3.4 FULL DEPTH RECLAMATION

3.4.1 GENERAL

3.4.1.1 Description

Full Depth Reclamation (FDR) is a pavement rehabilitation technique in which the existing asphalt pavement and a portion of the underlying granular base is pulverized; shaped and compacted; re-processed and stabilized with an asphalt product and, if required, other additives or additional granular materials; shaped and compacted to specified dimensions. After curing, an asphalt concrete mixture or other type of surfacing treatment is placed as specified.

3.4.2 DEFINITIONS

Foamed Asphalt means a process where heated asphalt cement is expanded from its normal volume by the addition of precise amounts of water.

Control Strip is a section of stabilized FDR constructed using the equipment and method of compaction as prescribed herein.

Control Density is the maximum wet density attained on a "Control Strip".

A Lot is normally defined as the quantity of stabilized FDR material processed in one day's production with no changes to the approved mix design. A days production of less than 4 hours may be combined with the previous or following days production at the Consultant’s option. If the Consultant suspects a portion of a Lot is substandard, he may order extra testing to define the area and severity of the deficiency. A new Lot will be designated for this portion if this extra testing indicates the FDR material is subject to rejection.

Visually Failed Area is an area of the FDR mat which fails, loses specified density, becomes too wet, ravels, contains excess asphalt stabilizer or oil spills, becomes rutted, distorted, loose or rough, or contains any other defect judged by the Consultant to negatively affect the long term performance of the pavement structure.

3.4.3 MATERIALS

All materials necessary for the work described herein shall be supplied by the Contractor.

3.4.3.1 Additive Aggregates

Additional aggregate added to the reclaimed pavement materials shall meet the requirements for either a Designation 2 Class 25 or Class 20 aggregate.

If applicable, requirements for the maximum percent passing the 80 μm sieve may be waived in order to meet the minimum percent passing for free fines in the combined reclaimed material. The Contractor shall produce crushed aggregate in accordance with Specification 3.2, Aggregate Production and Stockpiling. When required, the Contractor shall supply aggregate in accordance with Specification 5.2, Supply of Aggregate and haul materials in accordance with Specification 4.5, Hauling.
Additive aggregate used solely to improve the engineering properties of the stabilized FDR material and not specified to be added in the special provisions or shown on the plans shall be used at the Contractor's option and expense.

3.4.3.2. **Water**

The Contractor shall supply and haul all water required for the construction and maintenance of this work.

The water shall be clean and free from deleterious concentrations of acids, alkalis, salts or other organic or chemical substances.

3.4.3.3. **Asphalt Stabilizing Agent**

The Contractor shall supply asphalt products in accordance with Specification 5.7, Supply of Asphalt.

Unless otherwise specified the Contractor has the option of using either foamed asphalt or an asphalt emulsion as a asphalt stabilizing agent, but not both.

When using the foamed asphalt process the Contractor shall choose the grade of asphalt cement which displays the best foaming characteristics.

When using an asphalt emulsion the contractor may choose which grade of emulsion to use. Use of alternative grades not in listed Specification 5.7 will be allowed, subject to the approval of the Consultant. When proposing to use an alternative grade the Contractor shall indicate the appropriate ASTM or AASHTO material specification.

The type and grade of liquid asphalt for tack coat shall in accordance with Specification 3.19.2 Materials, unless otherwise specified.

Sampling of the asphalt stabilizing agent shall be as outlined in Specification 5.7 at a frequency of one sample per three Lots.

3.4.3.4. **Portland Cement**

The Contractor may use Portland Cement as a chemical stabilizing agent up to a maximum additive rate of 1.5% by weight of dry reclaimed material and additive aggregate.

Other chemical stabilizing agents may only be used subject to the approval of the Consultant.

3.4.3.5. **Interim Lane Markings**

The Contractor shall provide interim lane markings on the newly constructed FDR surface, or tacked FDR surfaces that are to be exposed to traffic overnight.

Interim lane markings shall meet all the requirements of Specification 3.50, Asphalt Concrete Pavement - EPS, Section 3.50.5.8, Interim Lane Markings.
3.4.4. **MIX DESIGN**

3.4.4.1. **Responsibility for Mix Design**

Preparation and submission of FDR mix designs for Consultant verification and approval is the responsibility of the Contractor. The design shall be prepared by a laboratory that is pre-qualified by the Department in the category of Mix Design - Marshall or can provide proof of experience in preparing FDR mix designs.

The mix design shall be submitted to the Consultant a minimum of seven days prior to the start of any stabilization operations.

All costs incurred in mix design formulation are the responsibility of the Contractor.

3.4.4.2. **Requirements for Mix Design**

For mix design purposes, prior to commencing the work, the Contractor shall obtain samples that are representative of the material that will be produced during the reclaiming operation. These samples shall be used, along with any additive aggregate and Portland Cement to establish the design rate of asphalt stabilizer as a percentage by mass of reclaimed asphalt pavement and additive aggregate.

The FDR mix design shall follow the procedures outline in the Wirtgen Cold Recycling Manual (Wirtgen GmbH, Windhagen, Germany, 2nd Edition, Appendix 2 - Mix Design Procedures) with the following changes.

- Optimum Fluid Content to be determined in accordance with ASTM 6698 (Standard Proctor).
- Specimens for the determination of Optimum (residual) Bitumen Content, including void and tensile strength testing, prepared using 75 blows per face with Marshall hammer at 60°C, followed by curing in a 60°C forced draft oven for 16 hours.
- The Maximum Theoretical Density determined on briquettes prepared and cured as listed above, then broken down for testing.

The FDR mix design at the Design Asphalt Content and Optimum Total Fluid Content shall meet the requirements outlined in Table 3.4.3.2 Full Depth Reclamation Design Criteria. The Design Asphalt Content shall be chosen to optimize the performance characteristics of the FDR and not just meet minimum design criteria.

**Table 3.4.3.2 Full Depth Reclamation Design Criteria (Emulsion or Foamed Asphalt)**

<table>
<thead>
<tr>
<th>Property</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Voids (%)</td>
<td>Report Only</td>
</tr>
<tr>
<td>Dry Tensile Strength (kPa) @ 25°C</td>
<td>250</td>
</tr>
<tr>
<td>Tensile Strength Ratio (%)</td>
<td>50</td>
</tr>
</tbody>
</table>
For materials stabilized using the foamed asphalt process, the minimum amount of free fines, or fines that are not bound within the reclaimed asphalt pavement, shall be 5% or greater passing the 80 \( \mu \text{m} \) sieve.

The percent by mass of asphalt stabilizing agent to be added to the unstabilized material shall be a minimum of 2.0%.

In addition to reporting the above listed criteria the mix design submission shall include:

i) Information on the type, manufacturer and supplier of the asphalt stabilizer.
ii) The asphalt content and aggregate gradation of the asphalt concrete being incorporated in the FDR process.
iii) The design percentage and gradation of additive aggregate.
iv) The design addition rate of asphalt stabilizer and foaming characteristics if the foamed asphalt process is used.
v) Percent of free fines passing the 80 \( \mu \text{m} \) sieve if the foamed asphalt process is used.
vii) Design addition rate for Portland cement.
vii) The percentage moisture content to obtain the Optimum Fluids Content.
viii) All calculations performed to determine the Optimum Fluids Content and design application rate for the asphalt stabilizer.
ix) Bulk and maximum theoretical densities at various application rates of the asphalt stabilizer.

A separate and complete mix design will be required for any significant changes to the composition of the existing pavement structure or materials.

The Contractor shall not produce any stabilized FDR mixture prior to receiving the Consultant’s written notice that the mix design has been verified. Any stabilized FDR mix produced prior to receiving such notice will not be accepted.

3.4.5. EQUIPMENT

3.4.5.1. Additive Aggregate

Any additive aggregate shall be uniformly distributed in front of the recycling train.

3.4.5.2. Recycling Equipment

The equipment used shall be specially designed for performing FDR including the ability to uniformly incorporate significant quantities of additive aggregate and the ability to add an accurate and uniform application of water and an asphalt stabilizing agent.

As a minimum, the milling machine shall have the following features:

- The capacity of milling to depths of a least 300 mm in a single pass and be equipped with an automated sensor system to accurately maintain a preset depth of cut.
- A milling head that rotates upwards into the direction of advance and achieves at least 2.0 metres of cut width in a single pass.

In order to mix the reclaimed material with aggregate, water and stabilizing agents, the milling,
or separate processing unit, shall include the following features:

- A micro-processor control system to regulate the application of water and stabilizing agents in relation to travel speed and mass of material.
- A dual pumping and metering system for applying water and asphalt stabilizing agent simultaneously. The pumping system shall be calibrated to deliver with a tolerance of +/- 3% by volume.
- A system of self-cleaning nozzles that provides uniform application of water and stabilizing agents across the full width of treatment. The application system shall be adjustable for varying widths of treatment.
- When using the foamed asphalt process an asphalt cement expansion system capable of producing optimum expansion and an injection system capable of injecting and blending the foamed asphalt uniformly throughout the combined reclaimed and aggregate materials.

3.4.6. CONSTRUCTION

3.4.6.1. General

The full depth reclamation operations shall be completed through a minimum of two separate processing phases. The first or pulverization phase shall consist of milling and mixing the asphalt concrete and base course materials to specified depths such that 100% of the pulverized material is smaller than 40 mm and a minimum 95% is smaller than 25 mm.

If specified, the reclaimed material shall be bladed and spread to a specified width and/or depth. The reclaimed material shall be lightly compacted for traffic accommodation and preparation for further processing.

The application of additive aggregate and stabilizing agent shall be completed in one or more subsequent mixing operations to the depths and limits specified in the contract documents. In all cases the full depth of pulverized reclaimed material shall be processed during the subsequent mixing operations, however the Contractor shall ensure that none of the underlying grade material is incorporated within the reclaimed material.

If required, additive aggregate shall be added to the roadway prior to stabilizing. The aggregate delivery vehicle shall have a system for controlled application of the aggregate.

During stabilization operations the Contractor shall overlap successive passes of the reclaimer-stabilizer by a minimum of 100 mm.

When an emulsion stabilizing agent is used stabilization operations shall not be carried out when the ambient temperature is less than 10°C, or when the overnight low is forecast to be less than 2°C.

When a foamed asphalt stabilizing agent is used stabilization operations shall not be carried out when the ambient temperature is less than 5°C.

Stabilization of reclaimed materials shall not proceed during periods of rain or if the surface is in a saturated condition.
3.4.6.2. **Density Control**

Compaction of the stabilized FDR material shall be carried out once the material has been spread to proper widths and thicknesses.

Control over the density to which stabilized FDR is compacted will be exercised by the construction of a Control Strip according to ATT-58 Control Strip Method, with the following changes.

- References to Granular Base Course shall apply to Full Depth Reclamation.
- Minimum length of Control Strip shall be 200 m.
- Maximum allowable thickness for the stabilized FDR material shall be 250 mm.
- Contrary to ATT-58 Control Strip Method the nuclear density readings shall not be adjusted for moisture content.
- Prior to compaction the moisture content of the stabilized FDR material shall be adjusted such that fluids content is within a range of 0.5% over optimum to 2.0% below the optimum moisture content.
- Minimum compaction equipment for determination of Control Maximum Wet Density shall be two - 12 tonne pad foot rollers, one - 10 tonne vibratory roller and one - self propelled pneumatic tire roller.

The Control Density determined on the Control Strip shall be the reference compaction standard for acceptance of all remaining FDR material. A new Control Strip and Control Density shall be determined for any new mix designs or significant change to the reclaim materials or processing depths or at any time throughout the project as directed by the Consultant.

Once the Control Density has been established, the Contractor may choose his own combination of compaction equipment.

All stabilized FDR shall be tested for compaction using the Test Section Density procedure as outlined in ATT 58.

3.4.6.3. **Adjustments to Mix Design**

The Lot Mean for Dry Tensile Strength and Tensile Strength Ratio shall meet minimum design criteria.

Adjustments to the mix design or to the FDR processing techniques in order to meet tensile strength requirements shall be taken by the Contractor subject to the approval of the Consultant. Prior to making any adjustments the Contractor shall review with the Consultant all available quality control and quality assurance inspection and test data.

3.4.6.4. **Surface Appearance and Tolerance**

The surface of the FDR mat shall be of uniform texture, free of severe segregation and any visually failed areas.

The compacted FDR mat shall be smooth and in compliance with the surface tolerance requirements for base course work as outlined in Specification Amendment AMC_S155, "Amendment to Specifications 2.3 Grading, 3.1 Subgrade Preparation and all Base Course Specifications Regarding Surface Finish."
3.4.6.5. **Interim Lane Markings**

The Contractor shall provide and maintain interim lane markings on all FDR surfaces that are exposed to traffic overnight.

Interim lane markings shall meet the requirements of Specification 3.50.5.8, Interim Lane Markings.

3.4.6.6. **Curing of Stabilized FDR Material**

No traffic shall be allowed on the stabilized FDR material until the tight blading and final compaction is complete and the material has sufficiently cured to support all traffic without rutting, distorting or displaying any sign of instability.

When using an emulsion stabilizing agent the asphalt concrete pavement or any other surface material shall not be placed until the FDR material has sufficiently cured such that the moisture content is 2% or less or when a core can be easily extracted in the presence of the Consultant. The Contractor will be responsible for obtaining cores to be given to the Consultant for moisture content determination and visual examination. The amount of time required for curing is typically 14 days or more but will vary according to weather conditions and shall be determined in the field.

When foamed asphalt is used as a stabilizing agent, the wearing surface shall not be placed until the FDR material has been allowed to cure for a minimum of 2 days and the Contractor has demonstrated that the specification requirements have been met.

The ACP wearing surface shall be placed no later than 30 days following FDR stabilization operations provided the FDR material meets specification requirements.

3.4.7. **QUALITY CONTROL TESTING**

3.4.7.1. **General**

Quality control activities and testing is the responsibility of the Contractor throughout every stage of the Work. Tests that may be performed by the Consultant to determine compliance with specifications will be quality assurance tests and will not be considered as quality control tests.

The Contractor shall submit all QC test reports and summaries in writing to the Consultant representative prior to 2:00 p.m., on the next working day, except when otherwise indicated by the Consultant.

The Contractor will be responsibility for all costs associated with quality control and for obtaining quality assurance samples as herein specified.

The Contractor shall sample, test, and evaluate the FDR process in accordance with the minimum frequencies provided in Table 3.4.6.
<table>
<thead>
<tr>
<th>Test or Action</th>
<th>Test Method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Inspection Report</td>
<td>Note 1</td>
<td>Daily - Provide to the Consultant the Following Day</td>
</tr>
<tr>
<td>Process Depth Checks</td>
<td>Note 2</td>
<td>One per 200 m</td>
</tr>
<tr>
<td>Bulk Application Rate of Asphalt Stabilizing Agent</td>
<td>See Section 3.4.7.2</td>
<td>Each Tanker Load of Asphalt</td>
</tr>
<tr>
<td>Gradation of Additive Aggregate</td>
<td>ATT-25 or ATT-26</td>
<td>One per 8 Hour Shift of Crusher Operation or a Minimum of Three Tests, Whichever is Greater</td>
</tr>
<tr>
<td>Sampling and Testing of Stabilised FDR Mix</td>
<td>See Section 3.4.7.3</td>
<td>Two Per Lot (Note 3)</td>
</tr>
<tr>
<td>Cores of Stabilized FDR Base for Moisture Content Determination (Emulsion Only)</td>
<td>Note 4</td>
<td>As Required To Prove Curing Requirements Are Met Prior To Placing Surfacing Material</td>
</tr>
</tbody>
</table>

Note 1 - The Contractor shall maintain a daily inspection report documenting the following information, where applicable:

- Date
- Highway and direction of travel
- Beginning and end stations
- Total treatment area (m²) – Pulverization & stabilization
- Calibration Control Settings
- Measurements from the processing depth checks – Pulverization and stabilization
- Water and asphalt counter reading (beginning, end, total)
- Individual and moving average determinations of bulk application rates for asphalt stabilizing agent.

Note 2 - To check that the automatic sensor system is functioning correctly, the actual depth of cut shall be physically measured by the Contractor at both ends of the milling drum at least once every 200 metres along the cut length.

Note 3 - Once test results for two consecutive indicate compliance to tensile strength requirements the frequency may be reduced to two samples and tests for every fifth Lot or a change in the composition of pavement materials, whichever occurs first.

Note 4 - A minimum of three cores for each days production to be obtained using stratified random sampling procedures as described in ATT-56. Cores to be provided to the Consultant for visual inspection and moisture content determination.

3.4.7.2. **Bulk Application Rates**

The Contractor shall be responsible for calculating the bulk application rates of asphalt stabilizing agent applied. Bulk application rates shall be determined by measuring the area and depth stabilized, calculating the mass of FDR material treated and calculating the mass of
asphalt stabilizing agent used. Bulk application rates shall be calculated for each tanker of asphalt used. Individual results shall not be more than 0.6% above, or more than 0.4% below the established mix design value. A moving average of four individual bulk application rates is to be calculated beginning with the fourth bulk rate determination and for each subsequent bulk rate determination. All moving averages so calculated shall not be more than 0.1% below the established mix design value.

3.4.7.3. **Moisture Content and Tensile Strength Testing of Stabilized FDR Material**

The Contractor shall obtain representative loose mix samples (minimum 15 kg per sample) of the stabilized FDR material for moisture content and tensile strength testing at a minimum frequency of two samples per Lot with a minimum period of 3 hours between sampling. The samples shall be obtained immediately following stabilization and shall be properly labelled and bagged to protect against moisture loss.

The Contractor shall arrange to have the samples delivered to a testing laboratory of his choice. The testing laboratory shall have obtained pre-qualification status from the Department in the category of Mix Design – Marshall or has experience in preparing FDR mix designs.

For each sample the moisture content of the stabilized FDR material shall be determined according to ATT-15.

Each sample shall be tested for dry tensile strength, wet tensile strength and tensile strength ratio according to AASHTO T283 using the same conditioning, preparation and curing conditions as were used during the mix design with the exception that the moisture content shall be adjusted, if required, to match field conditions.

Test results shall be reported to the Consultant in a timely manner and no later than 5 days following sampling.

The Lot Mean for Dry Tensile Strength and Tensile Strength Ratio will be determined as the arithmetic mean of all quality control test results plus, if available, quality assurance test results for the Lot.

3.4.8. **QUALITY ASSURANCE TESTING**

The Consultant may at any time take samples, carry out testing and inspection of materials incorporated or being incorporated into the work. The Contractor shall cooperate with the Consultant or his representative for such sampling, testing and inspection. Such inspection shall not relieve the Contractor from any obligation to perform all the work strictly in accordance with the requirements of the contract.

Sample locations for routine quality testing will be randomly selected as far as it is practical to do so. This will not limit the Consultant from testing at any additional locations deemed necessary.

Frequency of testing for Density Control is outlined in ATT 58.

Following the completion of compaction and final grading operations the Consultant will inspect the mat for compliance to surface appearance and surface tolerance requirements.
3.4.9. COMPLIANCE REQUIREMENTS

All stabilized FDR material shall be compacted to an average of 98.0% of the applicable Control Density with no single test less than 95% of the applicable Control Density.

The stabilized FDR mat shall be of specified thickness and meet all surface tolerances.

Visually failed areas or areas with severe segregation judged by the Consultant to negatively affect the long term performance of the pavement structure shall be rejected.

All rejected areas shall be repaired by the Contractor to the satisfaction of the Consultant. The following methods of repair are acceptable but subject to the approval of the Consultant:

• Remove rejected area to a minimum depth of 50 mm and replace with hot mix Asphalt Concrete Pavement as approved by the Consultant.
• Reprocess rejected area to full depth using FDR equipment and adding additional asphalt stabilizer if directed by the Consultant.
• To meet specified surface tolerances, all deficient areas shall be re-profiled by grading or levelled with the same ACP mix to be used for the overlay.

All costs associated for repairing rejected FDR material are the responsibility of the Contractor and no additional payment will be provided.

3.4.10. MEASUREMENT AND PAYMENT

3.4.10.1 Full Depth Reclamation

Accepted full depth reclamation will be measured in square metres of final finished surface from the top edge of FDR shoulder to the top edge of FDR shoulder. Width measurement for payment purposes will not exceed the dimensions shown on the drawings unless modified by the Consultant.

Payment for accepted full depth reclamation will be made at the unit price bid for “Full Depth Reclamation”. This payment will be full compensation for the pulverising and/or blending of all layers and materials regardless of the number of phases or equipment passes used; all traffic accommodation; all quality control sampling and testing; all mix designs; all compaction, blading and shaping of the FDR material both with and without additive aggregate; supplying water and adjusting the moisture content; supplying and adding an asphalt stabilizing agent; supplying and adding Portland cement or other additive; maintaining the treated surface; interim lane marking; supplying and applying asphalt material for tack coat and all materials and equipment necessary to complete the work.

3.4.10.2 FDR Additive Aggregate

Measurement of FDR additive aggregate will be in tonnes.

Payment for accepted FDR additive aggregate will be made at the unit price bid per tonne for "FDR Additive Aggregate". This payment will be full compensation for processing, hauling and placing the material on the roadway, intersections, entrances and approaches, and quality control.
Notes To The Designer (Not to be inserted into tender)

The maximum depth for processing or pulverizing asphalt and granular base course layers is 300 mm.

The maximum design depth for compacting stabilized FDR including aggregate additives is 250 mm (compacted).

A pre-engineering materials testing program is normally to be completed by the Consultant and involves testing of pavement cores and samples in general accordance to Transportation Laboratory Test procedure TLT-300 Recycling Asphalt Concrete Pavement (RACP Aggregate and Asphalt Requirements and Rheology Design and Pre-Engineering Material Evaluation). Test results typically include asphalt content, gradation and two face fracture count of the coarse aggregate for the asphalt pavement materials. FDR mix designs are not normally completed prior to tendering. Test results are to be included in the tender documents.

FDR material is usually overlaid with an asphalt concrete pavement, however other surface treatments may be considered.

Specification amendment AMC_S155 Amendment to Specifications 2.3 Grading, 3.1 Subgrade Preparation and all Base Course Specifications Regarding Surface Finish is to be checked off in the tender documents.