The City of Calgary's early Experiences with use of Fiberglass Grids for Asphalt Pavement Rehabilitation

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ABSTRACT

Two years ago, construction and monetary constraints presented the City of Calgary an opportunity to seek innovative options for pavement rehabilitation. The City undertook three pilot projects to address the issues using fiberglass grid asphalt reinforcement products for the rehabilitation of roads. Polymeric coated fibreglass grids and fibreglass grid–geotextile composites were used to reinforce asphalt concrete pavement (ACP) overlays to enhance their resistance to reflection and fatigue cracking and rutting.

This paper describes the experiences with different products with particular emphasis on the selection of appropriate candidate, installation, and post installation early performance review. Challenges associated with preparation of existing/milled surface, type and rate of application of tack coat and its state, various attributes of the products and proper installation techniques which are the key factors to ensure a good bond are also discussed.

The paper discusses experiences with self-adhesive polymer coated fibreglass grids and fibreglass grid bonded to nonwoven geotextiles. While the latter was installed directly on the treated milled surface, self-adhesive fiberglass grid was placed on a thin asphalt levelling course. The behaviour during installation was closely monitored. Core samples of the reinforced asphalt were retrieved and tested. Post installations periodic international roughness index (IRI) testing results of before and after rehabilitation are presented. Experiences from these pilot projects provide a learning experience for agencies trying to test such asphalt reinforcement products. It reinforces the fact that selection of proper installation technique appropriate for the product and careful supervision and control during the installation is essential for the success of the project.

INTRODUCTION

One of the important challenges faced by The City of Calgary is the effective maintenance of the roads in its jurisdiction. Asphalt pavements experience various modes of distress like wheel path rutting, fatigue cracks, longitudinal and transverse cracks, edge cracking etc. which compromises the structural strength and riding quality of the pavement. The City carries out maintenance and rehabilitation of the pavements periodically and in some cases, where the pavements have undergone extensive damage, reconstruction of the pavement also is carried out. As with most urban pavement, milling and overlay/inlay is extensively used for the rehabilitation of distressed asphalt pavements.

The City maintains a large network of 15,000 lane kilometers of paved road network comprising arterial, collector, industrial and local road classifications, with a total asset value of about $12.5 Billion. The latest condition assessment conducted in 2016 showed that 78% of the network was in good or better condition and the remaining 22% has met trigger for rehabilitation. This backlog translates to more than 10 years of current budget which is approximately $35 million per year. Allocated budget is only sufficient to treat about 275 lane kilometers out of approximately 3,300 lane kilometers that needs rehabilitation. Faced with construction and monitory constraints, The City started exploring innovative techniques for pavement rehabilitation. Asphalt reinforcement using fiberglass grids was identified as one of the techniques with potential benefits specifically to urban roads.

The benefits of using geosysthetics in pavements are reported in various studies. These include reduction in the thickness and enhancement of the performance of the pavement (Lytton, 1989, Austin & Gilchrist, 1996, de Bondt, 1999, Anon, 2008). However, quantification of the actual benefits arising from the use of geosynthetics involves some difficulties. In the case of the use of fiberglass grids for asphalt reinforcements there are several aspects like suitability of different types of products, appropriate techniques for the preparation of existing pavement surface, precautions to be taken during installation, the nature of the bond between reinforcement and asphalt etc., which needs to be addressed to ensure appropriate use of these products. Realizing the significant potential benefits of fiberglass grids for the rehabilitation of asphalt pavements, The City of Calgary, decided to carry out pilot studies to evaluate the performance of these products under actual field conditions.

The City of Calgary's pilot program on fiberglass grid reinforced asphalt was initiated in 2015 and comprised three locations – two roads with curb and gutter namely Sarcee Trail and 50th Ave., and rural road 101 Street SW. This paper presents the significant learning from these field trials.

OVERVIEW OF PILOT PROJECTS

Details of the Field Trial Locations Prior to Rehabilitation

Three projects were selected based on the merits and are listed in the Tables 1 and 2 below. To analyze pavements, strength testing was done using Falling Weight Deflectometer (FWD) and layer thicknesses were determined using Ground Penetrating Radar (GPR), cores and boreholes. FWD back-calculation was done using AASHTO methodology to determine Asphalt Concrete Pavement (ACP) overlay or strengthening needs.

Table 1 - Roadway classification and pavement structural analysis

Road Name	*Road Classification*	*AADT*	*Truck (%)*	*20 Yr. Design ESALs (Million)*	*Pavement Structure (mm)*	*Subgrade Modulus (MPa)*	*SN_{eff} (mm)*	*Overlay Need (mm)*
Sarcee Trail SW	Arterial – Divided, 2 lanes/dir.	42,000	4.1	13.72	160-210 ACP[1] 510-580 GBC	40	150-173	40
101 Street SW	Rural – Undivided, 1 lane/dir.	6,000	5.0	3.1	100-125 ACP 100 mm GBC[2]	25	56	60
50 Ave. SE	Arterial – Undivided, 2 lanes/dir.	15,000	20.0	30.0	250-300 ACP 400 GBC	53	106	80

[1] Asphalt Concrete Pavement (ACP)

[2] Granular Base Course (GBC) was found only at two locations. In general, the structure was full depth asphalt pavement on subgrade.

Table 2 - Pre-rehabilitation pavement performance

Road Name	***Longitudinal/Transverse Cracking***	***Fatigue Cracking***	***IRI[1] (mm/m)***	***Rutting (mm)***	***PQI[2]***
Sarcee Trail SW	30% Medium severity	5% Low Severity	2.15	5.5	5.8
101 Street SW	N/A	N/A	3.1	9.0	5.0
50 Ave. SE	10% Medium severity 5% Low severity	10% Low Severity	2.8	7.5	5.0

[1] International Roughness Index (IRI)
[2] Pavement Quality Index (PQI)

Sarcee Trail

Sarcee Trail is a four lane divided arterial road with two lanes in each direction. The section selected for pilot project was two northbound lanes (NBL), about 1 km in length. Observed pavement distresses were extensive and medium to high severity transverse cracking, semi continuous medium severity longitudinal cracking and frequent medium severity block cracking. Transverse cracks were generally spaced at 7-10 m intervals and about 15-30 mm in width. Average rutting was less than 6 mm.

A detailed pavement investigation was conducted which indicated an overlay need of 40 mm. Due to curb and gutter constraints, overlaying was not a viable option. Reconstruction was cost prohibitive and road closures and traffic detour management would have become very challenging. The larger problem was the functional deficiency of the road due to numerous surface distresses. Engineering study, based on life cycle cost analysis recommended the conventional treatment to cold mill 100 mm of existing pavement and inlay with 100 mm ACP. The geosynthetic alternative proposed was to cold mill 70 mm, install a fiberglass grid composite TE-FGS10 and inlay 70 mm ACP. The resulting net saving was about 14 % compared to conventional treatment. The general condition of the pavement after cold milling of ACP is depicted in figure 1.

Figure 1 - General pavement condition of Sarcee Trail after cold milling of ACP

101 Street

101 Street is a two lane undivided rural road with one lane in each direction. The section selected for pilot project was about 2 km in length. The typical condition of the pavement is indicated in figure 2.

Figure 2 - General pavement condition on 101 Street

Pavement boreholes indicated that the ACP thickness was about 100-125 mm, placed on medium to high frost susceptibility subgrade material. However there were two short stretches at approaches to intersection in the NBL that had granular base course (GBC) layer. The road connects Highway 8 on the south and to the gravel pit and asphalt and concrete plant to the north. Hence, the route is predominantly used by heavy trucks. Observed pavement distresses were extensive and high severity transverse cracking, semi continuous medium severity fatigue cracking and frequent centerline cracking. Transverse cracks were generally spaced at 20 m intervals and about 25-50 mm in width most of them were sealed. The average rutting was less than or equal to 9 mm.

To address fatigue cracking several asphalt skin patches were placed. However, the moisture trapped in the subgrade was pumping up under heavy truck loading, causing the disintegration of patches. New patches were not lasting more than a few weeks, requiring significant maintenance in spring and summer seasons.

Pavement investigation indicated the need for reconstruction. Furthermore, design called for drainage improvements and removal of frost-susceptible soils to a depth of up to 2 m deep. Reconstruction was ruled out due to budgetary constraints and also due to the fact that the road may be salvaged within 7-10 years with the development of the ring road. Based on the failures of the maintenance patches, thin mill and inlay was not considered as a viable option. Deeper mill and inlay of 80 mm was evaluated as an interim alternative. Since the average ACP thickness was relatively thin, overlaying over a thin layer of old ACP was considered as a risk.

To address the functional deficiency of the road and to improve the ride quality, fiberglass grid bonded with non-woven geotextile material was considered. It was believed that the geotextile would serve as a moisture barrier and the grid would provide additional reinforcement. To stay within the budget and at the same time to address some of the major concerns on an interim basis, 40-50 mm mill and inlay using SP 12.5 NMS with PG 70-31 binder with fiberglass grid composite as a reinforcing interlayer was the chosen option. Details of the conventional technique and the alternative proposal employing fiberglass grid composite reinforcement are summarized in Table 3.

Table 3 - Rehabilitation techniques for 101 Street

Section	***Conventional Method***	***Alternative using Fiberglass Grid Composite***
101 Street SW Between Glenmore Trail and 17 Ave.	Mill 80 mm and inlay with ACP 80 mm thick in two lifts (30 mm + 50 mm)	Mill 40-50 mm, Lay FiberGlass Grid TE-FGC10 and place ACP 40-50 mm thick (savings in asphalt material, cost reduction of \$ 8.78/m^2)

50^th^ Ave.

50 Ave. is a four lane undivided rural road with two lanes in each direction, a designated truck route with 20% truck traffic. The section selected for pilot project was about 0.5 km in length on the westbound lanes (WBL). Figure 3 shows typical conditions of the pavement

Figure 3 - General pavement condition on *50th Ave.*

GPR tests, pavement coring and bore holes indicated ACP thickness of about 250-300 mm with 400 mm of GBC. Observed pavement distresses were predominantly extensive and medium severity rutting, few transverse cracks of medium severity and few and low to medium severity fatigue cracking. Typical rutting was about 9 mm and 20 mm at approach to 25 Ave. intersections.

The ACP overlay need was 80 mm, but due to similar constraints as that of Sarcee Trail, reconstruction was not considered. The adopted treatment was to mill the existing distressed pavement to the specified depth, place first lift of asphalt (40 mm), install a fiberglass grid with polymeric coating TE-

FGP10 and provide 50 mm top lift asphalt concrete pavement. The intent was to evaluate whether the rutting performance would improve with the use of fiberglass grid and to observe the pavement strength enhancement.

Details of Asphalt Reinforcement Products

Three different products were used in the field trails – TE-FGS10, TE-FGC10 and TE-FGP10. The important characteristics of these products are summarized in Table 4.

Table 4 - Details of fiberglass grid and composites

Location	*Fiberglass Reinforcement Used*	*Important Properties*
Sarcee Trail SW	TE-FGS10 Fiberglass Grid Composite	Grid: Polymer coated fiberglass grid with 12.7 x 12.7 mm Apertures Geotextile: Very thin spun-bond nonwoven geotextile Ultimate tensile strength: 100 x 100 kN/m (MARV) Secant stiffness EA at 2 % elongation: 3750 kN/m (MARV
101 Street SW	TE-FGC10 Fiberglass Grid Composite	Grid: Polymer coated fiberglass grid with 12.7 x 12.7 mm Apertures Geotextile: 150 g/m2 nonwoven needle-punched geotextile with asphalt retention of 1.5 l/m^2. Ultimate tensile strength: 100 x 100 kN/m (MARV) Secant stiffness EA at 2 % elongation: 3750 kN/m (MARV)
50^{th} Ave. SE	TE-FGP10 Fiberglass Grid	Grid: Polymer coated (with pressure sensitive self-adhesive backing) fiberglass grid with 12.7 x 12.7 mm apertures Ultimate tensile strength: 100 x 100 kN/m (MARV) Secant stiffness EA at 2 % elongation: 3750 kN/m (MARV)

The fiberglass grid with a high tensile modulus is expected to reinforce the asphalt thus enhancing its resistance to fatigue cracking and rutting. Thus a reinforced asphalt pavement of lesser thickness theoretically can have the same structural strength of an unreinforced asphalt pavement of greater thickness.

The objectives of a composite by bonding a nonwoven geotextile to the fiberglass grid are twofold:

- When saturated with tack coat the nonwoven geotextile becomes an impervious membrane which acts as a moisture barrier preventing the entry of surface water into the pavement.
- The geotextile is generally considered to help installation by providing better bond to the existing pavement. Under favourable conditions this could facilitate installing fiberglass grid composites directly on milled surfaces, thereby avoiding a leveling course.

Design of Reinforced Asphalt Pavements

Geogrid reinforced base and sub-base courses are usually designed using a modification of the

AASHTO method of design of flexible pavements in which the contribution of the reinforcement is quantified in terms of a layer coefficient ratio which is determined using laboratory tests or full-scale trafficking tests in the field. However, in the case of reinforced asphalt pavements, widely accepted rational design methods are yet to be developed. The design of reinforced asphalt pavements are usually based on experience and engineering judgment. For the present pilot projects also, the thickness of the reinforced asphalt pavements were decided based on the manufactures experience and also available information in the technical literature. The absence of rational design methods underscores the need for carefully planned and scientifically monitored field trials which can contribute to a better understanding of the performance of reinforced asphalt pavements and assist the development of rational design methods.

INSTALLATION

The construction was carried out in accordance with the City of Calgary Roads specifications and practice. Fiberglass grid was installed on a newly laid first lift of ACP on Sarcee Trail and 50 Ave. except that a composite grid was used on Sarcee and a normal fiberglass grid was used on 50 Ave. on 101 Street, fiberglass grid composite was placed on prepared milled surface after applying tack coat at a rate of 0.75 litres/m^2. Whereas on other two projects with levelling course, tack coat was applied at a rate of 0.5 litres/m^2. These are summarized in Table 5.

Subsequent to milling, on Sarcee Trail the old ACP that was in poor condition started stripping under traffic which led to development of potholes. Hence the potholes and cracks were cleaned, tack coated using SS1, patched with asphalt concrete, and compacted prior to placing the first lift of ACP. SS1 tack coat was applied at a rate of 0.5 liters/m^2 and then the fiberglass grid was installed when tack coat has started curing. Grid was placed using the pick-up truck that was retrofitted to accommodate this installation. The grid was rolled with steel rollers to create good bond with the layer beneath. Once the track coat had cured, final lift of asphalt was placed and compacted using standard compaction equipments and procedures. Installation of fibreglass grid and composite is illustrated in figures 4 – 8.

Table 5 - Surface preparation and Installation of grid

Road Name	***Pavement Structure and Sequence of Placement***
Sarcee Trail SW	Mill 70 mm of existing ACP Tack coat and place 30 mm ACP (1st lift) Tack coat and place fiberglass grid composite Place 40 mm ACP (top lift) Asphalt mix SP 12.5 NMS, PG 70-31; Tack coat SS1 @ 0.5 liters/m^2
101 Street SW	Mill 40-50 mm of existing ACP Tack coat and place fiberglass grid composite Place 40-50 mm ACP (Single lift) Asphalt mix SP 12.5 NMS, PG 70-31; Tack coat SS1 @ 0.75 liters/m^2
50 Ave. SE	Mill 90 mm of existing ACP Tack coat and place 40 mm ACP (1st lift) Tack coat and place fiberglass grid Place 50 mm ACP (Top lift) Asphalt mix SP 12.5 NMS, PG 70-31; Tack coat SS1 @ 0.5 liters/m^2

Figure 4 - Sarcee Trail Grid Installation – well placed and bonded

Figure 5 - Sarcee Trail Grid Installation – not well placed

Figure 6 - Sarcee Trail Grid Installation – Excessive Overlapping corrected on site

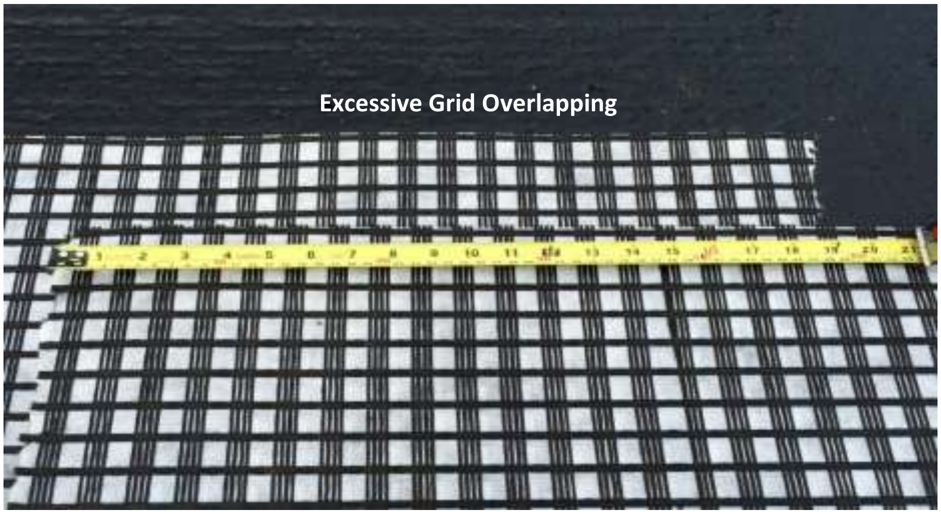


Figure 7 - 101 Street paving on Installed Grid

Figure 8 - 50 Ave. Grid Installation and Paving

BOND BETWEEN REINFORCEMENT AND ASPHALT

A key learning from the pilot projects is the importance of developing good bond between the reinforcement and asphalt concrete for a successful installation. Good bond must develop between the existing pavement and the reinforcement, between the reinforcement and the overlay and between the new asphalt and the existing asphalt. Several factors influence the interface strength development

- Proper filling and sealing of cracks and irregularities in the existing pavement
- Uneven surface of the existing pavement after milling
- Insufficient or poor tack coat
- Excessive wrinkles or inadequate tension in the reinforcement
- Type of product including whether grid or composite, aperture size, type of coating, self-adhesive

It is important to properly treat cracks, pot-holes and other irregularities of the existing pavement prior to placing the reinforcement, so that a good bond develops between the existing pavement and the reinforcement.

In the case of a milled pavement surfaces, the surface irregularities may prevent the development of good bond with the reinforcement. It is a good practice to provide a thin asphalt leveling course, typically about 20 mm thick over the milled surface and then place the reinforcement on the surface of the leveling course. This can ensure a good bond. However, providing a leveling course increases the time of construction. There were some indications that if a fiberglass grid composite (in which a nonwoven geotextile is bonded to the fiberglass grid) was used, perhaps the leveling course may not be necessary. In the field trials two types of composites were installed directly over milled surfaces – TE-FGS10 and TE-FGC10. It was found that in the case of TE-FGS10 with a relatively thin nonwoven, direct installation over milled surfaces gave rise to some problems. This was due to inadequate sealing of cracks and potholes and ACP cover provided (25 mm) was well below the recommended 40 mm. The experience with TE-FGC10 with a thicker nonwoven was better; the product could be successfully installed over treated milled surfaces. However, the thicker geotextile requires increased rate of application of tack coat in the range of 0.75 litres/m^2.

Cores of reinforced asphalt pavements were sent to SGI Testing Services (GAI-LAP accredited geosynthetics laboratory) Norcross- GA , USA to conduct interface shear testing as per ASTM D 5321 modified test method in order to determine the shear strength of the Fiberglass grid composite in the asphalt concrete. The test setup is shown in figure 9 and the core is shown in figure 10.

Figure 9 - Interface testing of reinforced asphalt concrete cores

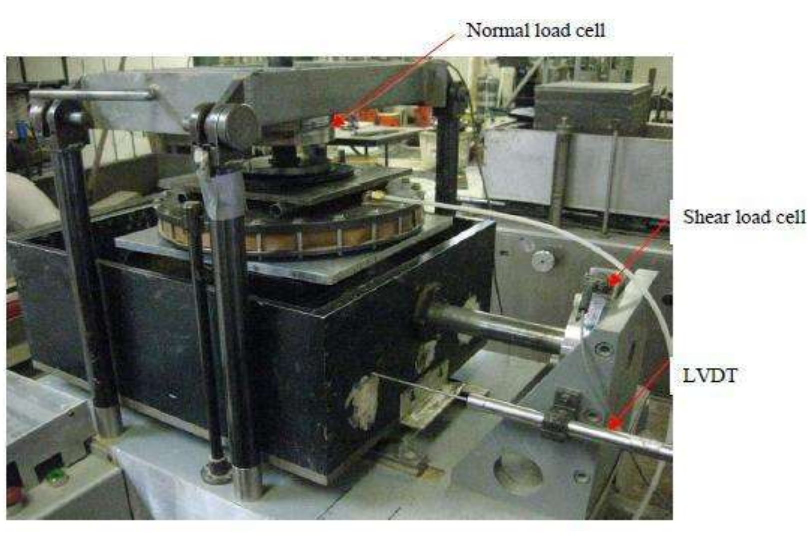


Figure 10 - Asphalt concrete core with fiberglass grid composite layer

Typical failure mode is illustrated in figure 11. Slipping occurred by separation of the nonwoven geotextile from the fibreglass. This suggests that the interface strength provided by a composite may be low because of the relatively low bond strength between the grid and geotextile components of the composite.

Figure 11 - Typical failure mode by slipping at the interface between fiberglass grid and nonwoven geotextile

The interface test results suggest that fiberglass grid composites should be used with caution since these products may have low interface strength due to the low bond strength between the grid and nonwoven textile components. The advantages of having a geotextile – bonding to milled surfaces and functioning as moisture barrier – may be offset by the poor interface shear strength. In the case of fiberglass grids, there is a large open area across which the old and new asphalt pavements could develop good bond.

EARLY PERFORMANCE EVALUATION

It is proposed to carry out periodic evaluation of the performance geosysthetics on three Roads of the City of Calgary (101 St SW, Sarcee Trail and 50 Ave. SE. IRI measurements and visual inspections were arranged to identify superficial distress like wheel path rutting, fatigue cracks, longitudinal and transverse cracks, edge cracking etc. The last visual evaluation was carried out in mid April /2017, and a new IRI evaluation is expected to be carried out this summer 2017.

Post- paving IRI Analysis

For the selected road segments treated with fibreglass grid/composite interlayers, IRI - roughness index was measured for evaluating the longitudinal road profiles and the values are presented in Table 6.

Table 6 – Post rehabilitation smoothness testing Comparison

Road Name	Direction	Average IRI October 2015	Average IRI March 2016	Average IRI July 2016	Average IRI Feb 2017	Average IRI June 2017
101 Street SW	Northbound Lane	1.28	2.71	1.38	2.74	1.46
	Southbound Lane	1.28	2.88	1.44	2.76	1.51
Sarcee Trail SW	Northbound Lane 1 (Median)	1.34	Not tested	Not tested	Not tested	1.40
	Northbound Lane 2 (Curb)	1.06	Not tested	Not tested	Not tested	2.27
50 Ave SE 25 St E 30 St E	EL1 (Median)	Not tested	Not tested	Not tested	Not tested	1.52
	EL2 (Curb)	Not tested	Not tested	Not tested	Not tested	1.69
	WL1 (Median)	Not tested	Not tested	Not tested	Not tested	1.52
	WL2 (Curb)	Not tested	Not tested	Not tested	Not tested	1.59

IRI is a performance indicator of the physical condition of a pavement and it is also used as a trigger level to identify whether pavement in need of rehabilitation. The values presented in Table 6 are in the range of acceptable values of paved lots according to the “2015 Smoothness Specification of the city of Calgary”.

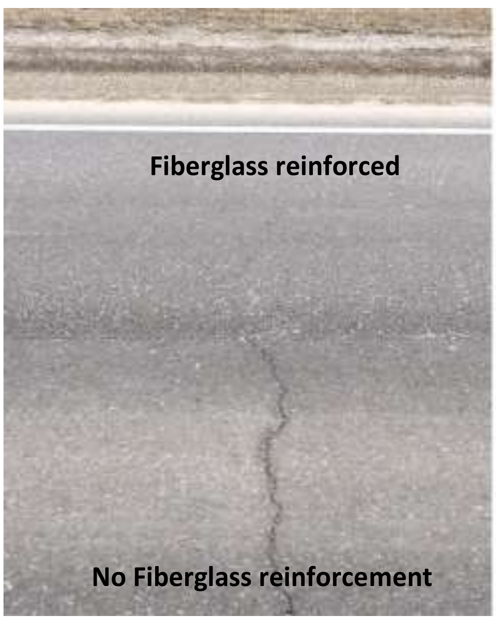
Visual evaluation

The following assessment of the three segments reinforced with asphalt reinforcement interlayers is based on the survey carried out in mid April 2017.

Sarcee Trail

The road, in general was in very good condition and offers very good riding quality. Some surface distresses were evident in the non-reinforced lane (curb lane). As seen in figure 12 , transverse cracks have propagated in the non-reinforced section and it stops at the joint where fiberglass grid reinforcement starts. This pattern was very much consistent along the section. About 25% of the cracks have propagated. Only two of those cracks were found on the fiberglass grid section. Although at a few locations segregation was observed, longitudinal and fatigue cracks or rutting were not noticeable on the wheel paths in the reinforced sections. There was slight separation/gap between the pavement surface and the curb & gutter likely due to lack of tack coat on the vertical edge.

Figure 12 - Sarcee Tr. – Transverse crack originates in non-reinforced median lane and stops at the fiber reinforced curb lane



101 Street SW

Pavement distress was identified during the visual inspection in 2017. While in 2016 Fall inspection only about five (5) transverse cracks had reflected through, in 2017 about 47 cracks were observed in between Glenmore and Lower Springbank Road and 13 were found between Lower Springbank and 17 Av SW. These cracks were of slight severity as shown in figure 13. It is important to mention that no drainage concerns were found on the site. No wheel path rutting was observed as shown in figure 14, and no loose aggregate situation was present on the surface.

Figure 13 - 101 Transverse crack have propagated through on 101 Street

Figure 14 - General condition of 101 Street

The pavement surface was generally in good condition; transverse and longitudinal cracks were between 6- 12 mm wide, some reflecting cracks were identified; alligator cracking was not evident in wheel paths. Seems like minor patching has been done on the surface, some oxidation of the pavement surface was present, and few low severity depressions were visible.

50 Ave. SE

According to the traffic patterns and road classification, the pavement is in excellent condition as shown in figure 15; the surface appears to be very smooth and is almost free of distress except for one longitudinal crack of about 8 m long and one half lane width transverse crack (less than 4 mm width) on the westbound and is in half lane from crown. This section of the road has some check-cracking before the railway intersection (westbound) and besides the curb and gutters on some spots, might be due to some compaction issues. No rutting in wheel paths was visible.

Figure 15 - General condition of 50 Ave.

CONCLUSIONS

The City has tried to evaluate the usefulness and viability of different kinds of fiberglass grid and composites through the pilot program. However it was learnt through the installation process that due care must be taken to install the reinforcement as per the approved installation methodology. Where it was installed properly, the early experience shows the product is performing fairly well. Of concern is the fiberglass composite grid with thicker non-woven geotextile material that was used on rural road where further investigation is needed to evaluate the performance, especially when placed directly over a milled surface.

In the coming season, The City will continue to monitor the visual distresses through automated data collection, falling weight deflectometer (FWD) testing, smoothness testing and visual inspections. It is also planned to core the samples and test the bond strength.

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