Production of a textile reinforced concrete protective layers with non-woven polypropylene fabric

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Abstract. Textile concrete with nonwoven polypropylene fabric can be used for protective layers of reinforced concrete structures, reducing the thickness of the cover layer or reducing the water penetration rate into the structure. The material consists of cement matrix with fine-grained aggregate and nonwoven textile reinforcement. The maximum grain size of the mixture suitable for the nonwoven textile infiltration is 0.25 mm. The interlayer contains larger aggregates and short fibers. Tensile loading causes a large amount of microcracks in the material. The material can withstand strain over 25% without collapsing. Increased quality and water-cement ratio reduction was achieved using the plasticizers and distribution of the mixture into a fabric using a vibrating trowel. It is possible to make flat plates and even curved structures from this material. Larger curvatures of structures should be solved by cutting and overlapping the fabric. Small curvatures can be solved within the deformability of the fabric. Proper infiltration of the cement mixture into the fabric is the most important task in producing this material.

1. Introduction
Textile reinforced concrete is currently used as a load bearing material [1], a part of sandwich panels [2, 3], or to reinforcing an existing structure [4]. The large advantage of textile reinforced concrete is increased tensile strength, high deformability and crack width reduction.

Textile reinforced concrete is thin-walled composite material which consists of cement matrix with fine-grained aggregate and textile reinforcement. Nonmetallic reinforcement allows small thickness of the structure. Carbon, alkaline-resistant glass or polypropylene fabric are the most commonly used. Fiber cords of reinforcing fabrics are oriented orthogonally. Effectiveness of the reinforcement is reduced by the inadequate activation of the internal fibers inside the cords [5]. This problem is solvable by nonwoven textile.

2. Production of a material with a nonwoven polypropylene fabric
Textile reinforced concrete with oriented fibers is produced in two ways. A layer of cement mortar is applied on the formwork and a reinforcing fabric is pressed into it. Or, a 3D reinforcement insert is prepared in advance and it is filling by a suitable cement mixture. Textile reinforced concrete with nonwoven fabric can be produced only as a layered structure.

Oriented fiber textiles have defined fiber distances such as 4.3 x 4.3 mm. Therefore, the maximum grain size of the mixture can be estimated. Nonwoven fabric is consisted of randomly oriented fibers with very small distances. Polypropylene nonwoven fabric was used for the experiment (figure 1). The
cement mixture infiltration into the nonwoven is influenced by grain size, water quantity, chemical admixtures and method of compaction.

![Figure 1. Polypropylene nonwoven fabric.](image1)

2.1. Infiltration of aggregate into the fabric

The maximum grain size of the mixture was determined experimentally because surface tension reduces water permeability (figure 2). Mixtures with a maximum grain size of 1 mm, 0.5 mm and 0.25 mm were prepared. Aggregates larger than 0.25 mm were not able to infiltrate the fabric (figure 3). The ideal size of the grain for the tested fabric was determined to 0-0.1 mm after further tests. A mixture with this size of aggregate is not suitable for the entire volume of material. Therefore, two different mixtures have to be used for the production of nonwoven multi-layered textile reinforced concrete.

![Figure 2. A water drop on the surface of a nonwoven polypropylene fabric.](image2)

![Figure 3. Infiltrated nonwoven textile surfaces.](image3)

2.2. Water-cement ratio and chemical admixtures

The amount of water and chemical admixtures influences significantly the process of mixture infiltration into the fabric. A larger amount of water (w/c ratio ≥ 0.5) facilitates the penetration of the mixture. After the saturation of the fabric, the excess water is accumulating on the surface of the
textile-reinforced layer (figure 4) and degrades the material properties. Chemical admixtures can reduce the water-cement ratio to about 0.35. Plasticizing admixtures usually have retarding effects that slow down the production process. Using large amounts of plasticizing admixtures is common in textile reinforced concrete production [6].

![Figure 4. Excess water on the fully saturated fabric.](image)

2.3. **Compaction**
The mixture is distributed within the fabric by vibration. Initially, the use of the vibratory table was tested. The mixture was laid on the fabric during vibration. Water infiltrated the fabric, but the aggregate began to move horizontally across the fabric surface. The next method involved pressing the mixture into the fabric with a vibrating trowel. But, the fabric was compressed and the mixture could not penetrate it. Therefore, a suitable method is to use a vibrating trowel to roll the mixture across the fabric. This method ensures infiltration of all mixture components (figure 5). This compaction method can reduce the w/c ratio even below 0.35.

![Figure 5. Vibration methods and material response.](image)

The quality of the mixture infiltration into the fabric determines total material properties. This quality can be assessed on the material cut surface. Inadequate infiltrated fibers stand out of the cut surface. Well infiltrated fibers are not visible at first glance of the cut surface (figure 6).

![Figure 6. Material cut surfaces: left – inadequate infiltration; right – suitable infiltration.](image)
2.4. Production process
The material is produced by layering the infiltrated textiles. It is also possible to make an interlayer from the mixture with a larger aggregate. Shear cohesion should be improved by using very short filaments (e.g. 6 mm long).

Flat prefabricated plate can be produced by infiltration of mixtures into the fabric directly in formwork. It is better to create space-curved elements by layering already infiltrated fabrics in the formwork, when the fabric must be pre-shaped into curved shape. Large curvatures can be solved by cutting and overlapping the fabric (figure 7). A small curvature can be solved within the deformability of the polypropylene textile (figure 8). The maximum usable stretching in this case is 20%, which can be determined from the uniaxial tensile test (figure 9).

Figure 7. Cut and overlapping fabric.  
Figure 8. Textile deformability.  
Figure 9. Results of uniaxial tensile tests.
3. Possible application

Textile concrete with polypropylene nonwoven reinforcement layers is suitable for protective layers of reinforced concrete structures as only microcracks are generated within the textile concrete layer during large deformations (figure 10). The macrocrack in reinforced concrete is then branched to more small cracks in the protective layer of textile concrete (figure 11) [7]. Reinforcing layers with glass and carbon fabric may cause tearing of the original cover layer due to their higher stiffness [8]. However, the protective layer with the polypropylene textile is less stiff than the protected structure and thus this risk is reduced.

![Figure 10. Microcracks.](image1)

![Figure 11. Cracks development.](image2)

One possible application is reducing the thickness of the cover layer. For example, the above-ground parts of noise barriers according to the Technical Quality Conditions of the Czech Railways have a minimum covering thickness of 45 mm due to environmental conditions (XF4 + XD3), 50 years of lifetime and other resistance requirements. Non-metallic reinforcement in textile reinforced concrete can reduce the cover layer or even replace completely the metallic reinforcement and thereby reduce significantly the overall thickness and transport weight of the wall panel.

Another possible application is reconstruction of bridge pillars with broken cover layer and corroded reinforcement (figure 12). Rehabilitation of pillars normally involves removal of surface concrete, welding of new reinforcement and concreting new sufficient layer of great quality concrete. Applying a protective layer of textile reinforced concrete can prevent the repeated damage of the covering layer.

![Figure 12. Pillar with damaged cover layer.](image3)

The surface layer of textile reinforced concrete reduces the water absorption into structure [9]. This can be used for making white tanks. Textile reinforced concrete can be used as a permanent formwork and at the same time it can reduce water penetration into the structure. Water penetration management is an important factor for the correct functionality of the crystallization additives.
4. Conclusions
In this paper, a method of production and application of textile reinforced concrete with polypropylene nonwoven fabric has been presented. The material is produced by layering the reinforcing and filler layers. The maximum grain size for infiltrating the nonwoven fabric was set at 0.25 mm. The mixture for the filler layer may include larger aggregates and short fibers to improve shear cohesion. The best method for textile infiltration is rolling the mixture over the fabric with a vibrating trowel. Sufficient mixture infiltration into the fabric was achieved with 0-0.1 mm aggregate, plasticizing additives and a water-cement ratio of 0.35.

Textile reinforced concrete with polypropylene fabric has the density between 1200-1500 kg/m$^3$. The material is suitable as a protective layer for reinforced concrete structures as many microcracks are created within the protective layer. The tested material was able to deform over 25%. A possible application is reducing the cover layer thickness for outdoor structures, rehabilitation of surface layers of structures or reduction of the rate of water penetration into waterproof reinforced concrete structures.

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