**FULL DEPTH RECLAMATION**

**What is Full Depth Reclamation?**

**Full Depth Reclamation (FDR)** is the process of pulverizing a roadway’s flexible pavement section and a portion of its underlying base, and crushing and blending the recovered material to create a uniform base material.

**Stabilized Full Depth Reclamation (SFDR)** pulverizes the flexible pavement section and a portion of the underlying base in the same way as FDR. However, stabilizing agents are added during the crushing and blending process to increase overall pavement stiffness.

SFDR can be accomplished in one or two passes, depending upon the thickness of SFDR desired. During SFDR, typically the first grinding pass pulverizes the bituminous pavement and can be completed to a variable depth. Stabilizing agents are added during the second mixing pass, which needs to occur at a uniform depth to correctly proportion the material mix.

In general, SFDR should not be compacted greater than 6 in. for each lift.

**Benefits of FDR**

Cold in-place recycling (CIR) and other rehabilitation measures generally mill only a few inches of the flexible pavement layer. Cracks that are not completely removed can reflect to the surface in a relatively short time requiring on-going maintenance and shortening the life of the pavement surface. FDR pulverizes the entire pavement layer and a portion of the base layer, with depth ranging from 5 to 16 inches.

This eliminates deep pavement crack patterns that can cause reflective cracking. The elimination of reflective cracking is a major benefit of FDR and may create a longer lasting pavement when compared to traditional rehabilitation methods.

In addition, FDR completely reuses the milled material, requiring less new material and reducing or eliminating the need to transport or...
Tankers are used to carry the asphalt binder directly to the reclamer. For these reasons, FDR tends to cost less than a full pavement reconstruction and provides environmental benefits. The reduction in material transport also results in faster and more efficient construction operation.

Available Stabilization Methods

FDR can be stabilized through bituminous or chemical methods.

**BITUMINOUS STABILIZERS**
Using bituminous stabilizing additives in FDR increases flexibility and fatigue resistance in the base course. Bituminous stabilizers may work alone or in combination with other additives. They are generally used either in an emulsion or a foam mixture.

**Bituminous emulsion**, a liquid consisting of bitumen droplets suspended in water, is added during the SFDR process to increase the stiffness of the base material. Stabilizing additives are injected into the reclaimed material during the pulverization or mixing pass.

Once added, the mixture is turned in the cutting/mixing chamber until the water dissipates and the bitumen droplets begin to rejoin. At this point, it is ready for compaction and shaping.

**Foamed asphalt** is created when hot bitumen is injected into an expansion chamber along with cold water. When the hot asphalt and cold water combine, a thermal reaction occurs that effectively decreases the asphalt viscosity and creates a foamed bitumen mixture of asphalt and water.

The foaming action increases the surface area of the bitumen and improves its ability to evenly coat the pulverized pavement materials. Once coated and laid back down in a loose state, the mixture maintains its workability for a relatively long time, and can even be stockpiled for later use. Compacted base materials stabilized with foamed bitumen can be opened to traffic immediately.

Foamed asphalt requires a minimum amount of fines to properly distribute itself throughout the mixture. Fines or lime can be added to the mixture to reach the ideal proportion.

Two counties in Minnesota have used foamed asphalt in coordination with CIR. In those cases, the foamed asphalt provided a smooth, durable base layer, and a longer period without reflective cracking.

Because FDR removes the entire flexible pavement layer, a proper mix design and site characterization is essential when using foamed asphalt. Variations in base thickness may cause the reclamation machine to incorporate subgrade materials into the pulverized pavement. This may add fines to the mixture.
within the reclamation chamber and upset the balance between percent fines and percent bitumen. The end result could be a pavement base that is more susceptible to water saturation and lower strengths.

CHEMICAL STABILIZERS
Chemical stabilizers include portland cement, lime, and fly ash, which increase pavement strength by cementing the material and aggregates. Calibrating the amount of chemical stabilizers used is important to the pavement’s success. Overuse of chemical stabilizers will reduce the flexibility in the base layer, which can lead to premature cracking.

Chemical stabilizers can be added to the pavement ahead of the reclaimer or can be added as a slurry into the mixing chamber.

What Questions Remain?
Stabilized full depth reclamation has been used on Minnesota County roadways over the last several years. However, it has not been widely used on state highways. The long term performance of SFDR has not been field-evaluated.

Little is known about the effect of spring-thaw on SFDR pavements. Laboratory testing has shown SFDR contains less moisture and has a higher stiffness than aggregate. This should make the base less vulnerable to spring-thaw and indicates that SFDR potentially provides a stiffer base layer than the aggregate base. However field testing is needed to substantiate these claims.

What Research Has Been Done?
RAP TESTING
A laboratory study recently investigated the effects of RAP content, freeze-thaw, and moisture on the base layer’s structural capacity with different aggregate materials.

The study compared the performance of samples containing virgin aggregate and RAP mixed with virgin aggregate. Samples were tested in a laboratory for gradation, stiffness, and shear strength.

Study results include:
- RAP gradation was coarser than the virgin aggregate but fell within MnDOT’s class 5 gradation limits.
- When well compacted, RAP was found to have a higher resilient modulus (stiffness) and shear strength compared to virgin aggregate.
- The resilient modulus (stiffness) of the RAP was found to increase as the moisture content in the sample decreased.
- The effect of freeze-thaw on RAP was insignificant in testing.

TESTING OF FOAMED ASPHALT
IN MINNESOTA (MNDOT)
MnROAD examined the success of several foamed asphalt CIR projects within two Minnesota counties. Falling Weight Deflectometer (FWD) and core data were collected to determine the strength of the stabilized layer and the foamed asphalt material.

FWD data showed the recycled pavement layer develops a relatively uniform strength despite the high variability in the pavement and base sections of most low-volume roads. Core data indicated the foamed asphalt forms a cohesive matrix with the fines in the reclaimed materials and appeared to be very similar to HMA layers.

CONSIDERATIONS
- FDR and SFDR require a stable sub base.
- Fly ash is now approved by MnDOT to use as a stabilized additive on certain projects.

What Is Next?
Three test sections (cells 2, 3 and 4) were constructed in 2007 in MnROAD to study performance and structural contributions of SFDR base materials. So far, the sections still perform well and FWD tests showed that SFDR layer has a high stiffness. Also, a study has been funded by the Local Road Research Board (LRRB) to evaluate structural contribution of SFDR using some of the existing county roads. Field evaluations include FWD and ground penetrating radar. The study is in still in progress. A SFDR experimental project was started in summer 2010 on State Highway 55, MnDOT district 4. Different stabilizing agents were used and the performance of the roadway is being monitored.

For more information about MnROAD and the Road Research program:
Shongtao Dai - Research
Mark Watson - Stabilized FDR

Terry Beaudry - Construction and Specifications

www.dot.state.mn.us/mnroad

REFERENCES
- Asphalt Recycle and Reclamation Association Basic Asphalt Reclamation Manual (BARM)
- Investigation of Stripping in Minnesota Class 7 (RAP) and Full-Depth Reclamation Base Materials http://www.lrrb.org/detail.aspx?productid=2293