

**EXPERIENCE WITH FULL DEPTH RECLAMATION / STABILIZATION
USING EXPANDED ASPHALT (FOAMED BITUMEN) IN EDMONTON,
ALBERTA**

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Paper prepared for Presentation
at the Recycling Materials for Use in Highway Design Session
Of the 2003 Annual Conference of the
Transportation Association of Canada
St. John's, Newfoundland and Labrador

1. ABSTRACT

Full Depth Recycling has been used in Western Canada since the early 1990's. The use of Expanded Asphalt (Foamed Bitumen) as a Stabilizer in the Full Depth Reclamation process has been used in Eastern Canada since the late 1990's.

In 2001, the City of Edmonton, Alberta, contracted with a local contractor and Wirtgen GmbH for the construction of a demonstration project using Foamed Bitumen in the Full Depth Reclamation of three locations. Ellerslie Road consisted of 4 lane-km of a two-lane, low volume, rural section, 70 Avenue consisted of 3.1 lane-km of a two lane, light industrial, rural section and 150 Avenue consisted of 6 lane-km of a four lane, bus route collector roadway.

With the assistance of AA Loudon and Partners, an Engineering Consultant from South Africa, a method specification for Foamed Bitumen Stabilization was developed for this demonstration project.

The existing Hot Mix Asphalt (HMA), Oil mix and Granular / Soil Cement base were pulverized, had Foamed Bitumen added as a stabilizer, were re-graded and compacted. The process utilized in the demonstration projects also called for the addition of cement as active filler. Foamed Bitumen Stabilization was carried out to a depth of 200 to 225mm. The Foamed Bitumen Stabilization operation proceeded well and provided a smooth, hard, uniform surface suitable for the accommodation of detour traffic, and in the case of 150 Avenue, was used as a running surface for a six-week period. Generally the stabilized base was overlaid with HMA wearing course following a two-day curing period.

This paper outlines the condition of the pavements prior to rehabilitation, basic design requirements, construction details, testing and evaluation completed and post-construction observations and monitoring of the three demonstration projects.

2. INTRODUCTION

The City of Edmonton, located in the North-Central portion of the Province of Alberta has a population of 975,000. The Edmonton Capital region also contains several smaller adjacent communities which when added in, results in a population of over 1,200,000. The City of Edmonton has approximately 15,000 lane-kilometers of paved-surface roadways including approximately 4,500 lane-kilometers of Major truck routes. Pavement structures within the City of Edmonton consist of approximately 1,000 lane kilometers of oil bound granular rural sections, 4,500 lane-kilometers of composite pavements (hot mix asphalt overlying concrete base), and 9,500 lane-kilometers of hot mix asphalt overlying either cement treated granular base and granular sub base or granular base. As the road network matures, the City of Edmonton finds itself spending less money on new construction and more money on maintenance and rehabilitation. As such the City of Edmonton has over a number of years been enthusiastically encouraging the development of innovative solutions for the rehabilitation of failing pavement sections, and maintenance of the remainder of its roadway network. One of the methods being evaluated by the City of Edmonton is Full Depth Reclamation (FDR) utilizing Foamed Bitumen as a stabilizer.

The City of Edmonton has been using in-place-recycling techniques employing cement as a stabilizer since 1993. The results of these techniques have been somewhat disappointing as cracking of the new pavement structure usually occurs within one to two years of the completion of the rehabilitation.

In late 2000, the City of Edmonton contacted Lafarge Construction Materials inquiring as to the possibility of utilizing Foamed Bitumen in a Full Depth Reclamation process as a demonstration project. Lafarge Construction Materials in turn contacted Wirtgen GmbH indicating the City of Edmonton's interest in participating in a demonstration project. The demonstration project would include the rehabilitation of a low volume, rural roadway consisting of oil bound granular material, a light industrial, rural roadway consisting of oil bound granular material and a bus route collector roadway consisting of hot mix asphalt on cement treated granular base.

In July 2001, the City of Edmonton and Lafarge Construction Materials / Wirtgen GmbH entered into a contract to rehabilitate approximately 13 lane-kilometers of roadway using full depth reclamation with foamed bitumen as a stabilizer. After stabilization all the roadways were to be surfaced with HMA.

Previously the City of Edmonton has selected structural asphalt overlays, in-situ stabilization using cement or full reconstruction utilizing granular and asphalt construction as rehabilitation measures, on these types of roadways.

This paper describes the FDR with foamed bitumen stabilization demonstration project undertaken in the City of Edmonton during August and September 2001. Extensive testing was carried out to determine the properties of the foamed asphalt mix, including existing material gradation, proctor density, mix design, dry and wet tensile strength and tensile strength ratio. Compaction and thickness of the material was verified in the field.

To be able to carry out the demonstration project, the City of Edmonton worked closely with Mr. Dave Collins of AA Loudon and Partners, Consulting Engineers of South Africa, to develop a specification for the project work. The pavement rehabilitation structures were designed by the City of Edmonton in consultation with AA Loudon and Partners and constructed by Lafarge Construction Materials in joint venture with Wirtgen GmbH.

3. SELECTION OF REHABILITATION OPTION

In selection of an appropriate rehabilitation treatment, the City of Edmonton has traditionally used the following primary criteria:

- Extent of the existing pavement distress;
- Subgrade strength and existing pavement thickness;
- Traffic volumes and type;
- Deficiency in existing pavement materials;
- Restrictions with respect to existing curb and gutter height;
- Cost of rehabilitation treatment.

However, traffic pressures – both public and commercial – have resulted in the City of Edmonton also having to consider the following secondary criteria:

- Cost to public and commercial traffic as a result of the delays due to rehabilitation projects (user costs);
- Cost and effect on businesses due to traffic disruptions and detours;
- Safety to construction workers and public during rehabilitation projects;
- Environmental issues.

The City of Edmonton now considers all of the above noted criteria when assessing a roadway for rehabilitation. They also have to be considered when choosing what treatment we are going to utilize on the project site.

Foamed bitumen stabilization was chosen for the three project locations based on the following factors:

- Existing pavement structures were suitable for the process;
- Construction time could be significantly reduced;
- Roadway would never be closed to traffic;
- Driving surface would be sound when opened to traffic, upon completion of compaction;
- Existing curb and gutter could be retained on the Bus Route collector.

4. PROJECT LOCATIONS, TRAFFIC VOLUMES AND EXISTING CONDITIONS

4.1 Ellerslie Road Project Site

The Ellerslie road project site extended from 150 Street to 142 Street and also included a 450-meter section of Ellerslie Road West of 127 Street. The Ellerslie Road test section was an old country road, which was acquired by the City of Edmonton by Annexation in the late 1970's. The actual age of the road structure was unknown. The road section consisted of approximately 2 kilometers of two-lane, seven-meter wide, rural cross-section comprised of bitumen treated gravel overlying a high plastic lacustrian clay. The distress found along the road was mainly severe alligator cracking and deformation. Transverse and longitudinal cracking were evident in some sections possibly due to the effect of freezing and thawing of the subgrade materials. The alligator cracks are evidence of fatigue failure of the upper pavement layers due to lack of subgrade support, especially when the subgrade is excessively moist. With water ingress through these cracks the failure of the pavement was accelerated. A photo of the existing Ellerslie Road is shown in Figure 1.

The 2000 traffic counts on Ellerslie Road indicate 9,000 equivalent single axle loading (ESAL's) per year. The estimated loading over a 20-year design period was calculated to be 0.28×10^6 ESAL's. This loading was used in the pavement design process.

4.2 70 Avenue Project Site

The 70 Avenue project site included a section of 70 Avenue from 18 Street to 20 Street, a section of 18 Street from 70 Avenue to 74 Avenue and a section of 73 Avenue from 17 Street to 18 Street. The 70 Avenue test section was an old rural section of roadway in a light industrial area towards the eastern limits of the City of Edmonton, the construction date for this roadway was again unknown. The road section consisted of approximately 1.5 kilometers of two-lane, seven-meter wide, rural cross section comprised of bitumen treated gravel overlying a high plastic lacustrian clay. As with the Ellerslie Road project, the distress found along this road was mainly severe alligator cracking and deformation. Transverse and longitudinal cracking was also evident in some sections. The alligator cracks are again evidence of fatigue failure of the upper pavement layers due to lack of subgrade support. A photo of the existing surface of 70 Avenue is shown in Figure 2.

The 2000 traffic counts on 70 Avenue indicated 15,000 equivalent single axle loading (ESAL's) per year. The estimated loading over a 20-year design period was calculated to be 0.75×10^6 ESAL's. This loading was used in the pavement design process.

4.3 150 Avenue Project Site

The 150 Avenue project site included a section of 150 Avenue from 87 Street to 94 Street and a section of 94 Street from 144 Avenue to 150 Avenue. The 150 Avenue test section is a bus route collector roadway constructed in 1971. The road section consisted of approximately 1.3 kilometers of four-lane, 14-meter wide urban cross section comprised of 70mm of hot mix asphalt overlying 200mm of cement treated granular base over 150mm of a 63mm granular sub-base. The portion of 150 Avenue and 94 Street earmarked for rehabilitation showed large areas of block and thermal cracking. In many places this primary cracking had degenerated into alligator cracks with hydraulic displacement of fines (pumping) from the underlying base material. Numerous hot mix patches were evident over the surface of the entire section inspected. These patches had probably extended into the base of the stabilized layer (± 200 mm thick) since the modes of failure being addressed (alligator cracking / pumping / loss of support) originated from that point in the pavement. Some patches observed were old and some new, indicating that such measures are part of an ongoing maintenance routine. The areas at the bus stops exhibited severe distress in the form of deformation and shoving of the surfacing. It was clear that the pavement at these locations had received additional maintenance work with numerous asphalt patches being evident both at the bus stops themselves, and on either side. A photo of the existing 150 Avenue showing the block cracking and numerous patches is shown in Figure 3.

The 2000 traffic counts on 150 Avenue indicate 50,000 equivalent single axle loading (ESAL's) per year. The estimated loading over a 20-year design period was calculated to be 1.5×10^6 ESAL's. This loading was used in the pavement design process.

A Map of the City of Edmonton, showing the three project locations, is shown in Figure 4.

5. SPECIFICATION DEVELOPMENT

Prior to our meetings with Wirtgen Inc. and AA Loudon and Partners, the City of Edmonton had no previous experience with foamed bitumen as a stabilizer in full depth reclamation. The City of Edmonton did however have several years' experience with the use of cement as a stabilizer in full depth reclamation. As a result, the City of Edmonton had a specification for full depth reclamation utilizing cement and used this specification as a starting point for development of a new specification for full depth reclamation utilizing foamed bitumen. The City of Edmonton, in consultation with AA Loudon and Partners developed the specification employed during the demonstration project.

The specification detailed the requirements for in-situ pulverization of the existing pavement structure including any base granular / soil cement, addition and mixing of stabilizing agents into the reclaimed base, grading and compaction of the reclaimed base course. Also included in the specification is a section describing quality control testing required to be performed by the contractor as well as quality assurance testing required to be carried out by the owner. The specification also required the contractor to be responsible for the mix design. However, as a result of the demonstration project being a partnership between all parties involved, it was decided that the City of Edmonton / AA Loudon and Partners would be responsible for the mix designs for the locations included in the demonstration project.

6. MATERIALS SAMPLING AND MIX DESIGN

On March 1, 2001, several test pits were excavated utilizing a rubber tire mounted backhoe. These test pits were excavated to determine the existing pavement structure as well as obtain samples for performing mix designs. Figures 5a through 5c show photos of the test pits for Ellerslie Road, 70 Avenue and 150 Avenue respectively.

The required mix designs were performed at the City of Edmonton's Quality Assurance laboratory in June 2001. AA Loudon and Partners, the staff of the City of Edmonton Quality Assurance Laboratory and J.R. Paine and Associates, Consulting and Testing Engineers, a local materials engineering consultant, were instrumental in preparing the mix designs. The mix designs were carried out in accordance with the Wirtgen Cold Recycling Manual, Appendix 2.3, Laboratory Procedure for the Mix Design of Foamed Bitumen Treated Materials.

Prior to the actual mix design process, the procedure requires, the identification of the asphalt bitumen to be used in the process as well as its foaming characteristics. This was performed utilizing a Wirtgen WLB10, Foamed Bitumen Laboratory. HMA mixes in the Edmonton area utilize 150-200A bitumen as the standard binder. As this material is readily available, it was chosen as the bitumen for use in the foamed asphalt project. Testing of the foaming characteristics of the asphalt bitumen was conducted in order to optimize the foaming properties through maximizing the expansion ratio and half-life of the foamed asphalt. This was completed by determining the optimum percentage of water needed for a given asphalt bitumen temperature. Characterization was carried out using injected water percentages ranging from 1.0% to 3.0%. During our initial testing of the bitumen it was clear the initial sample of 150-200A supplied by the Contractor for use in the mix design process was not acceptable, as the product would not foam properly. As a result, a second source of 150-200A bitumen was evaluated and found to have acceptable foaming characteristics. The testing indicated that the optimum percentage of "foaming" water required would be 2.5% with a temperature of asphalt cement at a minimum 160 °C.

Once the bitumen characteristics had been determined laboratory testing was carried out to determine the following:

- Gradation of the existing materials, all locations;
- Gradation of the corrective aggregate to be used for the Ellerslie Road and 70 Avenue Projects;

- Gradation of the combination of existing and corrective aggregate for the Ellerslie Road and 70 Avenue Projects;
- Moisture density relationship of the combined aggregate sample for the Ellerslie Road and 70 Avenue projects;
- Moisture density relationship for the material from the 150 Avenue project.

The results of gradation testing on the existing materials as well as the Cameron Pit material are presented in Table 1. It should be noted that the corrective aggregate that was utilized on the Ellerslie Road project was required to improve the overall grading of the recycled cold mix material. The cold mix was deficient in some particle sizes when compared to the ideal grading curve, in particular the fine fraction (material passing the 0.080mm sieve).

Upon completion of the initial testing, the sample from 150 Avenue and the blended samples from both the Ellerslie Road and the 70 Avenue project sites were stabilized with foamed bitumen contents ranging from 2.0% to 3.5%, in 0.5% increments together with 1.5% cement used as an active filler. Additional mixing was carried out on the samples from 70 Avenue and 150 Avenue Project sites using foamed bitumen contents from 2.0% to 3.5% together with 1.0% cement used as an active filler. Laboratory testing was carried out to determine the following mix characteristics:

- Percent by mass of the foamed bitumen to be added to the mix;
- Bulk specific gravity of the mixture at the various bitumen contents;
- Dry tensile strength of the mixture at the various bitumen contents;
- Wet Tensile strength of the mixture at the various bitumen contents;
- Tensile strength Ratio of the mixture at the various bitumen contents.

The results of the tensile strength and bulk specific gravity testing are presented in Table 2.

For the Ellerslie Road and 70 Avenue projects, the optimum foamed bitumen content for optimal strength was found to be at 2.5% foamed bitumen and 1.5% cement as active filler. For the 150 Avenue project, the optimum foamed bitumen content for optimal strength was found to be 2.0% foamed bitumen with 1.5% cement as active filler. The results of the mix designs for the foamed bitumen stabilization indicated that good strength characteristics could be obtained at each of the proposed project locations.

The following is a summary of recommendations for rehabilitation to be used on the demonstration projects:

6.1 Ellerslie Road and 70 Avenue Projects

- Import 100mm (compacted depth) of 20mm gravel (Cameron Pit), spread and compacted over the area earmarked for FDR;
- Pulverize the composite structure to a depth of 200mm simultaneously applying 1.5% cement and 2.5% foamed bitumen (both by mass);
- Shape and compact the material at optimum moisture content to 98% of the maximum density in accordance with ASTM D1557;
- Apply 35mm HMA surface course on the Ellerslie Road project and 75mm HMA surface course on the 70 Avenue project.

Table 3 is a summary of mix requirements for the rehabilitation of the Ellerslie Road and 70 Avenue demonstration sites.

6.2 150 Avenue Project

- Pulverize the existing road structure to a depth of 225mm simultaneously applying 1.5% cement and 2.0% foamed bitumen (both by mass);
- Shape and compact the material at optimum moisture content to 98% of the maximum density in accordance with ASTM D1557;

- Apply 75mm HMA surface course.

Table 4 is a summary of mix requirements for the rehabilitation of the 150 Avenue demonstration site.

7. PRODUCTION / CONSTRUCTION

Lafarge Construction Materials commenced construction August 20, 2001 on Ellerslie Road with the placement of 100mm of 20mm corrective aggregate placed utilizing an ABG Titan 511 Paver. See photo as Figure 6. The contractor chose to use the paver for placement of the granular material to ensure uniformity of the layer thickness. The contractor then commenced the FDR and foamed bitumen stabilization operation on August 21, 2001 at the 156 Street intersection under the guidance of Wirtgen GmbH, and AA Loudon and Partners personnel.

After some startup difficulties, which could be contributed to starting the project within an intersection the foamed asphalt operation proceeded well, with minimal interruptions.

The FDR and foamed bitumen stabilization was carried out in a single operation, with the exception of one portion of Ellerslie Road, where due to excessive rutting, the roadway was pre-pulverized, shaped and compacted prior to the placement of the corrective aggregate. See photo as Figure 7.

On Ellerslie Road and 70 Avenue, after the placement of the corrective aggregate and prior to the FDR and stabilization process, cement was added to the surface of the compacted aggregate. See photos as Figure 8a and 8b. On 150 Avenue the cement was spread directly on the surface of the existing roadway prior to stabilization. The cement was spread in sections no longer than 450m in front of the recycling train. It was found that pre-wetting of the aggregate surface and roadway surface prevented excessive loss of cement from the surface.

The FDR and foamed bitumen stabilization operation was carried out utilizing a recycling train consisting of a Wirtgen WR2500 Reclaimer coupled to a bitumen supply tanker and a water truck. See photo as Figure 9.

In the case of Ellerslie Road and 70 Avenue the road width to be pulverized and stabilized was approximately 7.5 meters. To facilitate the width, the reclaimer made a total of four passes using the following protocol:

Pass 1

- 2.4-meter full cutter widths with all nozzles on the spray / foaming bar open.

Pass 2

- 1.5-meter, from edge of pass 1 to center of roadway, allowing a 150mm overlaps each edge. Outer nozzles on the spray / foaming bar were shut off to prevent double dosing of the stabilized material with bitumen, same direction as pass 1

Pass 3

- 2.4-meter full cutter widths with all nozzles on the spray / foaming bar open, opposite direction to pass 1.

Pass 4

- 1.5-meter, from edge of pass 3 to center of roadway, allowing a 150mm overlaps each edge. Outer nozzles on the spray / foaming bar were shut off to prevent double dosing of the stabilized material with bitumen, same direction as pass 3.

The equipment moved slowly, generally processing somewhere in the order of 800 meters of two-lane roadway per day, and the result was a uniform, well-mixed and well-sized reclaimed material. Average recycling speed for these locations was 14 meters per minute. The limiting factor for the amount of roadway to be processed each day was the bitumen, which was delivered to the site from Lloydminster, Alberta, which is approximately 275 km from the project sites.

In the case of 150 Avenue, the road width to be reclaimed and stabilized was approximately 14.5 meters. To facilitate the width, the reclaimer made a total of six passes using the following protocol:

Pass 1

- 2.4-meter full cutter widths with all nozzles on the spray / foaming bar open.

Pass 2

- 2.25-meter, from edge of pass 1, allowing a 150mm overlaps each edge. Outer nozzles on the spray / foaming bar were shut off to prevent double dosing of the stabilized material with bitumen, same direction as pass 1

Pass 3

- 2.25-meter, from edge of pass 2, allowing a 150mm overlaps each edge. Outer nozzles on the spray / foaming bar were shut off to prevent double dosing of the stabilized material with bitumen, same direction as pass 1

Pass 4

- 2.4-meter full cutter widths with all nozzles on the spray / foaming bar open, opposite direction to pass 1.

Pass 5

- 2.25-meter, from edge of pass 4, allowing a 150mm overlaps each edge. Outer nozzles on the spray / foaming bar were shut off to prevent double dosing of the stabilized material with bitumen, same direction as pass 4.

Pass 6

- 2.25-meter, from edge of pass 5, allowing a 150mm overlaps each edge. Outer nozzles on the outside of the spray / foaming bar were shut off to prevent double dosing of the stabilized material with bitumen, same direction as pass 4.

The equipment moved slowly, generally processing somewhere in the order of 700 meters of two-lane roadway per day, and the result was a uniform, well-mixed and well-sized reclaimed material. Average recycling speed for this location was 10 meters per minute. Again the limiting factor for the amount of roadway to be processed each day was the bitumen supply.

Initial breakdown compaction of the stabilized material was carried out using a vibratory pad foot roller following immediately behind the train. See photo as Figure 10. Compaction with the vibratory pad foot roller continued until the roller walked itself to the surface of the stabilized material.

Once the stabilized material was compacted, the surface was then cut to grade using a motor grader. See photo as Figure 11.

A double drum vibratory compactor followed the motor grader to complete the final compaction. See photo as Figure 12.

Following final compaction, the surface of the stabilized material was flooded with water. See photo as Figure 13. While the surface was wet, a pneumatic tired roller was used to create a slushing effect. See photo as Figure 14. This slushing effect knitted together the finer particles in the surface and locked in the larger particles. This helped produce a surface that did not ravel.

On the project locations, materials from the corner radiuses were pulled into the center of the roadway, with the motor grader. This material was then stabilized with the main roadway. The blended stabilized material was then moved back into the corner radiuses with the grader ready for compaction and finishing.

8. QUALITY CONTROL / QUALITY ASSURANCE TESTING

As in-situ density of the compacted stabilized materials is important, a field density-testing program was set up for the project sites. This program consisted of obtaining samples for a Modified Proctor ASTM D1557, followed by field density testing utilizing a nuclear density gauge. Due to the variability of the in-situ

materials and therefore the anticipated variability of the test results, it was decided that all field density testing would be referenced to a one-mold Proctor sample taken from the location of each field density test location. Staff of the Engineering Services Section of the City of Edmonton performed the quality control testing. The results of the field density testing are presented in Tables 5 through 7.

As can be seen from the density test results, whether the testing was referenced to the Modified Proctor or a Modified one-mold Proctor made very little difference to the results obtained from field density testing.

An area of concern was the lack of data with respect to the performance of the foam-stabilized material in a freeze/thaw environment. . As there is no definitive test for determination of freeze-thaw or wet-dry susceptibility for stabilized materials, other than soil cement, the City of Edmonton choose to use the existing soil cement test procedures for testing the foam stabilized materials. The City of Edmonton opted to manufacture specimens with stabilized materials obtained from the 70th Ave project. These specimens were then subjected to the requirements of ASTM D560, Freezing and thawing tests of compacted soil cement mixtures and ASTM D559, Wetting and drying tests of compacted soil cement mixtures. The results of the testing performed on our samples showed average losses of 3.4% for freeze / thaw and average losses of 4.5% for wet / dry testing after 12 cycles. A summary of the results can be found presented in Table 8 and 9.

Whether these results and test methods utilized are indicative of actual performance is under review and further testing will be required, however early indications are promising. We will be undertaking a study on some of the completed sections to help better describe the foam stabilized material characteristics.

9. PERFORMANCE AND MONITORING RESULTS

The performances of the three road sections reconstructed with foam bitumen stabilization techniques are being monitored on an on going basis, with the use of deflection measurements and visual observations. The deflection measurements were taken several times a year, including immediately after the foam stabilization work was performed. Figure 15 shows the Dynaflect testing apparatus utilized by the City of Edmonton for deflection testing of the demonstration projects and Figure 16 shows the Falling Weight Deflectometer apparatus also used on the demonstration projects for comparison purposes. Figures 17-19 show the Dynaflect deflections measured prior to the foamed asphalt stabilization process, three weeks after the work was carried out and approximately one-year later.

The dynamic response characteristics of the pavement structure were determined by measuring the deflection at and at specific points away from the loading point. For the FWD the surface deflections of the pavement structure were measured by a total of seven sensors, and for the Dynaflect unit, the deflections were measured by a total of five sensors equally spaced 300mm from the loading wheel. In both cases the resulting deflections and applied loading were recorded on an onboard computer for subsequent analysis. The collected deflection basin data was analyzed using back calculation software to calculate the various layer and surface moduli. All the data was processed with the actual layer thicknesses. The resilient moduli of the various layers were obtained.

For the Ellerslie Road project site, the pre-construction Dynaflect deflection results ranged from 1.84 mils (0.047 mm) to 2.70 mils (0.069 mm), averaging 2.23 mils (0.057 mm). After completion of the stabilization and overlay, the Dynaflect deflection results ranged from 1.47 mils (0.037 mm) to 0.79 mils (0.020 mm), averaging 1.24 mils (0.032 mm). This results in a deflection reduction of 44% for this roadway.

For the 70 Avenue project site, the pre-construction Dynaflect deflection results ranged from 1.25 mils (0.032 mm) to 3.21 mils (0.082 mm), averaging 2.05 mils (0.052 mm). After completion of the stabilization and overlay, the Dynaflect deflection results ranged from 0.55 mils (0.014mm) to 0.91 mils (0.023mm), averaging 0.72 mils (0.018mm). This results in a deflection reduction of 65% for this roadway.

For the 150 Avenue project site, the pre-construction Dynaflect deflection results ranged from 1.61 mils (0.040 mm) to 3.42 mils (.087 mm), averaging 2.34 mils (0.059 mm). After completion of the stabilization and

overlay, the Dynaflect deflection results ranged from 0.70 mils (0.018 mm) to 1.68 mils (0.043mm), averaging 1.19 mils (0.030mm). This results in a deflection reduction of 49% for this roadway.

In all three cases, the results indicate that there has been a significant structural improvement to the pavement / subgrade system. The other phenomenon noted in reviewing the deflection plots it that the foamed bitumen stabilization process has resulted in a much more consistent pavement / subgrade system.

Subsequent deflection testing carried out in 2002 indicates a slight strength gain in the structure. This strength gain is represented by a further reduction in deflections generally in the order of 5 to 10% during this period. This is partly attributable to a further stiffing of the bitumen within the structure.

The Dynaflect and Falling Weight Deflectometer data was analyzed using the ILLIBACK and ELMOD computer analysis programs. All falling weight deflectometer deflection data was normalized to represent deflection load of 40 kN at 21°C. All Dynaflect deflection data was normalized to 20°C. Back calculation of the Resilient Modulus of the pavement layers based on deflection test results indicated values ranging from 2754 to 4209 Mpa for the hot mix asphalt. The range observed would be expected due to the differing thicknesses of hot mix asphalt on each project site as well as within each project site. The backcalculated resilient modulus for the stabilized layer ranged from 1195 to 1649 Mpa and the resilient modulus of the subgrade materials ranged from 19 to 27 Mpa. The results of the back calculation are presented in Table 10.

Based on the results of out testing, the granular base equivalency of the foamed bitumen stabilized materials was estimated to range between 1.6 and 1.7.

10. CONCLUSIONS

- The process followed by the City of Edmonton to undertake the trail projects discussed in this report resulted in significant growth of understanding of foamed bitumen stabilization in Edmonton. However it is obvious that there is still much to learn about the design, construction and performance of this material.
- Full depth reclamation utilizing foamed bitumen as a stabilizer used on the demonstration projects resulted in dramatic increase in the structural strength of the roadway section.
- The stabilized material resulted in a smooth hard and relatively durable surface suitable for temporary detour traffic.
- Ongoing deflection and performance monitoring of the sites will provide an opportunity to determine any increase or decrease in the overall strength of the pavement structure and the contributing strength of the stabilized layer as well as help access the long-term performance of the stabilized material.

11. REFERENCES

The Design and Use of Foam Bitumen Treated Materials, Interim Technical Guideline ISBN 0-7988-5542-6 Transportek, CSIR, Pretoria, South Africa, 2002.

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AASHTO Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, Washington D.C., 1993.

Asphalt Overlays and Pavement Rehabilitation, The Asphalt Institute, Asphalt Institute Manual (MS-17), USA, 1969.

Cold Deep In-Place Recycling: Technical Recommendations and Application Specifications, AA Loudon & Partners, ISBN 0620-19413-8, South Africa, 1995.



Figure 1 - Ellerslie Road Project Site



Figure 2 - 70 Avenue Project Site



Figure 3 - 150 Avenue Project Site

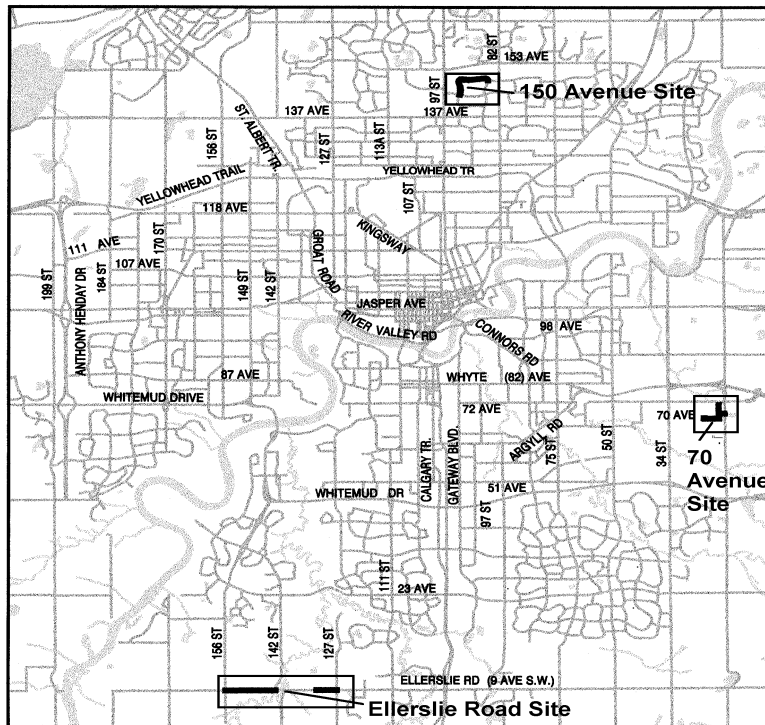


Figure 4 - Project Locations



Figure 5a - Test Pit on Ellerslie



Figure 5b - Test Pit on 70 Avenue



Figure 5c - Test Pit on 150 Avenue



Figure 6 - Placement of 20mm Corrective Aggregate with ABG Paver, Ellerslie Road



Figure 7 - Pre-pulverization of Heavily Rutted Section of Ellerslie Road



Figure 8a - Spreading of Cement on the Surface of Compacted Aggregate Ellerslie



Figure 8b - Spreading Cement on Surface of 150 Avenue



Figure 9a - Recycling Train Ellerslie Road



Figure 9b - Recycling Train 150 Avenue



Figure 10a - Vibratory Pad Foot 150 Avenue



Figure 10b - Vibratory Pad Foot Ellerslie Road



Figure 11a - Grading 70 Avenue



Figure 11b - Grading Ellerslie Road



Figure 12 - Final Compaction Ellerslie Road



Figure 13 - Watering of Surface Ellerslie Road



Figure 14 - Slushing with Pneumatic Roller



Figure 15 - Dynaflect Deflection Testing Apparatus



Figure - 16 Falling Weight Deflectometer Deflection Testing Apparatus

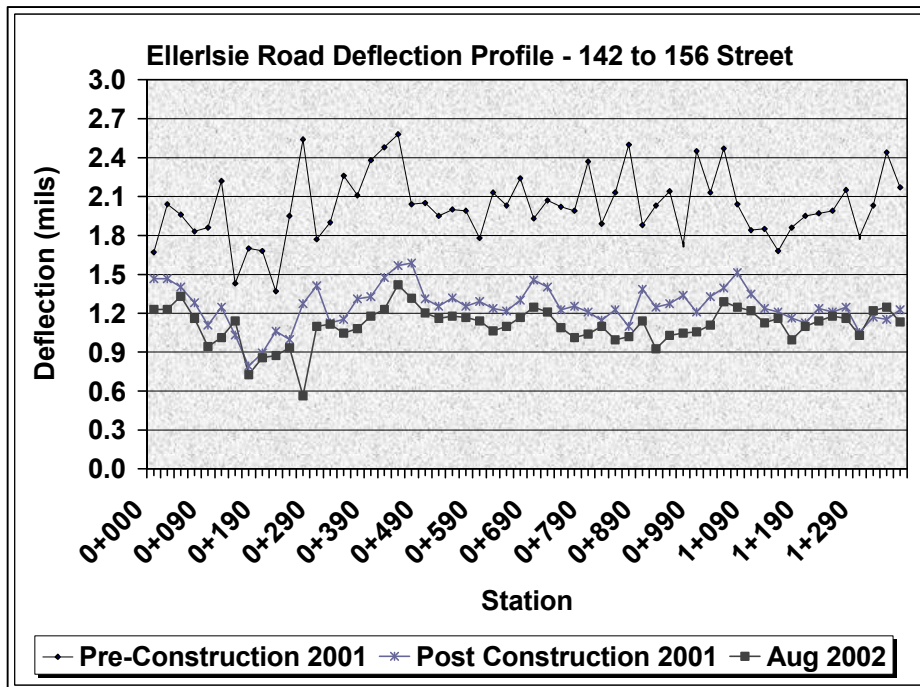


Figure 17 - Ellerslie Road – Comparison of Pre and Post Construction Deflections

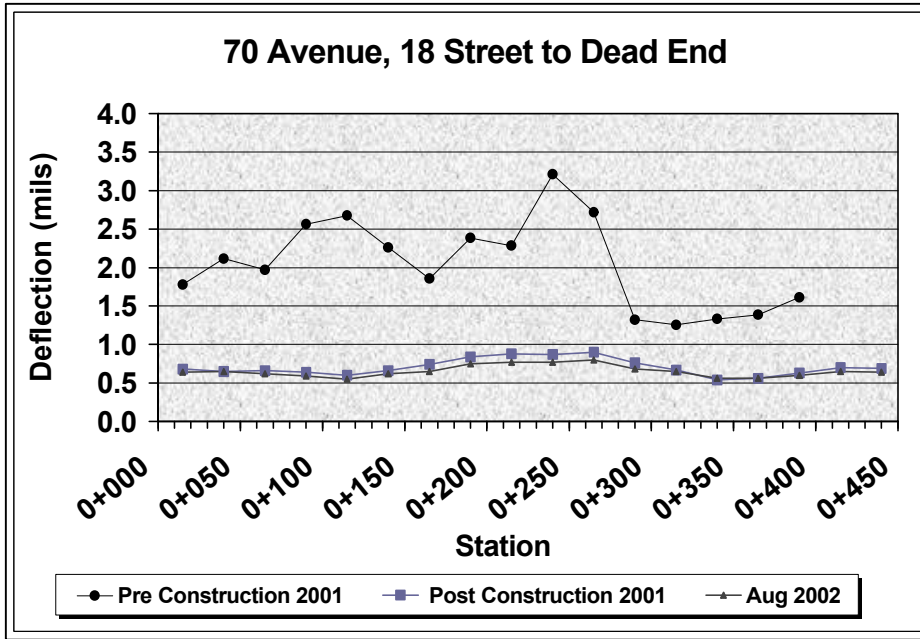


Figure 18 - 70 Avenue – Comparison of Pre and Post Construction Deflections

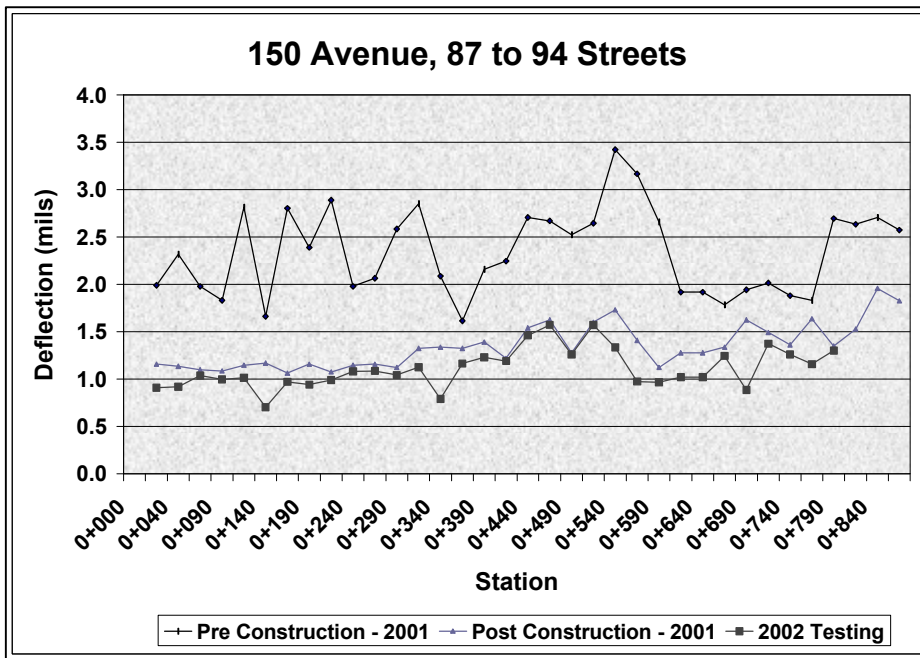


Figure 19 - 150 Avenue – Comparison of Pre and Post Construction Deflections

Table 1 – Gradation Requirements and Actual Gradations

Sieve Size (mm)	Gradation Limits	Ellerslie Road Project Combined	70 Avenue Project Combined	150 Avenue Project Pulverized	Cameron Material Add-mix Granular
25.000	100	100.0	100.0	100.0	100.0
20.000	100	100.0	100.0	95.3	100.0
12.500	60 - 85	83.1	88.1	84.0	76.1
10.000	55 - 80	74.8	79.8	76.1	67.3
5.000	45 - 70	54.1	58.4	51.2	51.1
2.500	35 - 60	38.7	42.1	37.8	42.0
2.000	30 - 55	34.5	37.2	34.0	39.5
1.250	25 - 50	29.0	30.3	29.1	35.6
0.800	22 - 45	24.1	25.1	25.8	32.3
0.630	20 - 42	21.6	21.7	23.8	29.9
0.400	17 - 35	17.1	16.7	19.9	25.6
0.315	15 - 32	15.1	14.3	16.5	23.4
0.160	10 - 25	11.1	10.5	10.6	18.9
0.080	5 - 20	8.8	8.4	7.6	15.4

Table 2 – Tensile Strength Properties and Bulk Density of Design Mixes

Property	Ellerslie Road Project	70 Avenue Project	150 Avenue Project
Bulk Density (kg/m ³)	2132	2121	2136
Dry Tensile Strength (kPa)	355	468	670
Wet Tensile Strength (kPa)	327	428	613
Tensile Strength Ratio (TSR%)	92.1	91.5	90.3

Table 3 – Mix Requirements Ellerslie Road and 70 Avenue

	Ellerslie Road Project	70 Avenue Project
Bitumen Used	Husky 150/200A	Husky 150/200A
Bitumen Temperature (C ^o)	160 +	160 +
Percentage “foaming “ Water (%)	2.5	2.5
Foamed Asphalt Added	2.5 ± 0.5	2.5 ± 0.5
Active Filler (%)	1.5 – Cement	1.5 - Cement
Optimum Moisture Content (%)	6.1	5.1
Maximum Dry Density (kg/m ³)	2002	1979

Table 4 – Mix Requirements for 150 Avenue

	150 Avenue Project
Bitumen Used	Husky 150/200A
Bitumen Temperature (C°)	160 +
Percentage “foaming” Water (%)	2.5
Foamed Asphalt Added	2.0 ± 0.5%
Active Filler (%)	1.5 – Cement
Optimum Moisture Content (%)	5.8
Maximum Dry Density (kg/m³)	1852

Table 5 – Ellerslie Road Field Test Results

Ellerslie Road Project					
Test Number	Field Dry Density (kg/m³)	One-mold Density (kg/m³)	Modified Proctor (kg/m³)	% Compaction (One-mold)	% Compaction (Mod Proctor)
1	1982	1955	2002	101.4	99.0
2	1898	1955	2002	97.1	94.8
3	1924	1955	2002	98.4	96.1
4	1951	1955	2002	99.8	97.5
5	1948	1956	2002	99.6	97.3
6	1995	2003	2002	99.6	99.7
7	1998	1998	2002	100.0	99.8
8	2020	2020	2002	100.0	100.9
9	1949	1930	2002	101.0	97.4
10	1991	1964	2002	101.4	99.5
11	1997	1985	2002	100.6	99.8
12	1994	2035	2002	98.0	99.6
13	1948	1982	2002	98.3	97.3
14	1940	1932	2002	100.4	96.9
Average	1967	1973	2002	99.7	98.2

Table 6 – 70 Avenue Field Test Results

70 Avenue Project					
Test Number	Field Dry Density (kg/m3)	One-mold Density (kg/m3)	Modified Proctor (kg/m3)	% Compaction (One-mold)	% Compaction (Mod Proctor)
15	1961	1979	1979	99.1	99.1
16	1928	1979	1979	97.4	97.4
17	1947	1981	1979	98.3	98.4
18	1956	1980	1979	98.8	98.8
19	1968	1980	1979	99.4	99.4
20	1959	1979	1979	99.0	99.0
21	2007	1979	1979	101.4	101.4
22	1984	1978	1979	100.3	100.3
23	1982	1978	1979	100.2	100.2
24	1997	1979	1979	100.9	100.9
25	1929	1978	1979	97.5	97.5
Average	1965	1979	1979	99.3	99.3

Table 7 – 150 Avenue Field Test Results

150 Avenue Project					
Test Number	Field Dry Density (kg/m3)	One-mold Density (kg/m3)	Modified Proctor (kg/m3)	% Compaction (One-mold)	% Compaction (Mod Proctor)
26	1809	1829	1852	98.9	97.7
27	1866	1831	1852	101.9	100.8
28	1848	1835	1852	100.7	99.8
29	1855	1835	1852	101.1	100.2
30	1872	1835	1852	102.0	101.1
31	1887	1906	1852	99.0	101.9
32	1820	1820	1852	100.0	98.3
33	1851	1870	1852	99.0	99.9
34	1862	1869	1852	99.6	100.5
35	1855	1868	1852	99.3	100.2
36	1896	1870	1852	101.4	102.4
37	1855	1857	1852	99.9	100.2
38	1858	1854	1852	100.2	100.3
39	1852	1848	1852	100.2	100.0
40	1847	1849	1852	99.9	99.7
Average	1856	1852	1852	100.2	100.2

Table 8 – Test Results from Freeze / Thaw Testing

	Maximum Density kg/m ³	Moisture Content %	Loss (%)
Sample #2	1999	5.1	2.2
Sample #4	1992	5.1	4.7
Sample #6	1986	5.1	4.3
Average	1992	5.1	3.4

Table 9 – Test Results from Wet / Dry Testing

	Maximum Density kg/m ³	Moisture Content %	Loss (%)
Sample #8	1990	5.1	3.6
Sample #10	1980	5.1	5.1
Sample #12	1988	5.1	4.8
Average	1986	5.1	4.5

Table 10 – Backcalculated Resilient Modulus (MPa)

	Ellerslie Road	70 Avenue	150 Avenue
Hot Mix Asphalt Resilient Modulus			
High Value (Mpa)	4020	4070	4209
Low Value (Mpa)	2754	2754	3060
Average Value (Mpa)	3312	3370	3907
Stabilized Layer Resilient Modulus			
High Value (Mpa)	1629	1609	1649
Low Value (Mpa)	1275	1195	1325
Average Value (Mpa)	1341	1375	1448
Subgrade Resilient Modulus			
High Value (Mpa)	29.1	54.7	42.7
Low Value (Mpa)	12.5	13.0	21.2
Average Value (Mpa)	19.1	24.7	26.9