

Design and construction of a geosynthetic reinforced pavement on weak subgrade

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*Challenges from North to South
Des défis du Nord au Sud*

ABSTRACT

This paper describes the salient features of the design and construction of a geosynthetic reinforced pavement and presents initial assessment of the performance. The project involved rehabilitation of old and damaged roads in the City of Calgary in Canada. At many locations the existing pavement was a full-depth asphalt pavement which was up to 20 years old and was in a distressed state. Poor sub-grade conditions were indicated to be one of the major causes for the distress in the pavement. As part of the city roads rehabilitation program, it was required to reconstruct the pavement as a pilot project. The proposed solution required replacement of the existing distressed pavement with a design comprising asphaltic concrete, granular base and granular sub-base. This required excavations to accommodate the designed pavement thickness. To minimize the disruptions and inconvenience to the road users, it was desirable to minimize the depth of excavation. Therefore it was necessary to minimize the pavement thickness as far as possible. It is known that reinforcement of the pavement with geosynthetics enhances the strength and stiffness of the pavement and also contributes to the fatigue life of the overlay and hence a reinforced pavement of lower thickness can give the same level of performance as an unreinforced pavement. Alternatives with different types and combinations of geosynthetics were evaluated. A design in which a bitumen coated fiberglass grid was incorporated at the center of the asphalt concrete layer and a biaxial geogrid composite comprising of a stiff polypropylene biaxial geogrid bonded to a nonwoven geotextile was incorporated at the bottom of granular sub-base was finally adopted for one section and only bitumen coated fiberglass grid was incorporated for the other section. The pavement was constructed without any significant issues and the initial assessment of the performance seems to be quite encouraging. The paper describes the site conditions and constraints, evaluation of alternative designs, design of the geosynthetic reinforced pavement, construction and the initial assessment of performance.

RÉSUMÉ

Le présent document décrit les principales caractéristiques de la conception et de la construction d'une chaussée renforcée par un matériau géosynthétique et décrit l'évaluation initiale de son rendement. Le projet visait la remise en état de vieilles routes endommagées à Calgary, au Canada. En de nombreux endroits, la chaussée existante, entièrement en asphalte, datait d'une vingtaine d'années et était lourdement endommagée. Selon des indications, le mauvais état du sous-sol était l'une des principales causes de la détérioration importante de la chaussée. Il fallait, dans le cadre du programme de remise en état des routes de la ville, reconstruire la chaussée. La solution proposée nécessitait le remplacement de la chaussée endommagée existante par une structure composée d'une base en béton asphaltique et granulaire et d'une fondation granulaire. L'épaisseur de la chaussée voulue nécessitait des travaux de terrassement. Pour que les usagers des routes subissent le moins de perturbations et d'inconvénients possibles, il fallait réduire au minimum l'ampleur de ces travaux. Il fallait donc réduire le plus possible l'épaisseur de la chaussée. On sait que l'armature de la chaussée par des matériaux géosynthétiques en renforce la solidité et la rigidité et contribue également à la durée de vie du revêtement, ce qui veut dire qu'une chaussée renforcée de moindre épaisseur peut donner le même rendement qu'une chaussée non renforcée. Des solutions de rechange faisant appel à des combinaisons et à des types différents de matériaux géosynthétiques ont été évaluées. On a finalement décidé d'adopter pour un tronçon une conception dans laquelle une grille de fibres de verre recouverte de bitume a été intégrée au centre de la couche de béton asphaltique et un composite de géogridle biaxiale, comprenant une géogridle biaxiale en polypropylène rigide liée à un géotextile non tissé à fibres longues, a été intégré à la base de la fondation granulaire, et pour l'autre tronçon, de n'utiliser qu'une grille en fibres de verre recouverte de bitume. La chaussée a été construite sans problèmes particuliers et l'évaluation initiale du rendement semble donner des résultats très encourageants. Le document décrit les conditions et les contraintes du site, l'évaluation des autres possibilités de conception, la conception de la chaussée renforcée par des matériaux géosynthétiques, la construction et l'évaluation initiale du rendement.

1 INTRODUCTION

As a part of the City of Calgary's Pavement Rehabilitation Program, strengthening and rehabilitation of distressed pavements is being carried out for many roads. The

treatment ranges from milling and inlay / overlay at most locations to full-depth reconstruction at some locations.

The challenges involved in the design and construction of pavement were two fold – to arrive at the most economical cross-section of the pavement that meets the

performance requirements and to complete the construction with minimum disruptions to traffic and inconvenience to road users. A solution which achieved a balance between these two objectives would be the most optimum. Reductions in the depth of excavation, depth of milling and thickness of inlay / overlay would help to achieve both objectives, i.e. savings in cost and reducing construction time and inconvenience to road users.

The benefits of using geosynthetics in pavements are well-known. These include reduction in the thickness and enhancement of the performance of the pavement (Lytton, 1989, Austin & Gilchrist, 1996, de Bondt, 1999, Perkins, 2002, Koerner, 2005, Anon, 2008, Holtz et al. 2008, Zornberg et al. 2008). Hence use of geosynthetics should be considered as an option. However, quantification of the actual benefits arising from the use of geosynthetics involves some difficulties. Realizing the significant potential benefits of geosynthetics and other materials and the difficulties involved in a realistic and reliable quantification of the benefits, City of Calgary engineers, decided to carry out a pilot program to evaluate the performance of geosynthetics in pavements under actual field conditions. Two pilot test locations were identified one in 17 Avenue SW and the other in Sarcee Tr. SW Richmond Road to South Corner of Optimistic Athletic Park.

17 Avenue SW is a major East-West arterial road in the south-west quadrant of the city of Calgary. Strengthening and rehabilitation of the pavement was carried out at several locations on this road. At locations where, the existing condition of the pavement was poor, complete reconstruction of the pavement was required, referred to as Tier 2 repairs. This would involve removal of the existing pavement and excavation up to the required level to accommodate the designed pavement thickness. Alternative design incorporating a biaxial geogrid composite at the interface between the subgrade and the granular base and a precision knitted fiberglass grid to reinforce the asphalt concrete layer was considered for this section.

For the Sarcee Tr. SW Richmond Road pilot test location which exhibits extensive moderate to high severity transverse and longitudinal cracks, milling and inlay width asphalt concrete has been proposed. The asphalt concrete inlay will be reinforced with a newly created TE-FGS10 fiberglass grid composite comprising of TE-FG10 fiberglass grid bonded to a light-weight (50gsm minimum) spun bonded polyester non-woven geotextile, this composite system is intended to facilitate easy installation and to provide an additional benefit of moisture proofing along with reinforcement.

This paper describes the details of the geosynthetic reinforced pavement adopted for the 17 Avenue SW location including considerations in the selection of geosynthetic products, design and construction.

2 SELECTION OF GEOSYNTHETICS AND DESIGN OF PAVEMENT

2.1 Geosynthetics in Pavements – Locations, Functions and products

Geosynthetics can be used in pavements in several ways:

- At the interface of the subgrade and granular subbase for separation and stabilization or as a capillary barrier. Here the functions may include one or more of the following - separation, filtration, reinforcement and drainage. The products include nonwoven and woven geotextiles, biaxial geogrids, geocomposites, etc.
- As a reinforcement within the granular subbase or granular base to enhance the strength and stiffness of the unbound aggregates. Product used is typically a biaxial geogrid.
- As a reinforcement of the asphaltic concrete layer where fiberglass grids are the most widely used product.
- A nonwoven asphalt overlay fabric as a stress-absorbing interlayer and moisture barrier between existing pavement and asphalt overlays.
- Other applications include use of geotextiles as a filter in aggregate drains, edge drains etc.

2.2 Selection of Geosynthetics

From the numerous available combinations of products and functions, the designer has to choose the optimum solution. Here the major considerations are the type of subgrade, site constraints and performance requirements. At the location selected for pilot study, the subgrade was a silty sand. Since this was a pavement reconstruction project, potential reduction in the thickness of the pavement was an important consideration. For the solution to be considered successful and suitable for wider application, it also needs to be economical. After evaluating different possible options, use of a bonded biaxial geogrid-nonwoven geotextile composite at top of subgrade and a bonded fiberglass grid – nonwoven geotextile composite within the asphalt concrete layer was considered to be the best option.

A bonded biaxial geogrid – nonwoven geotextile composite was considered since it can perform the functions of separation, filtration and reinforcement. The geotextile component acts as a separator and filter between the subgrade and the granular base preventing the intermixing of the layers during construction and service, thereby preserving the designed thickness and quality of the granular subbase. The apertures of the biaxial geogrid interlock with the aggregates and provided a high degree of lateral restraint. This greatly enhances strength and stiffness of the unbound aggregate layers. Also, as a single monolithic product, the composite is easy to handle and install.

A precision knitted bi-axial fiberglass grid with bituminous coating and a self adhesive backing was selected because it can function as a reinforcement and a stress relieving interlayer. The very high tensile modulus of the glass fibers enables the fiberglass grid to mobilize high tensile stresses at a low elongation and to function as an effective reinforcement to asphalt. Bituminous coating further optimizes the chemical compatibility between the fiber glass reinforcement and the pavement overlay. This bonding ensures that the reinforcing grid is in a position to accept the tensile stresses and to

distribute them. The asphalt particles penetrate through the optimal apertures of the fiberglass Grid and achieve high interlock and bonding among asphalt particles and allows two lifts of asphalt to be bonded effectively.

2.3 Properties of the Biaxial Geogrid Composite

The product selected was Titan's TE-BXC30, a biaxial geogrid composite consisting of a punched and drawn polypropylene biaxial geogrid with integral nodes which was bonded to a nonwoven needle-punched continuous filament nonwoven geotextile. The geogrid has same tensile properties in both machine and transverse directions. It has an aperture size of 34 x 34 mm and an ultimate tensile strength of 31.0 kN/m. The load at 2% and 5% elongation is 12.0 and 22.0 kN/m respectively. It has junction efficiency > 95%, aperture stability of 0.75 m-N/deg measured at an applied moment of 20kg-cm and carbon black content of 2%. The nonwoven geotextile has a mass per unit area of 200 g/m², grab tensile strength of 650 N, trapezoid tear strength of 300 N, CBR puncture strength of 2400 N and apparent opening size of 0.18 mm.

2.4 Properties of the Fiberglass Grid

The product selected for asphalt reinforcement was Titan TE-FG10, a precision knitted fiberglass biaxial grid with self adhesive backing. The grid has an ultimate tensile strength of 100 kN/m (MARV) in both directions, with the elongation at failure less than 3%. The tensile strength mobilized at 2% elongation is 87 kN/m. The nominal aperture size is 25.4 x 25.4 mm. The geotextile has a mass per unit area of 460 g/m². The fiberglass grid is coated with a custom formulated bituminous material to ensure excellent adhesion with the asphalt concrete layers.

2.5 Layer Coefficient Ratio (LCR)

Several laboratory and field studies have demonstrated the significant improvements in pavement performance resulting from the use of geosynthetics. The benefits are usually quantified in terms of a layer coefficient ratio (LCR) or a traffic benefit ratio (TBR). Layer Coefficient Ratio is defined as the ratio of the layer coefficient of the geosynthetic reinforced layer to the layer coefficient of the unreinforced layer. Traffic Benefit Ratio is the number of standard axles required to produce a certain rut-depth in the reinforced pavement to the number of standard axles required to produce the same rut-depth in the unreinforced pavement with other conditions remaining same.

The concept of the layer coefficient ratio, permits the design of the geosynthetic reinforced pavement to be carried out using a modification of the AASHTO method. In the AASHTO method for the design of flexible pavements, the structural number (SN) of the pavement is calculated as:

$$SN = a_1 d_1 + a_2 d_2 m_2 + a_3 d_3 m_3 \quad [1]$$

where a_1 , a_2 and a_3 are the layer coefficients of the asphalt concrete, granular base and granular subbase layers respectively, d_1 , d_2 and d_3 are the thicknesses in inches and m_2 and m_3 are the drainage coefficients.

If a_i is the layer coefficient of an unreinforced layer, then the layer coefficient of the reinforced layer (a_{ir}) may be calculated as the product of LCR_i and a_i . The structural number of the reinforced pavement (SN) may be calculated using the layer coefficients of the reinforced layers.

The layer coefficient ratio (LCR) for a product depends on the mechanical properties of the product. However, even for a particular product, LCR is not a constant and may depend on many factors like thickness of the layer, location of the layer, characteristics of the subgrade etc.

2.6 Pavement Design

The design of the pavement was carried out based on the following data:

- Design traffic : 16 million Equivalent Single Axle Load (ESAL, 30 years)
- Reliability : 95 %
- Overall standard deviation : 0.45
- Initial design serviceability index : 4.2
- Terminal serviceability index : 2.5
- Subgrade resilient modulus : 25 - 32 MPa

Based on the above data, the required structural number was calculated as 6.53.

The proposed configuration of the pavement included a granular subbase (with a nominal maximum particle size of 80 mm), granular base (with a nominal maximum particle size of 25 mm) and hot-mix asphalt. Based on the gradation and specifications, the design values of layer coefficients for the different layers were as follows:

- Granular subbase : 0.10
- Granular base : 0.14
- Asphaltic concrete : 0.40

The layer coefficient ratio (LCR) depends on various factors like mechanical properties of the geosynthetic reinforcement, thickness of the pavement layer, location of the reinforcement within the pavement layer etc. LCR's may be evaluated based on field testing or repeated load testing in the laboratory simulating field conditions. A test program carried out at an independent GAI-LAP accredited laboratory for a biaxial geogrid identical in all respects to the geogrid component of TE-BXC30, except that the tensile strength was 26 kN/m (in comparison to 31 kN/m for TE-BXC30) showed an LCR value of 1.54 (SGI Testing Services, 2011). This implies that that for the biaxial geogrid composite) (with higher tensile strength) the LCR values are likely to be higher. However, taking a conservative approach LCR values in the range of 1.3 – 1.4 were considered for the biaxial geogrid composite. For the fiberglass grid LCR of 1.2 – 1.25 was considered in design based on experience with similar products.

The City of Calgary Road Specifications prescribes the following minimum thickness for layers for roads with traffic > 5 million standard axles:

- Asphalt concrete : 200 mm (100 mm each for Mix B Bottom Lift, Mix A Top Lift);

- Granular base : 100 mm
- Total granular thickness : 300 mm

The pavement configuration was finalized such that it satisfied the requirements with respect to the structural number and also the above minimum specified thickness for the layers. Use of reinforcement helped to reduce the depth of excavation by reducing the total thickness of the pavement by about 200 to 350 mm. An alternative was to use greater thickness of asphalt concrete, but this would have been a costlier option.

3 PAVEMENT CONFIGURATION FOR PILOT PROJECT

For the reconstruction of 17 Avenue SW eastbound lanes, two locations (west and east) were identified for the pilot study of geosynthetic reinforcement. The pavement configurations adopted for the west portion is shown in figure 1 and that for the east portion is shown in figure 2. It may be seen that the only difference was that in the east portion, the fiberglass grid geotextile composite was not used. Hence comparison of the performance between east and west portions could yield some information on the contribution of the fiberglass grid in performance of the pavement.

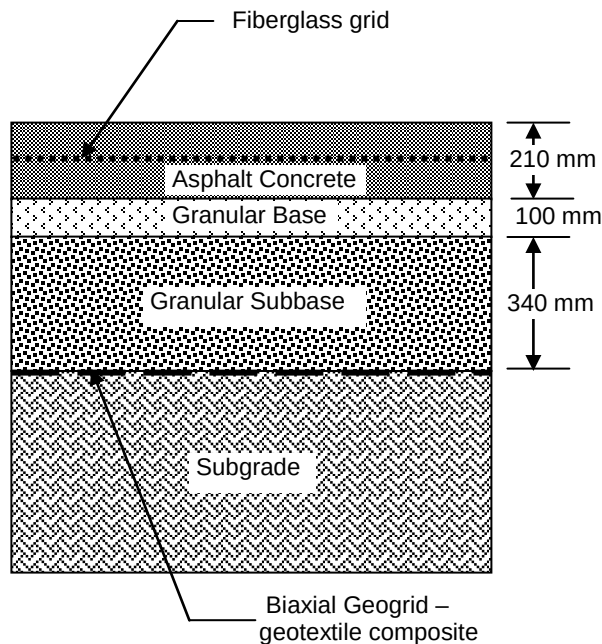


Figure 1. Pavement configuration – west portion

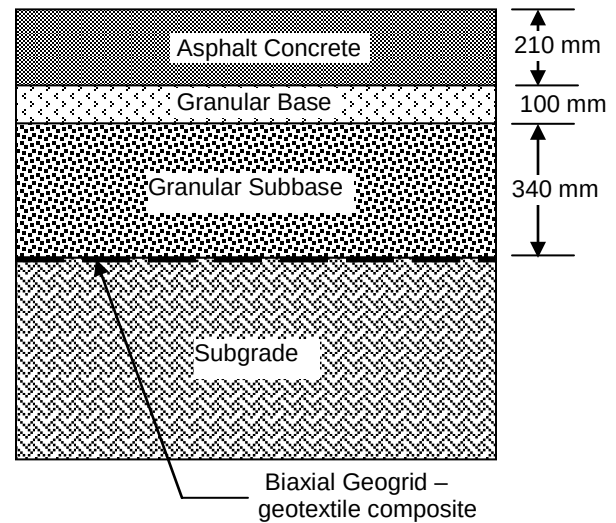


Figure 2. Pavement configuration – east portion

4 CONSTRUCTION

The construction was carried out in accordance with the City of Calgary Roads specifications and practice. The sequence of operations for the west portion was as follows. After making arrangements for diversion of traffic, the road was excavated to the required level. The approximate depth of excavation was 650 mm. The biaxial geogrid geotextile composite was installed on the surface of the excavated subgrade. The granular subbase was placed and compacted in two lifts. Next, the granular base was placed and compacted in a single lift (100 mm thick). The asphalt concrete layer of 210 mm thickness was placed in two lifts. After application of prime coat and tack coat over the finished granular base, first lift of asphalt concrete of 110 mm thickness was placed and compacted. After application of tack coat, the fiberglass grid was laid and over this the second lift of asphalt concrete was placed and compacted. For the east portion also the procedure was same except that the fiberglass grid was not provided at this location. Installation photographs are shown in figures 3, 4, 5, 6 and 7.



Figure 3. Laying of biaxial geogrid composite



Figure 4. Placing granular subbase over the biaxial geogrid geotextile composite.

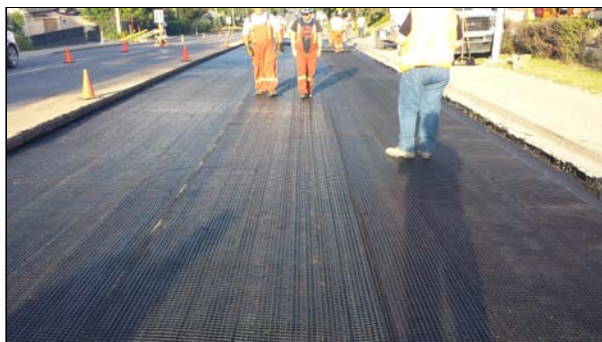


Figure 5. Fiberglass grid installed over the first lift of asphalt concrete.



Figure 6. Placing the second lift of asphalt concrete (over the fiberglass grid).

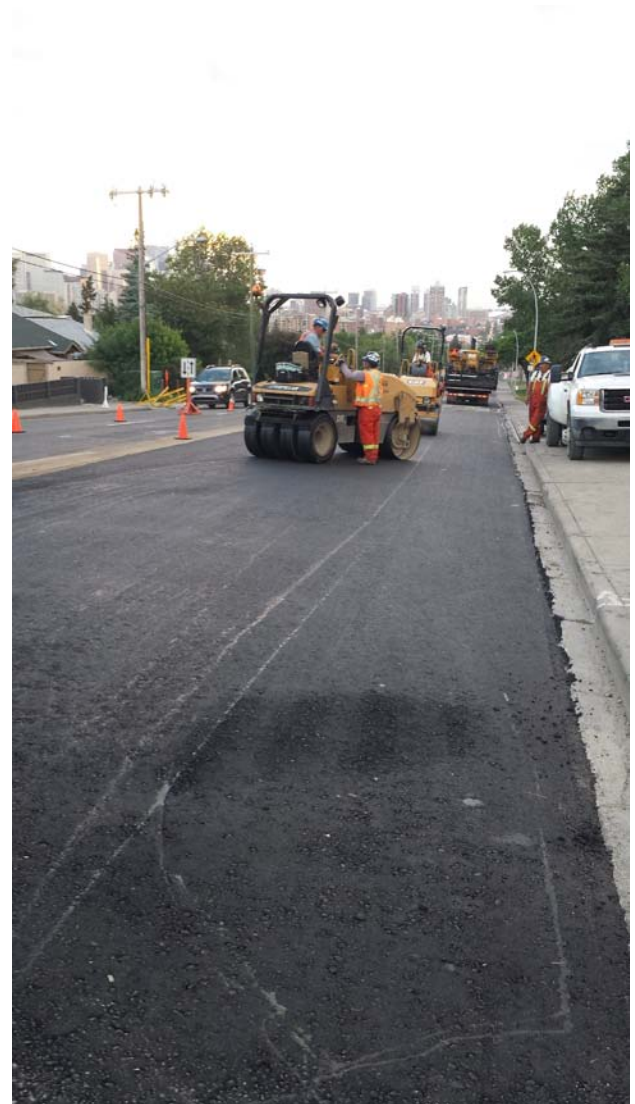


Figure 7. Final view after completion of construction

5 MONITORING

The objective of this pilot project is to evaluate the benefits of using geosynthetics in pavements. Valuable data can be obtained by proper monitoring of these test sections. It is proposed to monitor the condition of the pavement at regular intervals. Occurrence of cracks, deformation and roughness etc. would be recorded and formulated into standard quantitative measures of pavement condition like pavement distress index, rut depth and international roughness index. By comparing with the performance of the control sections, a realistic and reliable assessment of the effectiveness of geosynthetic reinforcement could be made. This product is environmentally friendly, easy to recycle due to being a natural material made out of quartz sand.

6 CONCLUSIONS

The combination of a biaxial geogrid – geotextile composite installed at the top of subgrade and a bituminous coated fiberglass grid placed within the asphalt concrete layer was evaluated as the optimum reinforcement solution for the reconstruction of an asphalt pavement in poor condition. With the incorporation of geosynthetic reinforcement, significant reduction in pavement thickness could be achieved. This reduced the required depth of excavation and thus minimized the problems during construction. Monitoring of the pilot sections would give valuable data for a realistic and reliable assessment of the benefits of geosynthetic reinforcement in pavements.

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