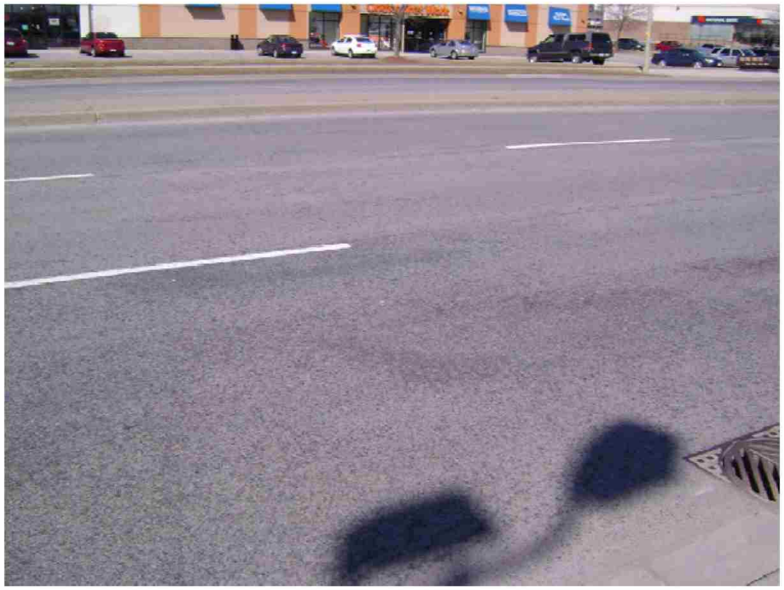
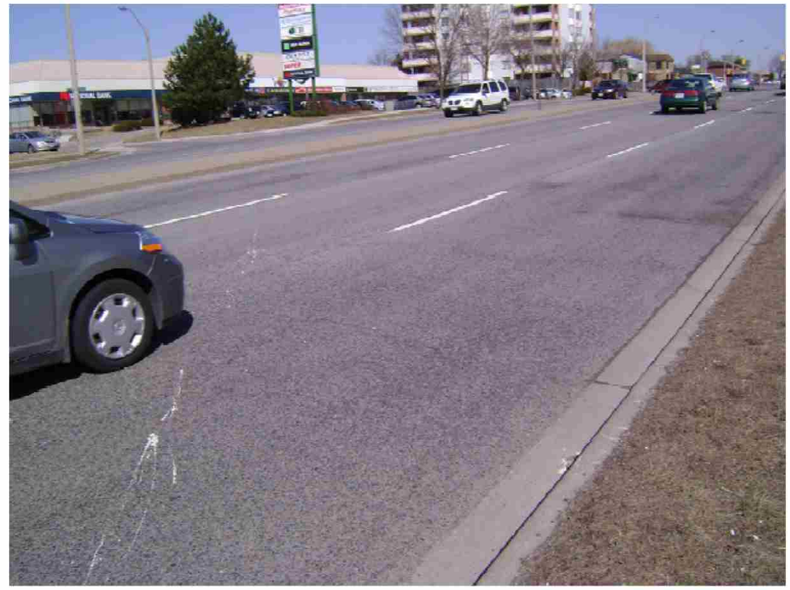


Figure G3 - Upper Wentworth (Linc Mohawk)



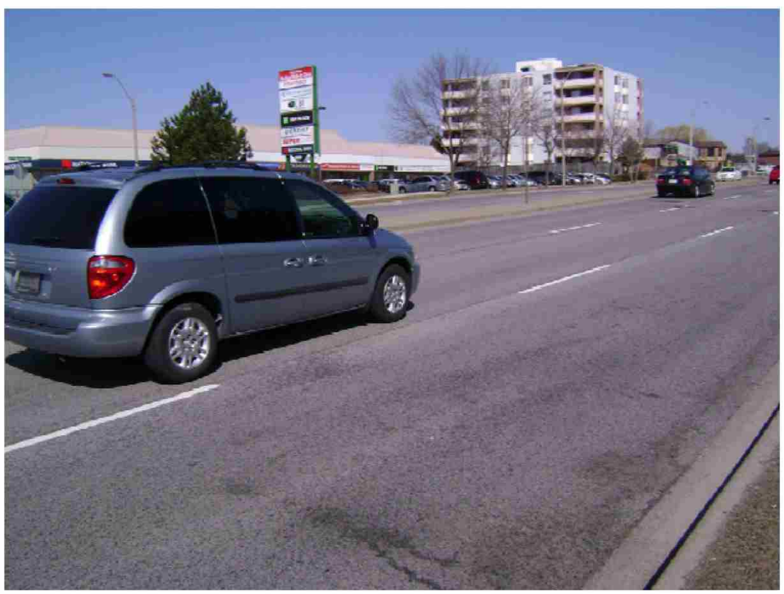
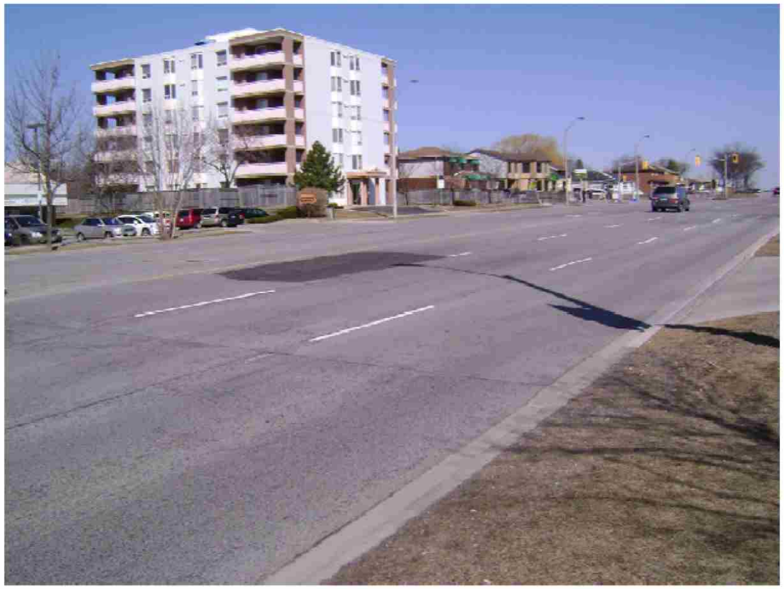
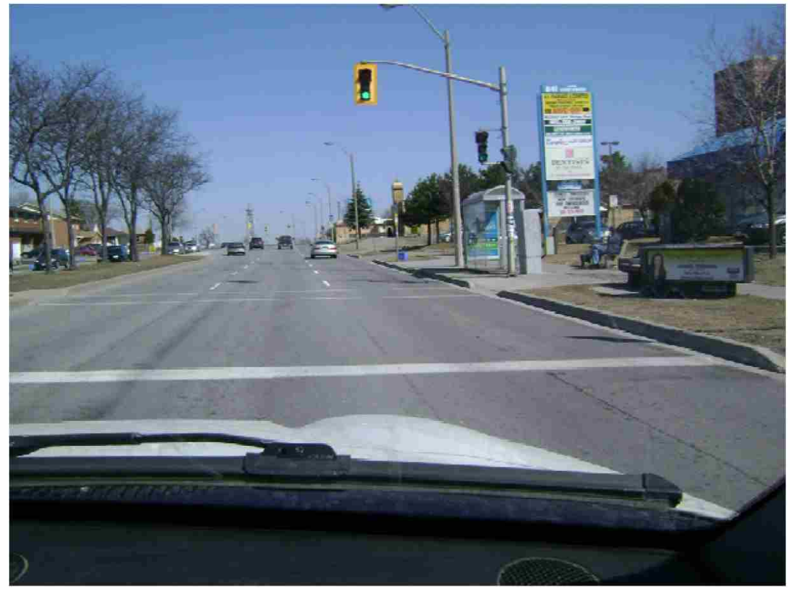


Figure G4 - Upper Wentworth (Mohawk to Fennell)





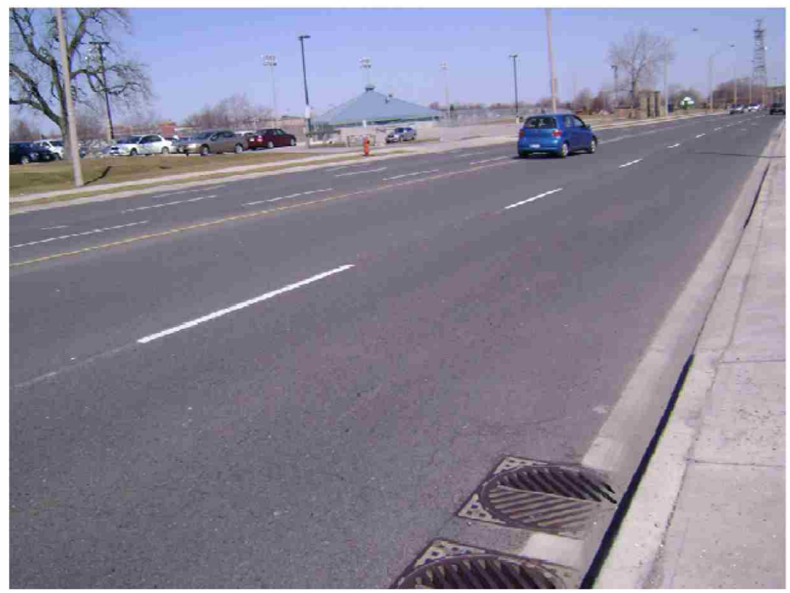
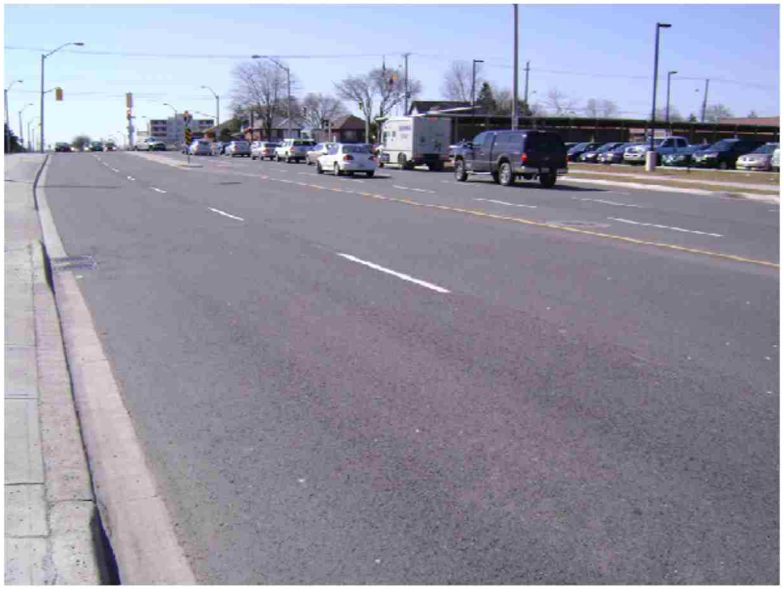


Figure G4 - Upper Wentworth (Mohawk to Fennell)



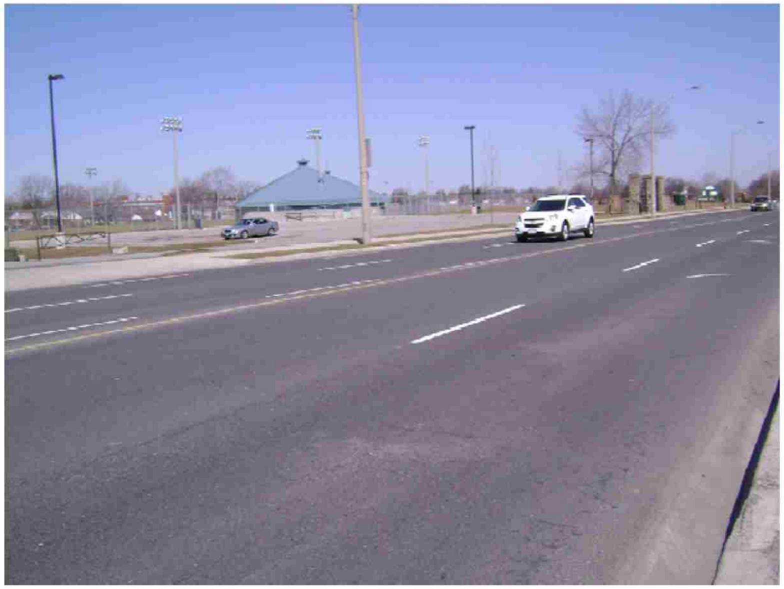
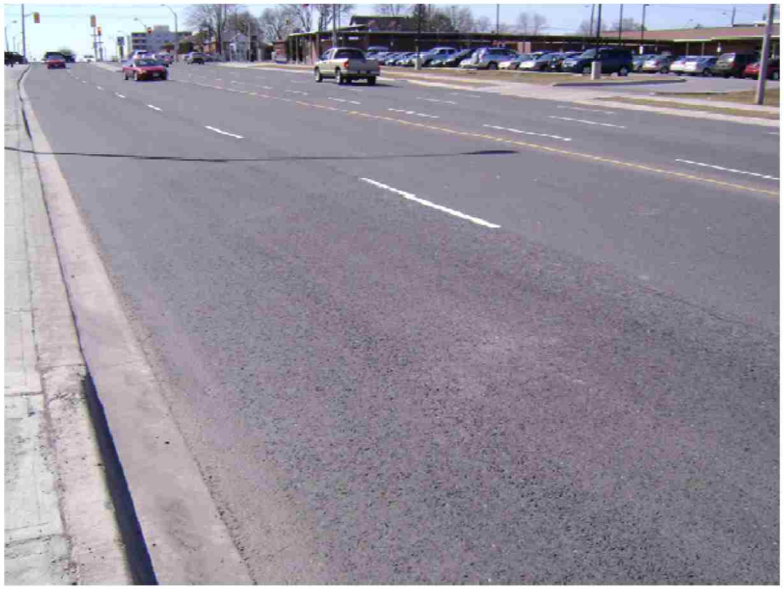
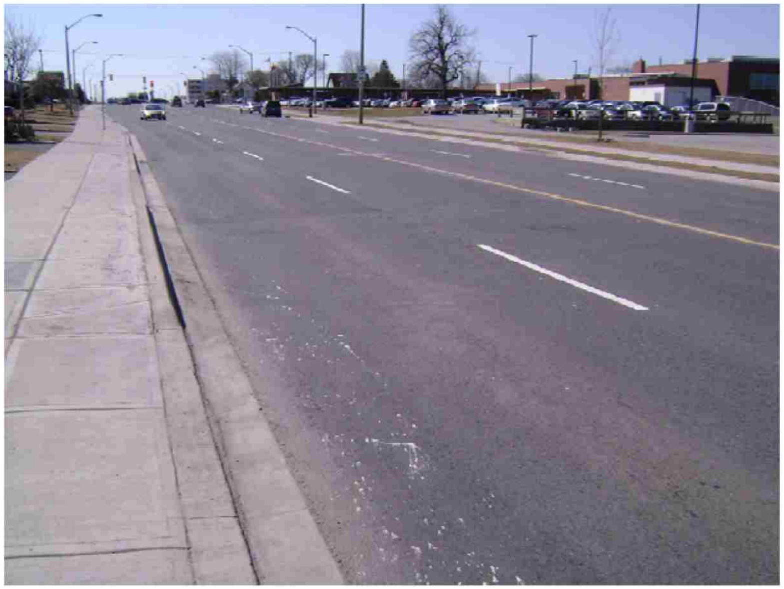


Figure G4 - Upper Wentworth (Mohawk to Fennell)





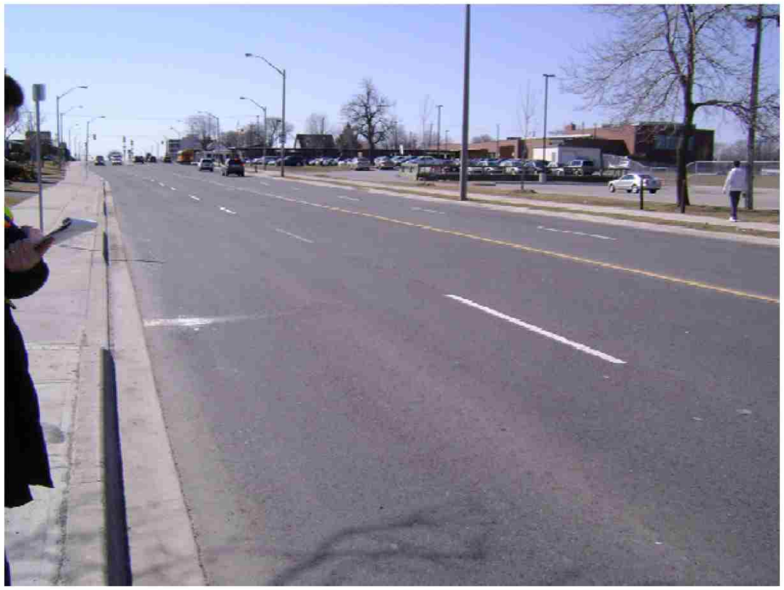


Figure G4 - Upper Wentworth (Mohawk to Fennell)

Figure G5-A - Garth (Linc to Stonechurch)

Figure G5-A - Garth (Linc to Stonechurch)

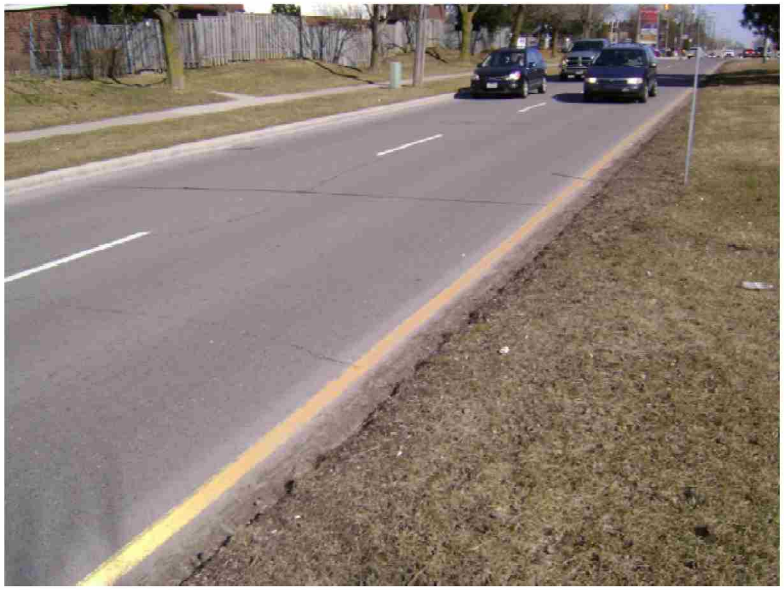


Figure G5-A - Garth (Linc to Stonechurch)

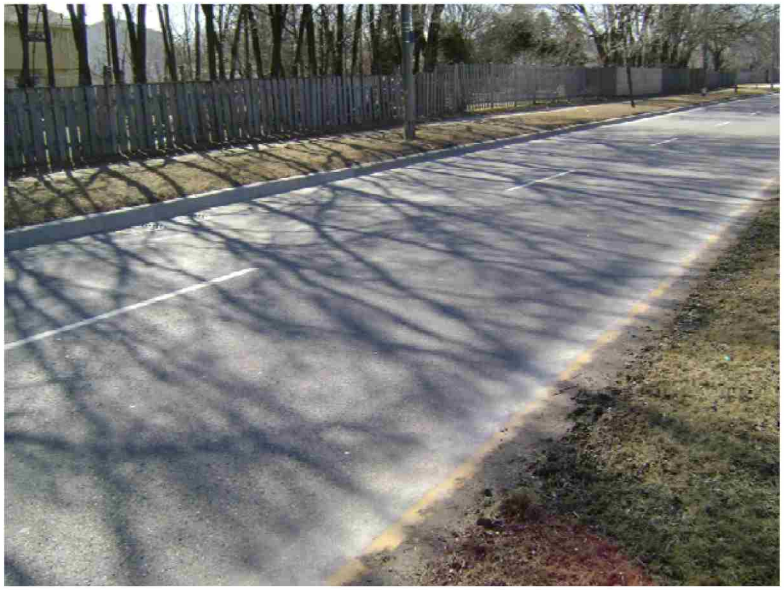
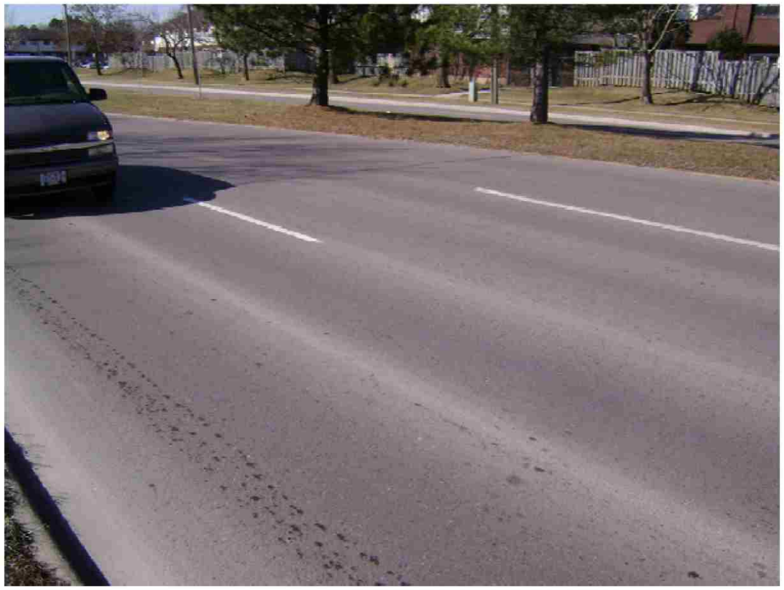


Figure G5-A - Garth (Linc to Stonechurch)

Figure G5-B - Garth (Linc to Stonechurch) Warm Mix Asphalt



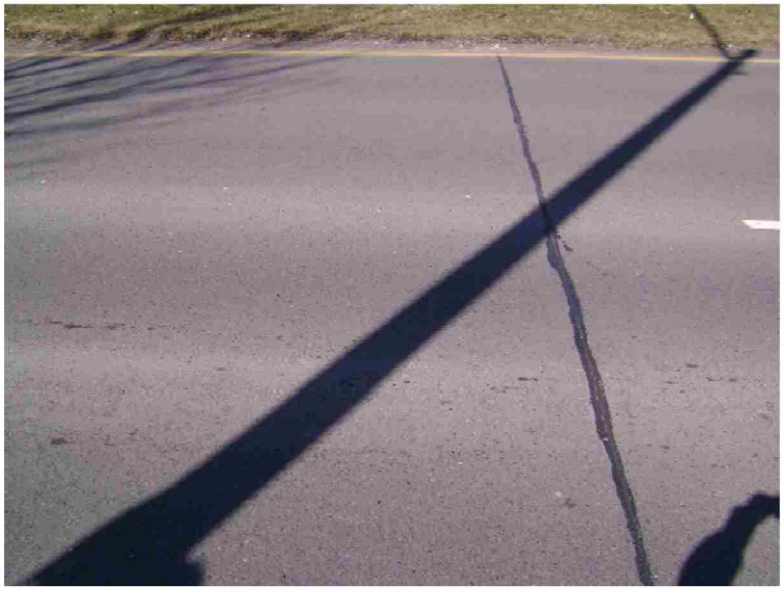


Figure G5-B - Garth (Linc to Stonechurch) Warm Mix Asphalt

Figure G6 - Eastport Drive (QEW Ramp to Woodward)

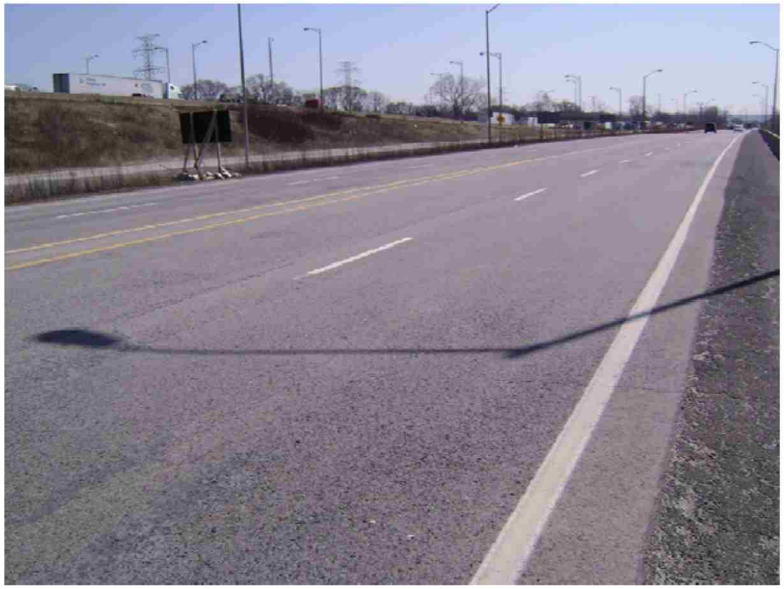


Figure G6 - Eastport Drive (QEW Ramp to Woodward)

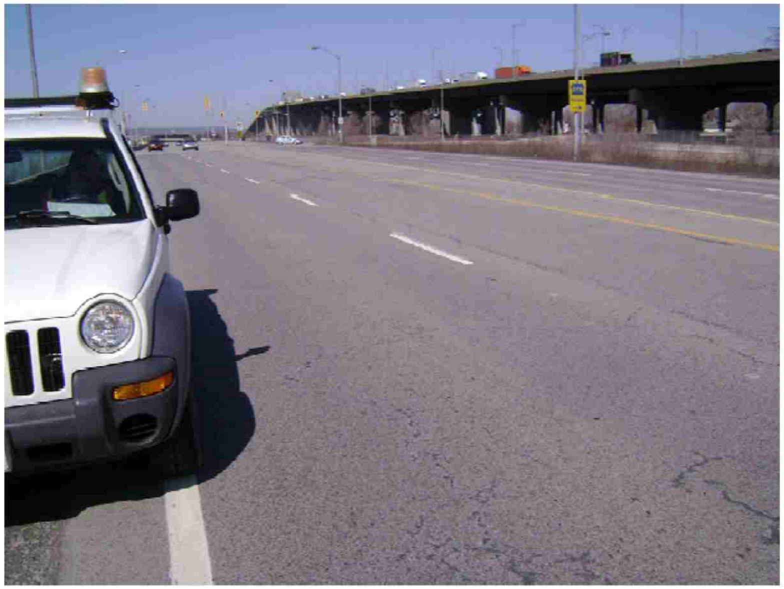


Figure G7 - Barton (Wellington to Wentworth)

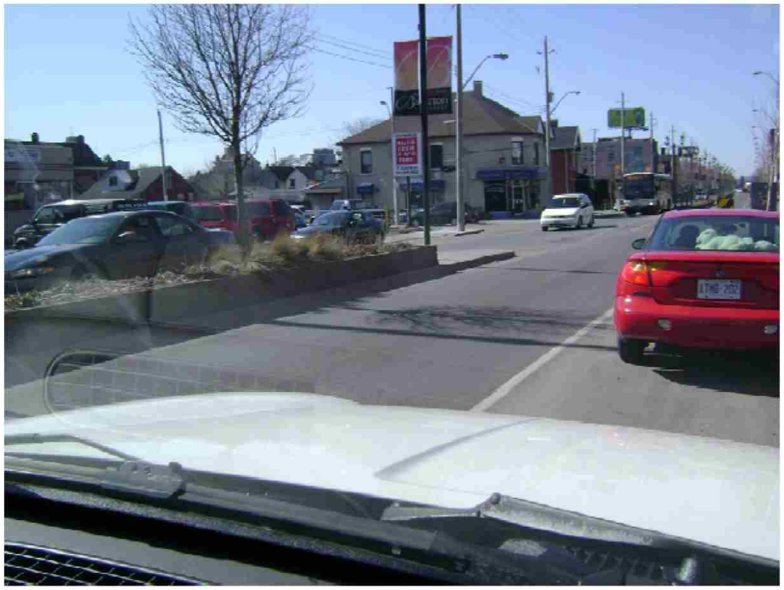


Figure G8 - Garth (Darlington to Fennell)

Figure G8 - Garth (Darlington to Fennell)

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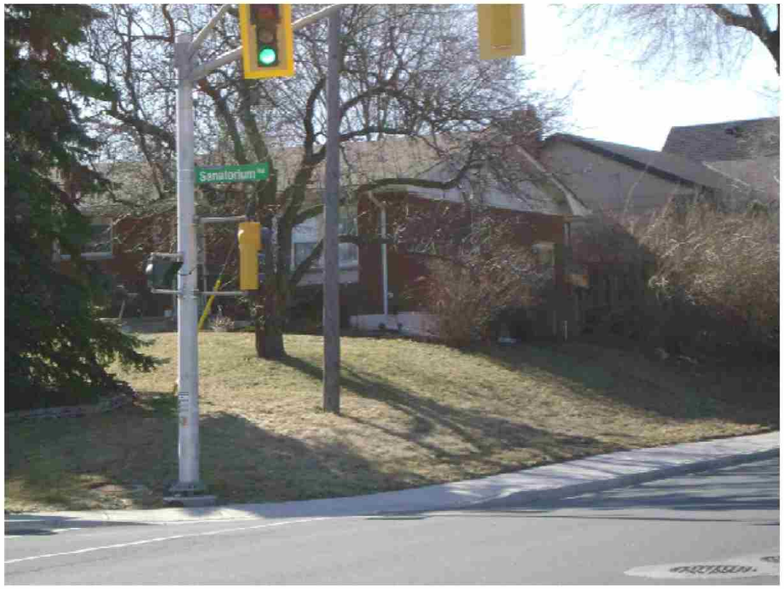

Figure G8 - Garth (Darlington to Fennell)

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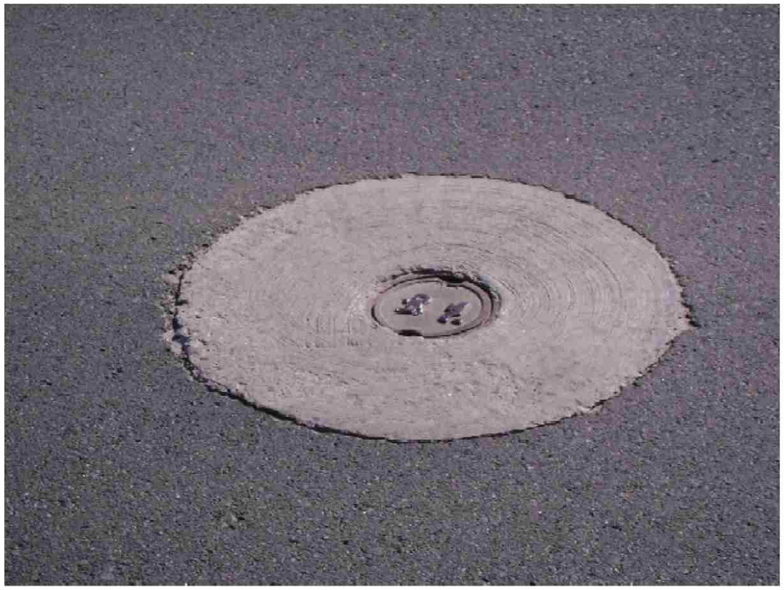
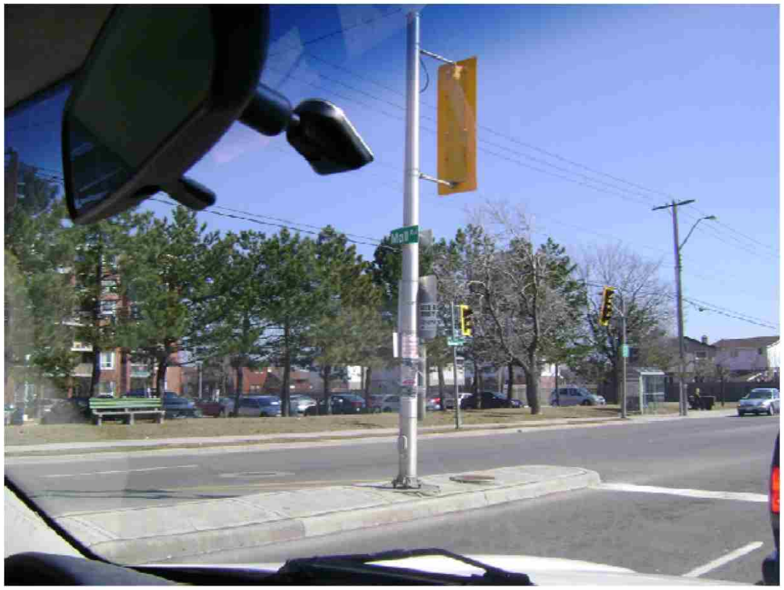




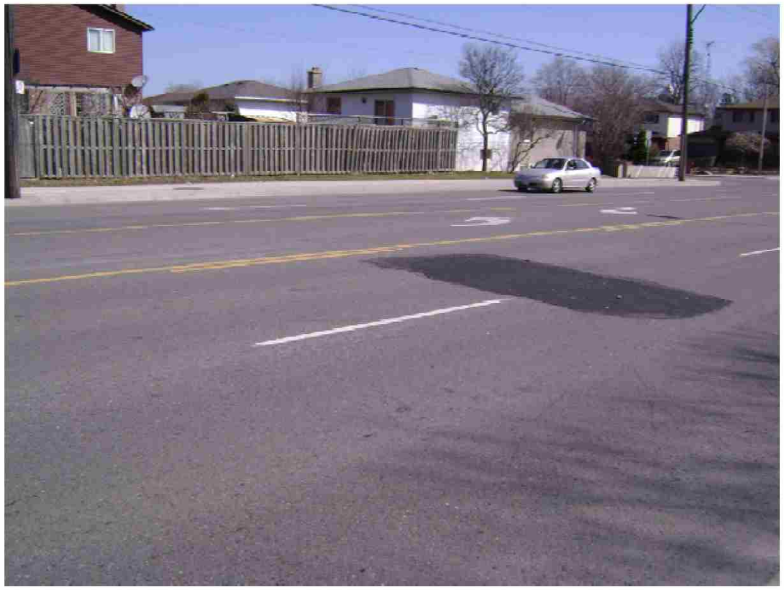
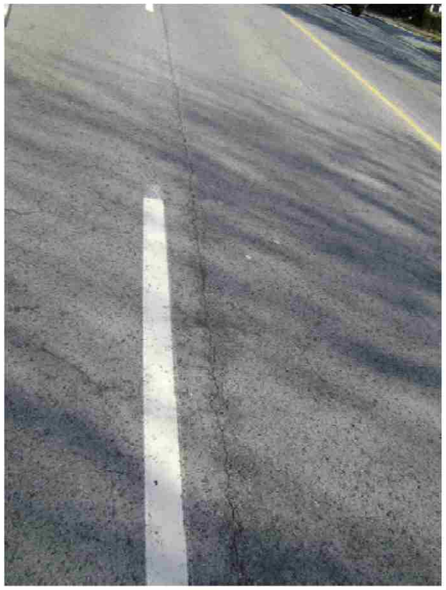
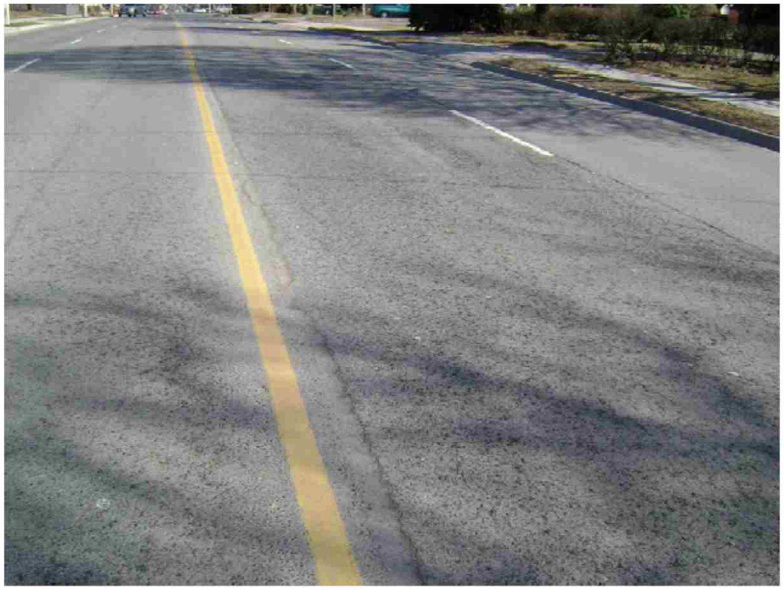


Figure G9 - Mohawk (Upper Wentworth to Sherman)

Figure G10 - Garth (Linc to Darlington)





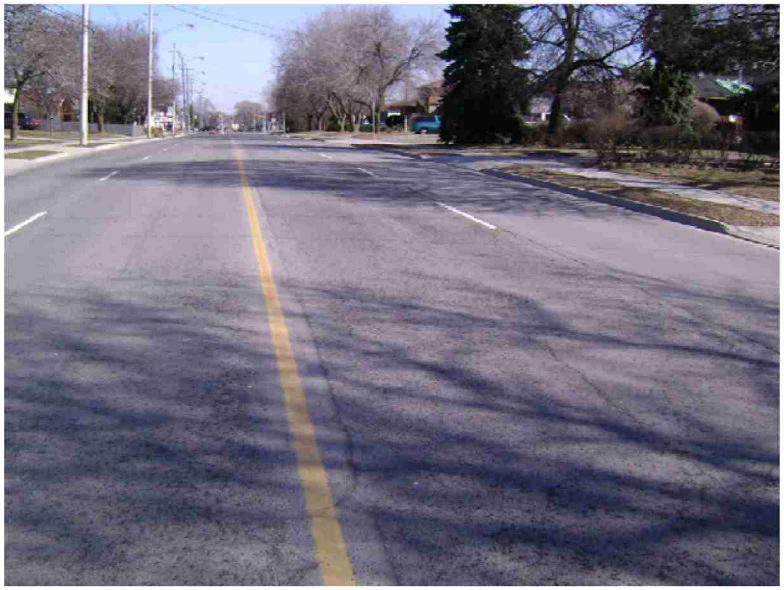


Figure G10 - Garth (Linc to Darlington)

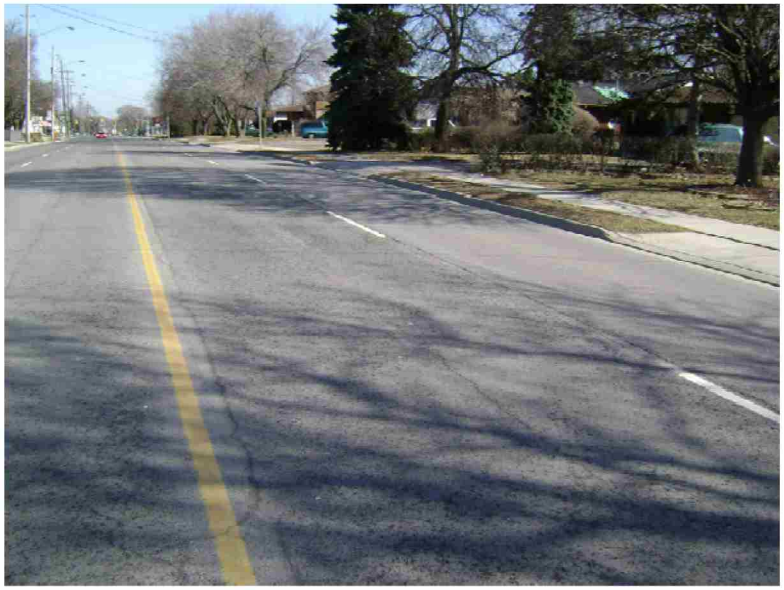


Figure G10 - Garth (Linc to Darlington)

APPENDIX H

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solutions@golder.com
www.golder.com

Golder Associates Ltd.
2390 Argentia Road
Mississauga, Ontario, L5N 5Z7
Canada
T: +1 (905) 567 4444