# Recommended Construction Guidelines
# For
# Full Depth Reclamation (FDR)
# Using Bituminous Stabilization
## FDR101

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## NOTICE

**It is not intended or recommended that these guidelines be used verbatim within a specification. Owner Agencies should use them to help establish their particular project specification. Owner Agencies should understand that all geographical areas and pavement rehabilitation/preservation projects are unique and the availability of materials and equipment may vary as well. ARRA assumes no liability for utilization of these guidelines by any individual or entity. Contact ARRA for answers to questions and for a list of ARRA member Contractors and Suppliers.**

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## 1. General

Full Depth Reclamation (FDR) shall consist of pulverizing (reclaiming) the existing flexible pavement and underlying materials (base and/or subgrade materials) to the length, depth and width as specified or as shown on the plans, blending with a bituminous stabilizing agent (either foamed asphalt, also known as expanded asphalt, or emulsified asphalt), water and other additives (cement, lime, lime kiln dust, fly ash or corrective aggregate) as required by the mix design, to produce a flexible, bituminous stabilized base. This material shall then be shaped, compacted, cured and protected in accordance with the plans and specifications.

## 2. Treatment Thickness

The existing flexible pavement, base and/or subgrade material shall be pulverized to a total depth of ____ inches (mm). The pulverized section shall then be re-graded, with excess material hauled away as necessary, so as to allow for the net placement of ____ inches of new pavement material. Bituminous stabilizing agent, water, additives, and/or corrective aggregate shall be added and blended to a total depth of ____ inches (mm) in accordance with the plans and specifications.

User Note: FDR treatment thicknesses may vary between 4 and 12 inches (100 - 300 mm) per lift and should be dependent on structural capacity requirements and project-specific criteria such as original asphalt pavement thickness and design life. Selecting the right FDR application for a particular project should be based on the judgment of those involved in the design process of the project after consideration of several key factors including: project location, existing roadway conditions, depth of current pavement layers, failure depths, reason for current failure (i.e. lack of maintenance, age, insufficient depth, lack of adequate drainage, etc.), traffic volume, available materials, and project budget.

## 3. Preconstruction Personnel Training

Personnel involved with the construction of FDR from both the Contractor and Owner Agency shall have successfully completed Preconstruction Personnel Training (PPT) to ensure that proper quality procedures are followed to construct high quality FDR stabilized base. The PPT shall be conducted at a location convenient for both the Contractor and the Owner Agency. The PPT shall be completed not more than ___ days, not including Saturdays, Sundays or holidays, prior to the start of FDR operations. The training shall be held during normal working hours. In lieu of this training, proof may be provided showing successful experience has been obtained by the individuals performing the work for the materials and construction techniques to be used in the FDR construction.

The PPT trainer shall be provided by the _____ *(Contractor or Owner Agency).* The PPT trainer shall be experienced in construction methods, materials, and test methods associated with construction of FDR projects. The Contractor and Owner Agency shall mutually agree to the course instructor, course content and training site.

User Note: PPT is optional to the agency. PPT should be conducted for agencies and Contractors new to FDR. It is recommended that the PPT takes place within 5 days from the start of the FDR so that it is current and allows some time to address any issues that may be raised during the training.

## 4. Materials

FDR shall consist of a homogeneous blend of reclaimed asphalt pavement (RAP), base material and/or subgrade materials, bituminous stabilizing agent (either foamed asphalt or emulsified asphalt), water, and other chemical additives and corrective aggregate as necessary. The actual

materials utilized and their respective usage rates are dependent on the mix design and project requirements.

## 4.1 Reclaimed Asphalt Pavement and Underlying Material

RAP and underlying material shall consist of the existing asphalt material, existing base course material and/or subgrade material. The underlying materials shall be free of roots, sod, topsoil, weeds, wood or any material deleterious to its reaction with the bituminous stabilizing agent. The gradation of the processed (pulverized) material shall meet the requirements of Table 1.

**Table 1 – GRADATION OF PROCESSED (PULVERIZED) MATERIALS**

| Sieve Size | Percent Passing |
|---|---|
| 3 in. (75 mm) | 100 |
| 2 in. (50 mm) | 95-100 |
| No. 200 (0.075 mm) | 2-20 |

Note: For asphalt emulsion, the recommended range on the No. 200 sieve is 2-15% and 5-20% for foamed asphalt. Although not specified, the optimal range for percent passing the No. 4 (4.75 mm) sieve is 35 to 60 percent.

Rubberized crack filler, pavement markers, loop wires, thermoplastic markers, paving fabric and other similar materials shall be removed as observed from the roadway during the reclaiming process. Residual materials that cannot be completely removed from the reclaimed material may be incorporated into the FDR mixture if the Contractor can demonstrate that those added materials will not adversely affect performance. Any such materials retained in the mixture shall be appropriately sized and blended so as to not adversely affect the appearance or strength of the FDR stabilized base.

## 4.2 Bituminous Stabilizing Agent

Bituminous stabilizing agent shall consist of either asphalt binder used to produce foamed asphalt or emulsified asphalt. Unless indicated elsewhere within the plans, project specifications, or an Owner Agency supplied mix design, the Contractor shall select the type and grade of stabilizing agent utilized.

### *4.2.1 Asphalt Binder for Foamed Asphalt*

Asphalt binder used to produce foamed bituminous stabilization shall be selected according to local temperature standards and specifications and to ensure that optimum foaming characteristics are met in the field. Polymer modified asphalt binders shall not be used. The asphalt binder shall not be heated above a temperature of 375° F (190° C). Asphalt binder provided to the job shall not have additives or properties which could inhibit the ability to produce asphalt foam with a minimum expansion ratio of ____, and a half-life of not less than ____ seconds. The application rate shall be determined by the mix design.

User Note: The expansion ratio is defined as the volume of foamed asphalt to residual unfoamed asphalt. The half-life is defined as the time for the foamed asphalt to lose half of its expanded volume. Typically, the asphalt binder must exceed 320° F (160° C) to achieve optimum foaming

characteristics; however, this temperature may vary depending on the type of asphalt binder used. Typical expansion ratios should be a minimum of 8 and the half-life should be a minimum of 6.

#### *4.2.2 Emulsified Asphalt*

Emulsified asphalt shall be selected to meet local standards and specifications and to achieve appropriate mixing with the pulverized material. A mixing grade emulsion shall be used. Polymer modification may also be used. The actual emulsion type and applicable rate shall be determined by the mix design.

### 4.3 Corrective Aggregate

Corrective aggregate may be required to supplement the existing material gradation and to meet performance requirements of the mix design. Corrective aggregate may consist of crushed rock, RAP, crushed concrete or other types of aggregate approved by the Owner Agency. The corrective aggregate gradation may vary according to its size and distribution, depending on the desired effect to the FDR stabilized base. When required by the mix design, corrective aggregate shall meet the requirements of Table 2.

**TABLE 2 – CORRECTIVE AGGREGATE**

| Tests | Method | Limit |
|---|---|---|
| Los Angeles Abrasion Value, % loss | AASHTO T 96<br>ASTM C131 | 40 max |
| Sand Equivalent,% | AASHTO T 176<br>ASTM D2419 | 60 minimum |
| Washed Gradation | AASHTO T 11 & T 27<br>ASTM C117 & C136 | As required |

### 4.4 Chemical Additives

If required by the mix design, bituminous stabilizing agents may be supplemented with small quantities of the following chemical additives to enhance mixture properties and facilitate constructability.

#### *4.4.1 Cement*

Cement (portland or blended hydraulic), in either dry or slurry form, may be added to the reclaimed mixture as determined by the mix design. Slurry made from cement shall contain a minimum of 30% dry solids content. Cement used for full depth reclamation shall comply with the latest specifications for hydraulic cement (AASHTO M 85, AASHTO M 240 or ASTM C150, ASTM C595. The ratio of residual asphalt in the bituminous stabilizing agent to dry cement shall be at least 3:1. In addition, the cement shall be limited to a maximum of 2.0 percent by dry weight of reclaimed material. At the time of mix design submittal the Contractor shall submit to the Owner Agency the type of process for incorporating cement into the reclaiming process.

#### *4.4.2 Quicklime or Hydrated Lime*

High-calcium quicklime or hydrated lime in either dry or slurry form may be added to the reclaimed mixture as determined by the mix design. Lime slurry shall contain a minimum of 30% dry solids content. Quicklime or Hydrated Lime used shall meet requirements of AASHTO M 216 or ASTM C977 (quicklime & hydrated lime for soil stabilization). At the time of mix design submittal the Contractor

shall submit to the Owner Agency the type of process for incorporating lime into the reclaiming process.

#### *4.4.3 Lime Kiln Dust*

Lime kiln dust (LKD) shall be a by-product of the production of quicklime and shall meet the requirements of Table 3 unless found by laboratory testing to be suitable for the application and approved by the Owner Agency or their representative:

**TABLE 3 – LIME KILN DUST MATERIAL REQUIREMENTS**

| Parameter | Test Method | Value |
|---|---|---|
| Total calcium and magnesium oxides (nonvolatile basis) | ASTM C25 | 60% min. |
| Available calcium hydroxide (rapid sugar test, plus total MgO content calculated to be equivalent $Ca(OH)_2$ | ASTM C25 | 30% min. |
| As-received loss on ignition (carbon dioxide plus moisture, combined and free) | ASTM C25 | 40% max. |
| Free moisture (as-received basis) | ASTM C25 | 4% max. |
| $SO_3$ | ASTM C25 | 10% max. |

| Sieve Size | Maximum Percent Retained |
|---|---|
| No. 4 (4.75 mm) | 5 |
| No. 30 (0.600 11) | 10 |
| No. 100 (0.150 mm) | 30 |

#### *4.4.4 Fly Ash*

Fly Ash, if used as an additive for FDR, shall meet the requirements of AASHTO M 295 or ASTM C618; Self-Cementing Class C Fly Ash, and/or be proven by testing to be acceptable to the application and approved by the Owner Agency or their representative. The Contractor shall inform the Owner Agency of the process for incorporating fly ash into the reclaiming process.

### 4.5 Water

Water shall be added to achieve the desired moisture content. Water added shall be free from deleterious concentrations of oils, acids, alkalis, salts, sugars, vegetation, as well as other organic, chemical or deleterious substances. The water shall not cause an adverse effect on either the bituminous stabilizing agent or the reclaimed mixture. If the water is of questionable quality, it shall be tested in accordance with ASTM C1602 or according to local standards and procedures. Water used specifically for foaming asphalt shall be filtered so that upon evaporation no deposits or residue are left behind that might clog or impede water flow to the foaming nozzles of the reclaiming unit.

## 5. Preconstruction Sampling and Mix Design

If not provided by the Owner Agency, a mix design shall be submitted by the Contractor for approval by the Owner Agency. The mix design shall be performed with representative materials to be encountered during construction of the FDR. When the in-place materials change significantly, additional mix designs shall be performed to establish representative mixtures for the entire job.

Representative samples of the in-place materials shall be obtained directly from the project site by sampling in accordance with ARRA *FDR201 Preconstruction Sampling and Mix Design Guidelines For Full Depth Reclamation Using Bituminous Stabilizing Agents* and delivered to an AASHTO or Owner Agency approved laboratory experienced in full depth reclamation. The asphalt materials shall then be crushed and mixed with the underlying base and/or subgrade materials at the percentages to be encountered in the field. This blended material, which may also contain corrective aggregate or RAP, shall then be treated with a bituminous stabilizing agent at various rates and compacted and tested according to the project requirements to obtain the optimum addition rates as outlined in the mix design procedures of ARRA *FDR201*. The mix design shall be the baseline measure for the rate of application of bituminous stabilizing agent, water, additives and corrective aggregate blended with the existing materials to construct the reclaimed mixture. The mix design shall indicate the allowable tolerance for stabilizing agent application, water, additives and corrective aggregate so as to not jeopardize the performance of the mixture but allow the Contractor to adjust the mixture so that it may be placed successfully.

## 6. Equipment

The FDR equipment shall be capable of pulverizing the existing asphalt pavement and underlying materials. The equipment used for blending/mixing the pulverized materials with stabilizing agent, water, additives and corrective aggregate, if used, shall be capable of producing a homogeneous and uniformly blended reclaimed mixture. The equipment used for placement of the FDR stabilized base shall be capable of placement to the lines, grades, and guidelines provided herein and shown on the plans and specifications. The equipment shall consist of the following major components:

### 6.1 Spreaders/Distributors

Spreaders or distributors used to apply dry powder additives shall be non-pressurized mechanical vane-feed, cyclone or screw type capable of providing a consistent, accurate and uniform distribution of material while minimizing dust during construction. Imported corrective aggregate may be placed by a mechanical spreader, a conventional paver or by tailgating with end dump trucks and spread to a uniform thickness with a motor grader.

### 6.2 Additive Slurry Storage and Supply Equipment

Slurry shall be produced using onsite portable batching equipment or in-line processed and fed directly to the reclaiming equipment. Additive slurry storage and supply equipment shall have agitators or similar equipment to keep the slurry in suspension when held in the slurry batch or storage tanks. Slurry shall be kept in suspension during transport using agitator equipment. The meter system controlling application of slurry shall apply the additive within a tolerance of ± 10% of the specified rate.

### 6.3 Mixing/Reclaiming Equipment

Only self-propelled, high powered, minimum _____ HP, rotary mixers/reclaimers capable of mixing in-place to a minimum depth of _____ inches (mm) shall be used. The cutting drum shall be a minimum _____ feet (meters) in width and fitted with cutting teeth capable of trimming earth, aggregate and asphalt materials and be so designed that they may be accurately adjusted vertically and held in-place. The machine shall not weigh less than 25,000 lbs. (11,300 kg) and shall have the strength and rigidity so that it shall not develop a center deflection of more than 1/8 in (3 mm). Disc harrows, bucket teeth and other equipment that does not meet the above requirements shall not be used for FDR.

The mixer/ reclaimer shall be fitted with an integrated additive injection system capable of introducing bituminous stabilizing agent into the cutting drum during the mixing process. The bituminous stabilizing agent metering device shall be capable of automatically adjusting the flow of the bituminous stabilizing agent to compensate for any variation in the amount of reclaimed material introduced into the mixing chamber. The injection rate of bituminous stabilizing agent shall be calculated on a volumetric basis tied to a foot per minute gauge using a calibrated meter that is capable of accurately measuring the amount of bituminous stabilizing agent to within ± 2.0% of the specified rate. Automatic digital readings shall be displayed for both the flow rate and total amount of reclaimed material and bituminous stabilizing agent in appropriate units of weight and time.

If a foamed asphalt bituminous stabilizing agent is used, the system shall be equipped with an electrical heating system capable of maintaining the temperature of the spray bar above 320 °F (160 °C). The system shall be coupled/interlocked with two microprocessor controlled systems complete with two independent pumping systems and spray bars to regulate the application of foamed asphalt separate from water that is used to increase the moisture content for compaction. The two spray bars shall be fitted with self-cleaning nozzles at a maximum spacing of one nozzle for each 6-inch (150-mm) width of the mixing chamber. The foamed asphalt shall be produced in an expansion chamber into which hot asphalt binder, water, and air are injected under pressure through individual, small orifices that promote atomization. The rate of addition of water into the hot asphalt binder shall be kept at a constant percent by mass of asphalt binder by the same microprocessor. An inspection or test nozzle shall be fitted at one end of the spray bar to produce a representative sample of foamed asphalt.

User Note: During calibration of the meter, if 4.0% stabilizing agent is required, based on the allowable tolerance, the meter must deliver the stabilizing agent between 3.92% and 4.08%. For example, if 8,000 pounds of stabilizing agent is used, then the tolerance is ± 160 pounds.

The application rate of bituminous stabilizing agent should be checked during production by evaluating the weight of reclaimed material against the volume of stabilizing agent used for a single tanker, as indicated in *FDR301 Recommended Quality Control Sampling and Testing Guidelines For Full Depth Reclamation (FDR) Using Bituminous Stabilizing Agents*.

### 6.4 Motor Grader

A motor grader for pre-shaping, aerating, spreading and final shaping of the material shall be provided. The motor grader shall have a cross-slope indicator.

### 6.5 Rollers

Compacting of the reclaimed mixture shall be completed using self-propelled rollers, complete with properly operating scrapers and water spray systems. The number, weight and types of rollers shall be as necessary to obtain the required compaction throughout the entire FDR thickness. A pneumatic roller of adequate size, a vibratory padfoot roller with an 84-inch (2.13-m) wide drum equipped with knockdown blade, and a single or double drum vibratory steel roller may be used in any combination to achieve density.

User Note: For some applications the vibratory padfoot roller may not be necessary. Any combination of rollers should be allowed provided the compaction requirements are met.

### 6.6 Water Truck

Water truck(s) for supplying water to the reclaimer or roadway for addition of moisture and for curing during the FDR operation shall be provided. Water truck(s) shall be capable of providing a

controlled and consistent spray without eroding or otherwise damaging the compacted FDR stabilized base surface.

# 7. Construction

Prior to the start of construction, employees representing both the Contractor and Owner Agency shall submit certification of PPT to ensure the FDR is constructed properly.

Throughout the pulverization, mixing, placement and compaction of the reclaimed materials, adjustments may be made to the bituminous stabilizing agent, water, and additives so as to produce a reclaimed mixture with optimal performance that meets specification requirements. All adjustments shall be recorded by the Contractor and submitted to the Owner Agency.

## 7.1 Roadway Preparation

Before the stabilization process begins, the area to be stabilized shall be pre-pulverized, graded, and/or shaped to the lines and grades as shown on the plans or in the specifications. During this process any unsuitable soil or material shall be removed and replaced with materials meeting project plans and specifications. The subgrade shall be firm and able to support, without yielding or subsequent settlement, the construction equipment and compaction of the FDR stabilized base. Soft or yielding subgrade shall be made stable before construction proceeds. Any manholes, valve covers, or other buried structures/utilities shall be protected from damage prior to processing. FDR shall be constructed in a series of parallel lanes such that longitudinal and transverse joints are minimized.

## 7.2 Weather Limitations

FDR processing shall not be conducted when the soil, aggregate or subgrade is frozen, or when the ambient temperature is below 45 °F (7 °C) or when freezing temperatures are anticipated within 7 days of the end of FDR placement.

## 7.3 Control Strip

During the first day of production the first load of bituminous stabilizing agent shall be used by the Contractor to construct a control strip to verify that the construction process meets specification requirements. The control strip shall be of adequate size for the Contractor to:

A. Demonstrate that the equipment, materials, and processes proposed can produce a reclaimed material layer that conforms to specification requirements.
B. Determine the optimal rates for bituminous stabilizing agent, water, and any additives recommended for the reclaimed material.
C. Determine the sequence and manner of rolling necessary to obtain specified density requirements.

FDR operations may continue through the first day unless the Contractor's equipment and process fails to meet the requirements for successful completion of FDR operations. FDR operations shall not continue beyond the first day unless a control strip has been approved by the Owner Agency. Cease production after the first load of bituminous stabilizing agent if any of the requirements of the specifications are outside specification tolerances. Change procedures to contingency plans approved in the QC plan to continue work. The first load of bituminous stabilizing agent applied with the contingency plans will be used as a control strip to evaluate the corrective action plan. If the requirements of the specifications are still not being met cease production and submit a revised corrective action plan to the Engineer for acceptance prior to continuing work. Continue with this process until all specification requirements are met. Upon acceptance of the control strip by the

Owner Agency, the Contractor shall use the same equipment, materials, and construction methods for the remainder of FDR operations, unless adjustments made by the Contractor are approved by the Owner Agency. If adjustments are made, the Contractor shall produce a new control strip.

In lieu of a control strip the Owner Agency may allow the Contractor to provide proof, based on previous experience with the same equipment, personnel, and materials that the work will conform to specification requirements.

## 7.4 Pulverization

The pre-determined full depth of asphalt material and underlying materials (base and/or subgrade) shall be pulverized to a homogenous mixture and specified gradation using a mixer/reclaimer meeting the requirements of Section 6.3. The mixture shall be brought to the desired moisture content during this process by means of surface application or through the mixer/reclaimer's integrated fluid injection system.

User Note: Desired moisture content of a pulverized mixture will vary on every project, based on the material to be stabilized as well as the type of stabilizing agent used. Desired moisture content should be determined prior to construction.

Longitudinal joints between successive cuts shall overlap a minimum of 6 inches (150 mm) and transverse joints shall overlap a minimum of 2 feet (0.60 m).

When a paving fabric is encountered during the pulverizing operation the Contractor shall make the necessary changes in equipment or operations so that incorporation of shredded fabric into the reclaimed material does not affect the performance parameters or inhibit placing or compaction of the FDR stabilized base. The Contractor shall be required to remove and properly dispose of oversized pieces of paving fabric as indicated by the plans and specifications.

Rubberized crack filler, pavement markers, loop wires, thermoplastic markers and other similar materials shall be removed from the roadway as observed during the reclaiming process. Residual materials that cannot be completely removed from the processed materials may be incorporated into the reclaimed materials if the Contractor can demonstrate that those added materials will not adversely affect the performance of the FDR stabilized base. Any such materials retained in the mixture shall be appropriately sized and blended so as not to adversely affect the appearance or strength of the FDR stabilized base.

## 7.5 Corrective Aggregate

Corrective aggregate, if stipulated in the mix design, shall be spread uniformly on the roadbed using equipment as specified in Section 6.1. Aggregate may be placed either prior to pulverization or following pulverization, but prior to addition of the stabilizing agent. If applied following pulverization, the corrective aggregate shall be blended with the reclaimed material by means of additional full depth mixing to form a homogeneous mixture prior to application of the stabilizing agent. No traffic, other than the reclaiming equipment, shall be allowed to pass over corrective aggregate until the reclaiming operation is complete.

## 7.6 Additives

Removal and disposal of excess material, if required, shall be performed on the pulverized asphalt, base and subgrade materials prior to bituminous treatment. Following pulverization and any trimming, if

necessary, the stabilizing additive shall be spread on or applied to the pulverized material in accordance with the mix design using an approved spreader/distributor or slurry equipment at the applied rate of __ lbs./yd$^2$ (kg/m$^2$ ) for dry additive and __ gal/yd$^2$ (L/m$^2$) for slurry application. The actual final dry unit weight shall be determined during construction.

Dust control measures shall be employed to minimize fugitive dust. The distance between the dry additive spreader and the reclaiming operation shall be reduced appropriately during windy days. Slurry may be spread on the pulverized material in front of the reclaiming operation or may be added directly to the reclaimer's mixing chamber through the reclaimer's integrated fluid injection system. If slurry is spread in front of the reclaiming operation, the subgrade shall be scarified prior to spreading slurry to prevent excessive runoff or ponding. Slurry shall be produced at the jobsite. The Contractor shall provide the Owner Agency with batch logs daily. If cement slurry or LKD is used, the time from first contact with water to application on the pulverized material shall not exceed 60 minutes. The time from additive placement on the pulverized material to start of mixing shall not exceed 30 minutes. Additives shall not be allowed to remain exposed at the end of the workday. No traffic, other than the reclaiming equipment, shall be allowed to pass over the spread additives until the reclaiming operation is complete.

Mixing shall begin as soon as possible after the additive has been spread and no additive shall be spread that cannot be mixed during the same day. Mixing shall continue until the entire mixture (asphalt, base and/or subgrade materials) is pulverized and gradation requirements are met. The final check for gradation requirements shall not be made until conclusion of mixing operations.

Moisture control of the mixture is critical. Prior to compaction the mixture shall be at the required moisture content throughout its depth. Lime additives may have water added on the surface but the use of the mixer/reclaimer's integrated fluid injection system is preferred. For cement, LKD, and fly ash, water application shall only be through the mixer/reclaimer's integrated fluid injection system during mixing. The entire operation of additive spreading, water application and mixing shall result in a uniform mixture for the full design depth and width.

## 7.7 Bituminous Stabilization

Following pulverization and roadbed shaping, moisture content before emulsified asphalt or foamed asphalt addition shall be within 2 percent of the mix design recommendation; aerate if too wet and add water if too dry. The amount of emulsified asphalt or foamed asphalt used shall be applied at a rate of not less than_____ percent (*or in accordance with the mix design*) based on an assumed unit weight of _____ for bidding purposes (*of the in-place dry unit weight determined in the mix design*) of pulverized material and for the depth of subgrade treatment specified or as shown on the plans. The actual final dry unit weight shall be determined during construction. The required depth of reclamation shall be consistently monitored and gradation requirements verified. The entire mixing process of reclaiming the existing road, incorporating corrective aggregate, water, additives and bituminous stabilizing agent shall continue until adequate mixing is achieved. If the entire operation cannot be completed in one pass, then the existing road shall be reclaimed to the depth on the plans, and during this first pass, water, corrective aggregate and additive shall be added; pre-shaping can also be accomplished at this time. After completion of the first pass, the road shall be shaped with a motor grader and compacted with a steel wheel roller to provide better depth control. A second pass of a reclaimer shall be completed with the required amount of bituminous stabilizing agent (emulsified asphalt or foamed asphalt) added.

Longitudinal joints between successive passes shall overlap a minimum of 6 inches (150 mm) and

transverse joints shall overlap a minimum of 2 feet (0.60 m).

To ensure a uniformly treated section, any material/soil around manholes, utility risers, valves and adjacent to curbs/gutters or in corners shall have that material/soil pulled out to the depth of treatment and placed where it is accessible for mixing. After mixing, that material shall be replaced and compacted.

User Note: It has not been determined at this time if electromagnetic gauges are suitable for use on FDR mixtures; therefore, they are not recommended for use.

## 7.8 Compaction

The processed material shall be uniformly compacted in one layer to a minimum of 95% of a field compacted modified Proctor (AASHTO T 180 or ASTM D1557). Field density of compacted material can be determined by nuclear method in direct transmission mode (AASHTO T 310, ASTM D6938) or sand cone method (AASHTO T 191, ASTM D1556). At the start of compaction for all materials, the moisture content shall be within ± 2% of the specified optimum moisture for compaction. Initial compaction with the breakdown roller (padfoot or pneumatic) shall not be behind the reclaimer by more than 500 feet (150 m). The padfoot roller, applying high amplitude and low frequency, or the pneumatic roller, shall perform initial compaction at a sufficient number of passes until it "walks out" of the material. Walking out for the padfoot roller is defined as light being clearly evident between all of the pads at the material–padfoot drum interface and the indentations being no more than 3/16 inch (4.75 mm) deep. Walking out for the pneumatic roller is defined as no significant wheel impressions being left on the surface. After completion of padfoot rolling, any remaining pad foot marks shall be removed and the material spread using a motor grader cutting no deeper than necessary to remove the padfoot marks. Desired slope and shape shall be achieved.

For intermediate and final compaction, a vibratory steel wheel roller and/or pneumatic roller shall compact the bladed material. The combination of number of passes and order of rollers shall be used to meet compaction requirements. Finish rolling shall not be performed in vibratory mode. A light spray of water may aid in final compaction and appearance. Construction joints shall have vertical faces and shall be made in thoroughly compacted material. Additional mixture shall not be placed against the construction joint until the joint has been approved by the Owner Agency. The face of the cut joint shall be free of deleterious material and shall be kept moist until the placing of the adjacent material.

## 7.9 Finishing and Surface Tolerance

As compaction nears completion, the surface of the FDR stabilized base shall be shaped to the specified lines, grades and cross sections. After the first day of emulsified asphalt or foamed asphalt addition the reclaimed base shall not be shaped or significant chunking could result. Compaction shall then be continued until uniform and adequate density is achieved. During the finishing process the surface shall be kept moist by means of water spray devices that shall not erode the surface. Compaction and finishing shall be performed in such a manner so as to produce a surface free of compaction planes, cracks, ridges or loose material. The surface tolerance shall not vary more than 1/2 inch (12 mm) from a 10-foot (3.0-m) straight edge placed on the surface. The Contractor shall correct humps exceeding this tolerance by trimming, milling or abrasive grinding. Feathering shall not be permitted for repair of low areas. Depressions exceeding the specified depth tolerance shall have a tack coat applied and filled with asphalt material just prior to placement of the final surfacing.

## 8. Curing

After compaction has been achieved and prior to opening the stabilized base to traffic, a fog seal, if required, shall be applied to the surface. The fog seal shall be composed of either CSS-1h or SS-1h emulsified asphalt, or other approved emulsified asphalt, diluted up to 50 percent by volume with water. Fog seal shall be applied at a rate of 0.05 to 0.15 gal/yd$^2$, (0.2 to 0.7 L/m$^2$). When a sand blotter is required, it shall be applied to the surface at 2 to 3 lbs./yd$^2$, (1 to 5 kg/m$^2$). Sand shall be free from clay or organic material. Application rates of the fog seal and sand blotter shall be determined by the Contractor and shall be such that a stable and safe roadway surface can be maintained until the surface course is placed.

## 9. Traffic

Completed portions of FDR stabilized base can be opened immediately to low speed local car traffic and to construction equipment, provided the curing material is not impaired. Finished portions of the FDR stabilized base traveled on by construction equipment used in constructing an adjoining section shall be protected in such a manner so as to prevent equipment from marring or damaging the completed work. If damage occurs, it may be necessary to keep heavy truck traffic off the stabilized base until the final surfacing is placed, and/or the stabilized base has passed proof roll testing. Proof rolling shall represent the type of traffic expected on the pavement. If deformation does not occur, moving truck traffic can be allowed at speeds less than _____ mph (kph) until the final surfacing is placed. If deformation does occur, truck traffic shall be kept off the stabilized base until it is firm enough to support the loads.

## 10. Maintenance

After opening to traffic and prior to placing the surface course, the surface of the FDR stabilized base shall be maintained in a condition suitable for the safe movement of traffic. The Contractor shall protect and maintain the surface from nuisance water, other deleterious substances, and/or any other damage. Any damage to the completed FDR stabilized base shall be repaired by the Contractor prior to placement of the final surfacing. If it is necessary to replace any processed material the replacement shall be for full depth, with vertical cuts, using an approved material. Skin patches shall not be permitted. No direct payment shall be made and costs shall be included elsewhere for protection and maintenance of the stabilized base.

## 11. Surfacing

Final surfacing (hot or warm mix asphalt, seal coat, or concrete) can be placed any time after finishing, as long as the FDR stabilized base is sufficiently stable (proof roll) to support the required construction equipment without marring or permanent distortion of the surface and the surface has been free of rain for a minimum of two days.

## 12. Quality Control Testing

The Contractor shall perform process and quality control (QC) sampling and testing, and exercise management control to ensure that FDR base conforms to the project plans and specifications. Sampling and testing shall be performed as outlined in *ARRA FDR301 Recommended Quality Control Guidelines For Full Depth Reclamation Using Bituminous Stabilizing Agents*. The Contractor or Owner Agency shall provide a qualified technician, testing laboratory and personnel to perform process and quality control sampling and testing during the FDR. The proficiency of testing laboratories and sampling and testing personnel shall be reviewed and approved by the Owner Agency prior to providing services to the project. The Owner Agency shall have unrestricted

access to the laboratory, sampling, testing sites, and all information resulting from mix design and quality control activities. All quality control testing results shall be submitted to the Owner Agency.

## 13. Measurement and Payment

Quantities of FDR stabilized base shall be measured by the square yard (square meter) completed and accepted by the Owner Agency to the depths specified or shown on the plans. Bituminous stabilizing agent and additive weights shall be based upon certified delivery weight tickets, less any unused portion. Water used in this operation shall not be paid for directly and shall be considered subsidiary to the bid item.

Payment for FDR shall be made at the contract unit price per square yard (square meter). The price shall be full compensation for all labor, materials, tools, equipment, and incidentals; for doing all the work involved in full depth reclaiming, complete in-place; for pulverizing, mixing, blending, placing, compacting and curing of the FDR stabilized base; for protection and maintenance of the FDR stabilized base; for performing all QA testing including mix design, if required to be provided by the Contractor and for PPT training and instructor, if provided by Contractor, for obtaining measurements and recording results of all tests as shown on the plans and specifications.

Bituminous stabilizing agents shall be paid for at the contract price per ton (metric ton).

Additives shall be paid for at the contract price per ton (metric ton).