INTRODUCTION

Full Depth Reclamation (FDR) is a particularly useful method for rehabilitating structurally failed pavements. City streets, once beyond their design life, tend to fail due to structural problems such as moisture damage in the base layer or alligator cracking. FDR is a relatively low-cost, energy saving method that is capable of solving pavement problems associated with the deeper layers of the base. It has been adopted as the preferred recycling technique in the USA and many other parts of the world. In addition, introducing an injected emulsion to the FDR materials further improves the overall pavement strength and resistance to moisture ingress. In this sense, FDR with injected emulsion is an ideal technique for rehabilitating or reconstructing low-volume roads that do not require a thick mat of hot mix asphalt (HMA), but could use some improvement of the pavement structure to resist moisture and improve strength. See Figure 1.

FDR involves the pulverization of the in-place asphalt pavement and blending it with the unbound granular base to a depth determined by initial studies of the in-place pavement structure. See Figure 2 for a photograph of the initial reclamation process. Once the pavement has been reclaimed and mixed with the underlying base material, the emulsion is injected and mixed with the reclaimed materials with a second pass of the FDR equipment. The second pass of the FDR equipment is performed with the reclaiming machine pushing a tanker truck, which supplies the emulsion to the reclaimer. See Figure 3 for a photograph of the second pass of the reclamation process. Once injected and mixed, the emulsified base materials can then be compacted with pad foot and smooth drum rollers to provide a hard, cohesive base layer. Stabilized FDR has also been successful with additives such as cement, lime, fly ash, and calcium chloride as well as others. In Minnesota, FDR is normally used on rural roads because the equipment train used can pose special limitations given certain roadway conditions and geometries.
This project demonstrated that FDR can be used in an urban street section (See Figure 4 for a map of the project area). It is common to use FDR as an unbound base in greater Minnesota. However, this case is unique in that an emulsion was used as a stabilizer for the reclaimed material, increasing the strength and moisture resistance of the reclaimed material while retaining the existing street elevations dictated by the in-place curb and gutter.
CONSTRUCTION

The Mn/DOT Materials and Road Research section provided expertise and support to the City of Shoreview for implementing an FDR project with stabilized base on some of its neighborhood roads during the 2007 construction season. The roads were originally graded in 1987, and subsequent coring and GPR scans showed that the old pavement structure consisted of anywhere from 5-10 inches of base, and 3-7 inches of bituminous. Some of the extra thickness of bituminous may have been due to patching efforts, but the variation in base thickness is likely due to lack of pavement specifications when the roads were built.
Regular maintenance on the roadways, consisting of crack sealing and patching, began in 1994 and continued to the present. Some of the roads had received a chip seal over the years to seal cracks, distress, and patched areas. The condition of the roads prior to the 2007 reconstruction was highly variable due to the nature of the construction methods used in 1987, as well as variations in the subgrade soil structure present at the various streets. The reconstruction methods used during the 2007 rehabilitation should provide greater continuity of pavement structure thicknesses, equivalent or better pavement strengths, and improved resistance to moisture issues.

The rehabilitation of the various streets consisted of three general types of construction:

1) Reclamation of 6 inches of pavement/base material without injection of emulsion, topped with 3” of HMA wearing course.

2) Reclamation of 6 inches of pavement/base material, and subsequent injection of emulsion and mixing to a depth of 4 inches and compacted, topped with 2” of HMA wearing course.

3) Complete reconstruction of a 9-ton route with storm sewer replacement, no use of emulsion.

Construction types 1 and 3 use the City of Shoreview’s usual method for construction, and employs a joint sealant material at the curb-and-gutter interface to deter water ingress to the pavement system. Construction type 2 uses a slightly thinner wearing course due to the additional strength provided by the four inches of emulsified base, and uses a Mn/DOT spec joint adhesive (Figure 5) at the curb and gutter interface to deter water ingress.

Figure 5. Fawn Lane, Mn/DOT spec joint adhesive.
Mn/DOT Research collected various data regarding the pre-construction and after-construction state of the pavement. Photographs were taken to document the condition of the pavement before construction. More photographs were also taken during and after construction as well to fully document the construction process. Before-construction GPR scans have been performed, and show the widely varying base and wearing course structure. See Figure 6 for a GPR scan showing the variability of the pavement structure before the pavement was reconstructed. After-construction GPR scans were also taken, and will be used to check the variability in layer thicknesses as well. Pavement layer thicknesses derived from the GPR scans will be used to back calculate modulus values for the pavement structure.

Falling Weight Deflectometer (FWD) and Lightweight Deflectometer (LWD) data was gathered before and after the reconstruction. Additional LWD tests were taken on the emulsified base layer before the wearing course was laid down. The Mn/DOT Research Section will back calculate pavement modulus values from the FWD and LWD data, and correlate them if possible. Due to the nature of back calculation it remains to be seen how much detail and statistical inference can be obtained from the deflection testing data, which tends to exhibit high spatial variability for urban streets.

![Figure 6. GPR scan of Westview Drive right wheel path](image)

Figure 6 shows 1) Probable bottom of base materials, 2) bottom of pavement, 3) top of pavement.
NEED MORE INFORMATION ON RECYCLED MATERIALS OR LOW VOLUME ROAD REHABILITATION OR THE MINNESOTA ROAD RESEARCH PROJECT (Mn/ROAD)?

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