Pilot Case Study of Geogrid Reinforcement in Concrete

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ABSTRACT: Advanced geogrid used as an alternate to conventional steel for concrete reinforcement is an innovative, non-corrodible material technology in the world of geosynthetics. This advanced geogrid is woven or knitted, made of high modulus fiberglass or basalt fiber and coated with a stiff modified polymer coating. It is well known that steel corrodes with time and possesses a risk to the reinforcement integrity. The goal of developing the geosynthetic concrete reinforcement is to replace conventional steel as reinforcement for concrete in both aggressive and non-aggressive environments. This newly developed geogrid called ConForce Grid, features a woven grid structure; high modulus glass fibers with stiff engineered polymeric coating, and open apertures. Its design is intended to facilitate a solid mechanical interlock between the geogrid apertures and concrete. This would result in an increase in the tensile, flexural and shear strength of regular concrete and provide post-crack ductility of the concrete structure. This paper presents preliminary results from studies on two applications of ConForce Grid as concrete reinforcement. The first is a pilot field case study showing the use of ConForce Grid in concrete sidewalks using 125 mm thick concrete slabs to control the shrinkage cracking on the surface and increase the life cycle of the sidewalks. The second is a laboratory investigation on the effectiveness of the same ConForce Grid as structural reinforcement in 8’’ and 10’’ diameter laterally loaded concrete piles in sand. The ConForce Grid was tested in independent accredited laboratories for its tensile and corrosion resistance properties. The aging testing results of this geogrid and the conventional steel rods are compared. The ConForce Grid placed in sheet form in the ground supported concrete sidewalk slabs is performing very well after passing through 3 tough winter cycles. The rolled ConForce Grid in concrete piles did not perform as expected and a basalt fiber grid is being developed for this application.

Keywords: Basalt, concrete, reinforcement, ConForce, fiberglass, geogrid, performance, sidewalk, pile

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1. INTRODUCTION

The City of Calgary was trying to reduce construction and maintenance costs of concrete pedestrian sidewalks. They were using thick unreinforced concrete slabs and yearly rehabilitation work was required to repair major cracking of the slabs shortly after installation. The City of Calgary was looking for a reinforcement system not susceptible to corrosion, and that would work to minimize and delay surface cracking of concrete.

2. CHALLENGE

The City of Calgary maintains about 5,000 km of sidewalk network. City specifications recommend 100 mm of concrete placed on compacted subgrade. This is thin compared to most other Canadian city specification. Common concrete defects therefore are observed on both new and old concrete. Damages caused by equipment moving over sidewalks built in new divisions is another issue wherein a considerable amount of sidewalk is replaced prior to construction completion. With aging infrastructure, changes to the specifications and freeze-thaw cycle, the City of Calgary's emphasis was on building lasting concrete. Budgetary constraints did not permit the replacement of all of level 4 or 5 severity distresses. In such a situation, The City wanted to evaluate options that would provide a lasting sidewalk with minimal maintenance.

3. CONFORCE GRID SOLUTION

ConForce Grid is a new generation stiff geogrid that was developed to be used for concrete reinforcement in both aggressive and non-aggressive environments, namely concrete pathways, ground support concrete slabs, bridge beams, exposed concrete surfaces, concrete piles, columns, beams, floating slabs etc. as an alternate to conventional steel reinforcement.

It has been evidenced that polymeric stiff geogrids show higher energy – absorption capacity in Portland cement concrete, compared to that of flexible geogrids from the study conducted by Tang et al. 2008. However, the elongation at break for the stiff geogrids used in that study was between 10.5 – 20.6% which is quite high.

The goal of the current study was to create the geogrid with less than 3% elongation at break along with having high stiffness and higher tensile modulus, so that the grid has similar physical behavior as concrete to provide effective reinforcement.

Hence a woven geogrid using high modulus (<73,000 MPa) fiberglass grid with stiff polymeric coating and having nominal square aperture sizes of 1 in (ConForce Grid TE-SCR100) and 1.6 in (ConForce Grid TE-SCR150) were designed and created. Both of these geogrids possessed the same mechanical properties, but only differed in their aperture sizes.

Figure 1. ConForce Grid TE-SCR150

The principal function of this lightweight, high-stiffness polymer geogrid in concrete is to distribute stresses and resist the tensile stresses in the concrete structure that might cause unacceptable cracking and/or structural failure and also increase the flexural stiffness, shear strength and significantly improve post crack ductility of the concrete structure. The ConForce Grid was used by the city in ground supported concrete slabs for the construction of new pedestrian sidewalks in August 2017. The ConForce Grid was supplied in sheet form and not rolled.

3.1 Tensile Properties

TE-SCR100 having 1 in x 1 in aperture size was tested for its tensile strength properties as per ASTM D 6637 in machine and cross-machine directions by SGI Testing Services LLC -GA, USA. The mean value of Secant stiffness EA at 2% strain calculated was 4,265 kN/m in the MD and 4,140 kN/m in the XD from the testing data shown in Figure 1.

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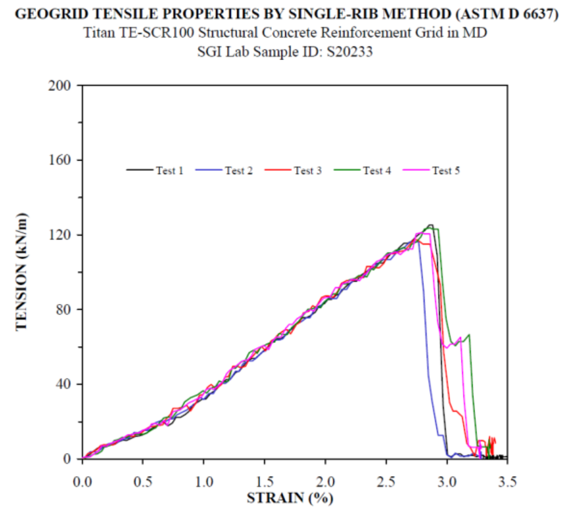
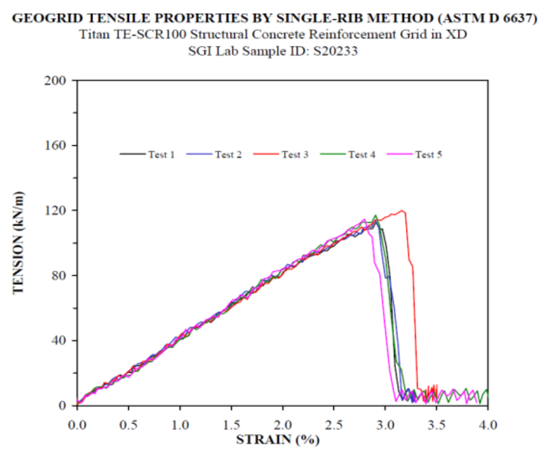


Test No.	Tension at Select Strains				Ultimate Strength (kN/m)	Strain at Ultimate (%)
	at 0.5% (kN/m)	at 1% (kN/m)	at 2% (kN/m)	at 5% (kN/m)		
1	13.1	32.1	83.7		125.3	2.9
2	15.3	31.9	84.6		116.3	2.7
3	14.8	35.2	87.3		117.4	2.7
4	13.3	36.3	84.4		123.8	2.8
5	15.5	35.3	86.4		121.2	2.8
Mean	14.4	34.2	85.3		120.8	2.8



Test No.	Tension at Select Strains				Ultimate Strength (kN/m)	Strain at Ultimate (%)
	at 0.5% (kN/m)	at 1% (kN/m)	at 2% (kN/m)	at 5% (kN/m)		
1	20.4	40.8	81.4		113.8	3.0
2	21.2	41.7	83.6		115.0	3.0
3	20.7	43.0	80.8		120.0	3.2
4	18.6	40.6	84.1		117.1	2.9
5	17.4	41.5	84.0		114.7	2.8
Mean	19.7	41.5	82.8		116.1	3.0

Figure 2. ConForce Grid Tensile Testing Properties.

3.2 Corrosion Resistance Properties.

TE-SCR100 ConForce Grid as well as steel and galvanized steel rods were tested for corrosion resistance as per ASTM B117-16 using a laboratory-controlled procedure by SAGEOS division of CTT Group -Quebec. The salt spray (fog) aging test did not cause any visual degradation for the ConForce Grid after 600 hours of exposure, whereas clear evidence of corrosion was observed on the steel and galvanized steel rods, as shown in figure -2a and 2b.

Figure 3. Steel Rod before and after aging test.

Figure 4. ConForce Grid before and after aging test.

4. PILOT PROJECT ON CONFORCE GRID REINFORCED SIDEWALK SLABS

4.1 Details of Construction.

For this pilot project, three 125 mm thick concrete slabs creating 3 sections of sidewalk were reinforced with ConForce Grid (TE-SCR150) and placed on a 50-100 mm thick compacted granular base course. The slabs consisted of concrete with 32 MPa compressive strength and 80/plus slump mix.

Figure 5. Prepared base course, Conforce Grid installation

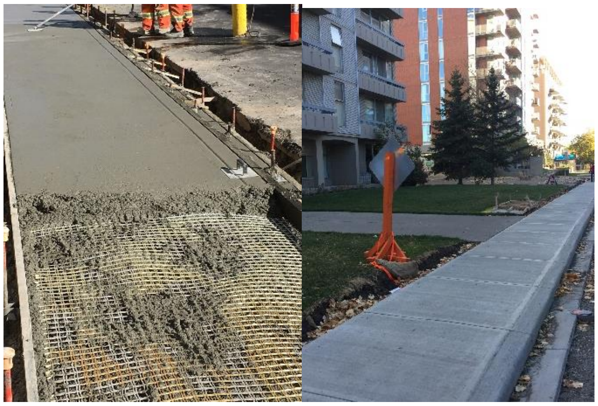


Figure 6. Concrete poured and finished sidewalk

The ConForce Grid was placed at different levels in each of the slabs with the objective of studying its performance in each sidewalk section. In the first section the grid was placed towards the top of the concrete slab. In the second section the grid was placed in the middle of the concrete slab, and in the third section the grid was placed towards the bottom of the concrete slab. The illustration is shown in figure 3. In the first section, the grid is placed towards the top surface to act as an energy absorption membrane and minimize the shrinkage cracking on the concrete surface, while in the third section where the grid is placed towards the bottom to provide structural response and increase the loading capacity.

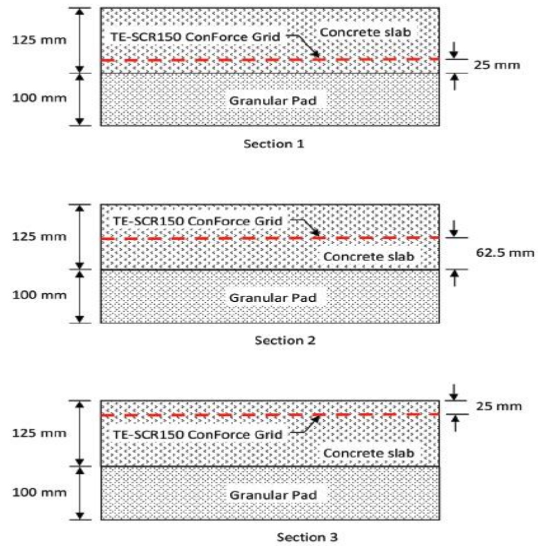


Figure 7. ConForce Grid Installation Sequence

4.2 Performance after One Year

The visual inspection after one year of installation shows that there was no surface cracking in any of the sidewalk sections where ConForce Grid was installed.

Figure 8. Results after one Year

The visual inspection after two years was similar to the first year with no visible distresses.

Figure 9. Results after two years

5. CONFORCE GRID REINFORCED CONCRETE PILES

Favaretti (2018) investigated the performance of fiberglass grids as structural reinforcement of concrete piles by conducting lateral load tests on model piles embedded in sand. Tests were conducted on 8-inch diameter concrete piles reinforced with ConForce Grid TE-SCR100 and TE-SCR150 and their performance compared with similar piles reinforced with steel rebars. Results showed that lateral capacity of piles reinforced with fiberglass grids were less than that of piles reinforced with steel rebars. It was found that when the stiff fiberglass grid was rolled into a circular shape for placement in the pile casting molds, the yarns were subject to significant breakage. It is thought that this could be the main reason for the less than satisfactory performance as pile reinforcement. A grid manufactured from basalt fibers was developed which has higher tensile modulus and better flexibility. More tests are planned with this new basalt fiber grid and it is expected that these grids will have a much better performance as structural reinforcement in piles.

6. CONCLUSION:

The visual observation of the pilot project two years after it was placed showed no surface distresses, cracking or settlements. There was no observable difference between the three pilot segments. More field installations are being planned with reduced thickness of concrete slabs to 100mm and reinforced with ConForce Grid, that would achieve about 12% material cost savings as compared to concrete. Greater long-term savings can be realized by increasing the life cycle of their sidewalks and reducing maintenance costs associated with frequent premature repairs.

ConForce Grid in sheet form is performing very well, whereas the roll form did not perform to the level of steel reinforcement which is attributed to the breaking of the glass fibers when rolling the stiff grid. This has led to the development of the grid using basalt fiber, which is high modulus, more flexible, and expected to perform well in the rolled state.

ConForce Grid presents a unique alternative to municipal infrastructure in public realm such as concrete sidewalk, pathways, bus pads etc. by enhancing the life cycle performance and potentially reduce maintenance and rehabilitation costs.

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