1.0 DESCRIPTION

This item covers requirements for the in-place full depth reclamation with cement consisting of pulverization and mixing the existing asphalt concrete pavement and underlying granular base with Portland cement, soil and water to produce dense, hard cement treated base. It shall be proportioned, mixed, placed, compacted, and cured in accordance with this specification and shall conform to the lines, grades, thicknesses, and cross-sections described in the Contract.

2.0 REFERENCES

All reference standards shall be current issue or latest revision at the first date of tender advertisement. This specification refers to the following standards, specifications or publications:

- AASHTO T134, Standard Test Method for Moisture - Density Relations of Soil Cement Mixtures
- AASHTO T310, Standard Test Method for In-Place Density and Moisture Content of Soil and Soil Aggregate by Nuclear Methods (Shallow Depth)
- ASTM C136, Test Method for Sieve Analysis of Fine and Coarse Aggregates
- ASTM D75, Practices for Sampling Aggregates
- ASTM D4791, Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
- ASTM D5444, Test Method for Mechanical Size Analysis of Extracted Aggregate
- ASTM D5821, Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
- CAN/CSA A 3001, Cementitious Materials for use in Cement
- Occupational Health and Safety Act
- PCA EB052, Soil-Cement Laboratory Handbook
- PCA EB068, Thickness Design for Soil-Cement Pavements
- TPW TM-2, Test Method for the Petrographic Analysis of Coarse Aggregate
- TPW TM-12, Test Method for Determination of Indirect Tensile Strength of Recycled Asphalt Mixes

3.0 SUBMISSION AND DESIGN REQUIREMENTS

3.1 Mix Design. Preparation and submission of the Full Depth Reclamation with Portland cement (FDR-PC) mix design will be the responsibility of the Department. The Department or its representative will assess the in situ asphalt concrete pavement and underlying base gravels and soils. The determination if corrective aggregate is required will be the responsibility of the Department or its representative as well as the development of the design of the cement stabilized mix.

3.2 Requirements for Mix Design. A FDR-PC mix design will be conducted in accordance with the procedures outlined in the latest edition of the Portland Cement Association’s Soil-Cement Laboratory Handbook.

For mix design purposes, prior to commencing the work, the Department or its representative will obtain samples that are representative of the materials that will be produced during the in-place processing operation. As a minimum the Department or its representative will retrieve a sample of the surface course materials, underlying base gravels and soils to a depth no greater than the proposed depth of recycling, at an interval such that a minimum of ten (10) samples are recovered. These samples will be used to establish the design rate(s) of the cement content as a percentage of mass of the dry unstabilized material.

The mix design(s) will identify the type, manufacturer and supplier of the Portland cement, total cement content, total water content, optimum moisture content, maximum dry density and seven (7) day compressive strength. The mix design(s) will identify the area(s) that it applies to. Using the optimum moisture content from the initial moisture density test, a series of FDR-PC specimens will be developed at varying cement contents. For each cement content, a minimum of two (2) specimens will be prepared, moist cured for a period of seven (7) days and be tested for unconfined compressive strength. The mix design(s) will include a copy of all calculations performed to determine the design rate(s) of cement. The mix design(s) will also identify the type, source, gradation and quantity of any corrective aggregate if required to be used in the mix.
The mix design report will also contain a summary of the sample locations with approximate stationing and depth and will include photos of the samples recovered. The report will contain information on the type, manufacturer and supplier of the Portland cement with the technical specifications of the product, details of the moisture-density characteristics, including a graph plotting moisture versus density, graphical plots of strength with incremental changes in cement content and the design cement content.

4.0 MATERIALS

4.1 Corrective Aggregate. Corrective aggregate includes imported granular material spread on the road in order to improve the grading of the recycled material. The corrective aggregate shall conform to the physical requirements stipulated in Division 4 Section 4 of the Standard Specification and a maximum 25% loss resulting from the Micro-Deval test.

4.2 Cementitious Materials

All cementitious materials used shall comply with the latest specifications for Portland cement (CAN/CSA A 3001).

4.3 Water. Water shall be free from substances deleterious to the hardening of the cement-treated material.

4.4 Cement Treated Mixture. The combined material constituents shall produce a mix conforming to the gradation requirements of Table 4.1. Corrective aggregate shall be incorporated into the mix if the existing aggregate blend does not conform to the specified gradation as referenced in Table 4.1.

<table>
<thead>
<tr>
<th>Sieve Designation (mm)</th>
<th>Cumulative Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5</td>
<td>95 - 100</td>
</tr>
<tr>
<td>4.75</td>
<td>45 - 65</td>
</tr>
</tbody>
</table>

5.0 CONSTRUCTION METHODS

5.1 Equipment

5.1.1 Pulverizer. The pulverizer shall be a self-propelled machine, specifically manufactured for Full Depth recycling work and capable of reducing the existing materials to a size that will pass a 75 millimeter (mm) sieve. The pulverizer shall be capable of processing to a minimum depth of 300 mm. The specified depth of pulverization will be identified in the Special Provision of the Contract. The machine shall be equipped with standard depth control and must maintain a consistent cutting depth and width. The machine shall also be equipped with a gauge to show the depth of the material being processed.

5.1.2 Cement Spreader. The cement shall be incorporated into the mix by means of a bulk spreader. Application of cement using a bulk spreader will be subject to approval by the Engineer following an assessment of the current or anticipated environmental conditions. For bulk spreading, the Contractor shall provide a method for verifying that the proper amount of cement is being applied. The Contractor shall provide proof of calibration if the cement spreader.

5.1.3 Spreading Equipment. Distribution of the processed material shall be carried out by means of a grader capable of spreading the mix to the specified cross-fall and grade. The grader shall be equipped with an automated grade control system.

5.1.4 Aggregate Delivery Vehicle. The aggregate delivery vehicle shall have a system for controlled applications of any corrective aggregate to be incorporated into the mix.

5.1.5 Compaction Equipment. Compaction equipment shall be appropriate to achieve the required compaction. Along curbs, manholes and similar structures and locations not accessible to full size rollers, the mix shall be densified with smaller compaction equipment, such as vibrating plate tampers or by hand tampers. The FDR-PC process shall also include a vibrating pad/tamping foot roller in the compaction train.

5.1.6 Water Tankers. The number and size of the water tankers shall be balanced with the size of the work.

5.2 Full Depth Reclamation and Stabilization. The Contractor shall reclaim and stabilize the existing asphalt concrete pavement and underlying granular base and/or soil to the limits described in the Contact’s Special Provisions. The pulverized material shall be reduced in size such that 100% of the materials pass the 75 mm sieve. Where the Contractor opts to
pre-pulverize the roadway prior to stabilization, the depth of the pre-pulverization shall be 50 mm less than the depth of stabilization. Corrective aggregate, if required, shall be added to the roadway prior to stabilization. The mixture shall be comprised only of materials that are identified in the mix design unless otherwise approved by the Engineer.

5.2.1 Scarification. Before the cement is applied, scarification may be required to the full depth of mixing. Scarification is required when the processed material is more than 2% above or below the optimum moisture content. When the material is below optimum moisture content water shall be added to the material. The pre-pulverized material shall be sealed and properly drained at the end of the day or if rain is anticipated.

5.2.2 Application of Cement. The specified quantity of cement applied shall be that which is identified in the mix design and shall be applied uniformly in a manner that minimizes dust and is satisfactory to the Engineer. The time from cement placement on the soil to start of mixing shall not exceed 30 minutes. The overlap of successive passes of cement shall be a maximum of 100 mm.

5.2.3 Mixing. Mixing shall begin as soon as possible after the cement has been spread and shall continue until a uniform mixture is produced. The mixed material shall meet the following gradation conditions:

The final mixture (bituminous surface, granular base and subgrade soil) shall be pulverized to the blend ratio as per the mix design. Additional material can be added to the top of from the subgrade to improve the mixture gradation, as long as the material was included in the mix design.

Mixing shall be continued until the product is uniform in colour, meets gradation requirements and is at the required moisture content throughout. The entire operation of cement spreading, water application and mixing shall result in a uniform pulverized mixture for the full design depth and width.

The Contractor shall be required to recycle the entire roadway pavement area, including tapers, radii and widening. This may require modifications or specially adapted equipment to complete the work. All areas not recycled must have the existing pavement excavated and replaced with Type C-HF and/or B-HF asphalt concrete or riding surface approved by the Engineer, all at the unit price for FDR-PC.

5.3 Compaction. Field density of the compacted material shall be determined by nuclear method in the direct transmission mode. Optimum moisture and maximum dry density shall be determined prior to the start of construction and in the field during construction by moisture-density testing.

At the start of compaction, the moisture content of the material shall be within 2% of the specified optimum moisture content. No section shall be left undisturbed for longer than 30 minutes during compaction operations. All compaction operations shall be completed with two (2) hours from the start of mixing.

The processed material shall be uniformly compacted to a minimum of 98% of the maximum dry density established during the mix design procedure.

5.4 Finishing. As the compaction operation nears completion, the surface material shall be shaped to the specified lines, grades and cross sections. If necessary, the surface shall be lightly scarified or broom dragged to remove imprints left by the equipment.

Compaction shall then be continued until a uniform and adequate density is obtained.

During the finishing process, the surface shall be maintained at optimum moisture content by means of water spray devices that will not erode the surface. All finishing operations shall be completed within four (4) hours from the start of mixing.

5.5 Curing. Finished portions of the FDR-PC base that are travelled on by equipment used in constructing an adjoining section shall be protected in a manner as to prevent equipment from damaging completed work.

After completion of final finishing, the surface shall be cured by application of a bituminous or other approved sealing membrane. The curing material shall be applied as soon as possible, but not later than twenty-four (24) hours after completing finishing operations. The surface shall be kept continuously moist prior to the application of the curing material.

For bituminous curing material, the FDR-PC base shall be dense and free of all loose and extraneous materials and shall contain sufficient moisture to prevent excess penetration of the bituminous material. The bituminous material shall be uniformly applied to the surface of the completed cement treated material. The exact rate and temperature of application for complete coverage, without undue run-off, shall be specified by the Engineer.
Should it be necessary for construction equipment or other traffic to transit the covered surface before the bituminous material has cured sufficiently to prevent pickup, sufficient sand cover shall be applied before such use.

Sufficient protection from freezing shall be given to the FDR-PC base for 7 days after its construction or as approved by the Engineer.

**5.6 Traffic.** Completed section of the FDR-PC base can be opened to low speed local traffic and to construction equipment provided that the curing material is not impaired and the FDR-PC base is sufficiently stable to withstand marring or permanent deformation. The section can be opened to all traffic after the FDR-PC base has received a curing compound or subsequent surface and is sufficiently stable to withstand marring or permanent deformation.

**5.7 Micro-cracking.** The Department or its representative will monitor the strength gain of the FDR-PC material. Micro-cracking will begin when the modulus of the FDR-PC base is within the range of 1000 to 1400 MPa, approximately 24 to 72 hours after construction.

The Contractor shall perform the micro-cracking operation using the same (or equivalent tonnage) steel wheel roller that has a minimum mass of 12 tonne. The Contractor shall operate the roller at maximum amplitude and a speed between 3 and 5 kilometers per hour. The Contractor shall take care to maintain the lines, grades and cross section established during finishing operations. The Contractor shall not bridge the centerline crown during the micro-cracking operation.

The micro-cracking operation is completed when the modulus of the FDR-PC base is reduced by 50 to 70 percent.

**5.8 Surfacing.** Subsequent pavement layers (asphalt concrete, seal coat or concrete) can be placed at any time after finishing operations, as long as the FDR-PC base is sufficiently stable to support the required construction equipment without marring or permanent deformation of the surface.

**5.9 Maintenance.** The Contractor shall maintain the FDR-PC base in good condition until all work is completed and accepted. Such maintenance shall be performed by the Contractor and at the Contractor’s own expense.

Maintenance shall include immediate repairs of any defects that may occur. If it necessary to replace any processed material, the replacement shall be to full depth, with vertical cuts, using either cement-treated material or asphalt concrete approved by the Engineer.

**5.10 Operational Constraints.** The Contractor shall not place the FDR-PC mix or apply curing seal coat during rain, or when the surface is frozen, nor when the mix shows signs of free-standing water or when the ambient temperature is below 10°C.

### 6.0 QUALITY CONTROL / QUALITY ASSURANCE

Quality Control (QC) testing will be carried out by the Department or its representative for the purpose of ensuring that the material placed in the work conforms to the requirements of this specification.

**6.1 Cementitious Materials Testing.** The Contractor shall be responsible for ensuring that the Portland cement meets the requirements of this specification and shall submit documentation verifying that the cement meets the requirements outlined in CAN/CSA A-3001.

**6.2 Sampling and Testing of Corrective Aggregate.** The Department or its representative will conduct sampling and testing to ensure that any corrective aggregate incorporated into the mix meets the physical property requirements as outlined in Table 4.1: Physical Requirements of Corrective Aggregate.

**6.3 Lot Size.** The lot size shall as determined by the Engineer.

**6.4 Sampling and Testing of FDR-PC.** The Department or its representative shall conduct sampling and testing to ensure that the FDR-PC meets the requirements of this specification. Samples shall be taken at a frequency determined by the Engineer.

**6.5 Thickness.** The Department or its representative shall conduct all testing to ensure that the Emulsified Asphalt Mix meets the thickness requirements specified in the Contract Documents. Thickness measurements will be taken by the Engineer at a frequency determined by the Engineer. Thickness will be checked during production by hand excavation and also will be measured by collecting representative specimens measuring 150 mm by 150 mm. Thickness requirements are met when no individual thickness measurement is 20 mm less that the specified thickness. Individual sub-lots failing to meet the requirements shall be subject to reprocessing to the satisfaction of the Engineer.

**6.6 Compaction.** The processed material shall be uniformly compacted to a minimum of 98% of maximum dry density as per
AASHTO T134. The frequency of compaction testing shall be ten (10) per sub-lot. The testing shall be conducted by the use of a properly calibrated nuclear gauge in accordance with AASHTO T 310. Compaction testing will be conducted with the gauge in direct transmission mode. At each location, the material will be tested at a depth no less than 50 mm above the bottom of the stabilized layer. Four readings will be taken at each location, each 90° from the previous. QC compaction tests will be submitted to the Engineer within three (3) working days of testing. Compaction measurements will be taken at a minimum frequency of ten (10) locations per sub-lot. Compaction requirements for the lot are met when no individual compaction measurement for the lot is less than 98% of the maximum dry density. Individual sub-lots failing to meet the requirements shall be subject to reprocessing to the satisfaction of the Engineer.

6.7 Surface Defects. The Department will assess the completed work prior to application of the riding surface. Defects such as ravelling, segregation, contamination shall be evaluated by the Engineer. Corrective action shall be undertaken by the Contractor in accordance with the required remedial action outlined in Table 6.1. It is the responsibility of the Contractor to meet the established cross-slopes and grades. Smoothness of the recycled mat is the full responsibility of the Contractor. Repairs shall be for the full width of the recycled area to the depth specified in the Contract documents. Reprocessing may be considered as a repair method, upon submission of a proposal by the Contractor and approval by the Engineer.

Table 6.1: Required Remedial Actions

<table>
<thead>
<tr>
<th>Defect</th>
<th>Severity</th>
<th>Remedial Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ravelling / Coarse Aggregate Loss</td>
<td>Very slight to slight</td>
<td>Corrective action required</td>
</tr>
<tr>
<td></td>
<td>Moderate to severe (1)</td>
<td>Mill 50 mm and replace with the same asphalt concrete mix and spread rate specified for the surface course</td>
</tr>
<tr>
<td></td>
<td>Very severe (2)</td>
<td>Remove all stabilized mix and return to grade with asphalt concrete mix specified for the surface course</td>
</tr>
<tr>
<td>Segregation</td>
<td>Slight to moderate</td>
<td>Corrective action required</td>
</tr>
<tr>
<td></td>
<td>Severe (3)</td>
<td>Mill 50 mm and replace with the same asphalt concrete mix and spread rate specified for the surface course</td>
</tr>
</tbody>
</table>

(1) Moderate to severe ravelling is defined as shallow disintegration of pavement structure with shallow pot-holes.
(2) Very severe ravelling is defined as significant disintegration of pavement structure with full depth pot-holes.
(3) Severe segregation is defined as a distinctly inconsistent texture, having an absence of aggregate fines in the matrix and coarse aggregate (stone on stone contact).
*Alternate repair methods proposed by the Contractor must be approved by Highway Construction Services*

7.0 METHOD OF MEASUREMENT

The quantity of FDR-PC mix is to be measured for payment will be the area in square meters placed at the specified depth outlined in the Contract’s Special Provisions. The quantity of corrective aggregate to be measure for payment will be in tonnes.

8.0 BASIS OF PAYMENT

8.1 Stabilized Mix. The FDR-PC mix will be paid for at the Contract unit price per square meter at the specified depth for mix incorporated and accepted in the work, which price will be full compensation for mobilization of all equipment, pulverizing the existing asphalt concrete, granular and soils to the specified depth, supply and addition of water to maintain optimum moisture content, supply and addition of water to suppress dust, grading, compaction of the mix to the specified density, curing, micro-cracking, re-grading and repair as directed by the Engineer, the supply of all equipment, plant, labour and incidentals, including traffic control necessary to complete the work to the satisfaction of the Engineer.

Portland cement will be paid as a separate item. Compensation to the Contractor or the Owner for differences between actual Portland cement content, as verified by the Contractor’s daily weigh slips plus appropriate documentation from the supplier, to verify the amount in the last tanker for the total payable tonnage, will be as follows:
Payment to the Contractor will be made for Portland cement identified in the mix design. Payment will be based on the actual unit bid price per tonne as invoiced by the Contractor by the supplier for the work.
Corrective aggregate, for gradation modification, will be paid up to a maximum allowable unit price per tonne, as detailed in the Contract Special Provisions, plus the truck haul rate per tonne for gravel, established in the Special Provisions, for approved corrective aggregate incorporated and accepted in the work. The price shall be full compensation for furnishing of all materials, equipment, plant, labour and incidentals, including traffic control, necessary to complete the work to the satisfaction of the Engineer.

**8.2 Payment for Rejected Mix.** The Department will pay for only the original FDR-PC mix. The Contractor is fully responsible to bear all costs associated with repair of areas rejected by the Engineer, including all materials, equipment, plant, labour, traffic control and incidentals necessary to complete the work to the satisfaction of the Engineer.

**9.0 WARRANTY**