A Novel Pre-Fabrication Technology to Produce Textile Reinforced Concrete Structural and Non-Structural Components

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The present paper gives an outline about a novel manufacturing technology developed to produce textile reinforced concrete (TRC) components. Recently, the construction sector has adapted and gained popularity for the use of fiber and textile reinforced concrete in many western countries in many applications. It is convincingly proved that TRC can be used both in standalone applications and also as a repair and retrofitting material. However, the use of these materials in India is yet to be popularized mainly due to lack of awareness about the potential of these materials, lack of codal provisions and guidelines for implementation in site and unawareness of construction technologies. Hence, this paper tries to bring in an insight into the various possibilities TRC can offer along with a ready to use technology, named as textile reinforced concrete prototyping technology (TRCPT) developed at CSIR-Structural Engineering Research Centre.

Keywords: Textile Reinforced Concrete, Fiber, Pre-fabrication, Concrete, Construction.

Introduction

Reinforced Concrete (RC) is the most popular construction material used all over the world. However, the concerns related to durability and corrosion of steel reinforcement does exist with this material. Recently, Textile Reinforced Concrete (TRC) in which steel reinforcement is replaced with alkali-resistant textiles has proved to be a viable option in the construction field leading to reduction in concrete consumption, embodied energy and weight of the structure. In addition, TRC offers a solution that progresses beyond the state of the art short fibre reinforced concrete. TRC can be tailor made in various applications by using different textiles and binders to suite the requirements. In the global scenario, many practical applications of TRC are established in western countries. Guidelines has been recently issued for the acceptance, design and construction of TRC systems (ACI 549.4R 2013, ICC-AC434-2013, RILEM TC 232-TDT). A production method known as the pultrusion process was developed for fabric cement composites sheets (Peled & Mobasher 2005, Peled et al. 2004, 2009). It was observed that the combination of the capabilities of fabric reinforced cement composite and the pultrusion process, is expected to lead to an effective novel class of TRC applications.

The present paper reports a pre-fabrication technology developed to produce textile reinforced concrete products for structural and non-structural applications. It is named as textile reinforced concrete prototyping technology (TRCPT) and using this single technology, multiple products can be produced.

Textile reinforced concrete

Textile reinforced concrete consists of fine grained cementitious matrix as binder and a technical textile as reinforcement. The textile carry loads and provides the necessary high tensile strength in a cementitious matrix and is a suitable solution to the reinforcement within concrete matrices. These textile structures are engineered in order to provide the high tensile requirements. There are various types of textile available in the market made of alkali resistant glass, carbon, aramid, polypropylene, nylon, coir, and jute. The fibers of the textile are required to have features such as: small relaxation under permanent load, an appropriate and constant adhesion between reinforcement and concrete, low cost of production and the possibility of processing them easily on textile machinery. The fibres mentioned can be used in filament or twisted filament form. These filaments are a better choice because they possess only a
small structural elongation. Features which play a vital role are the applied size on the filaments, the thickness and number of filaments. The use of fibres and their properties are mentioned in Table 1.

Most of the textiles has two dimensional geometrical architecture, which is preferable along with a cementitious matrix. The most important criterion for selecting appropriate textile in concrete is the possibility to create open structures with high displacement stability. A good permeability and complete envelope with concrete is desired with an open grid structure. To ensure satisfactory handling no displacement of a thread is desired. The various types of textiles available in market is shown in Figure 1. The generalized properties of various textiles are given in Table 1. A geometrical architecture of the commonly used textiles for concrete applications is shown in Figure 1.

**Textile reinforced concrete prototyping technology (TRCPT)**

CSIR-Structural Engineering Research Centre, India has developed a pre-fabrication methodology to produce TRC components and an Indian patent has been filed on this aspect (Patent filing number: 2751DEL2014). TRCPT is an innovative technology to produce textile reinforced concrete (TRC) products for various structural and non-structural applications. It can serve as an effective indigenous technological solution for pre-cast construction industry. It completely avoids the conventional way of concrete construction, which makes use of moulds. The prototyping helps the TRC sheet to adapt to the specific configuration and many products of various shapes and forms for various structural and non-structural applications are produced. Using this single technology, the Textile/Fabric reinforced composite sheets are prototyped to produce many products of various shapes and forms. The prototyping is done by placing the Textile reinforced concrete sheets over

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**Table 1 - Details of various fibers used to make textiles**

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Diameter [μm]</th>
<th>Number of filaments (per roving)</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR-Glass filaments</td>
<td>9 – 27</td>
<td>800 – 2000</td>
<td>The fibre is alkali resistant but not immune to degradation. Fibre size was developed to increase the alkali resistance. Tenacity - ~1400 N/mm². Modulus of Elasticity - 70 – 80 kN/mm². Density - 2.8 g/cm³.</td>
</tr>
<tr>
<td>Carbon filaments</td>
<td>7</td>
<td>3000 – 12000</td>
<td>Modulus of Elasticity - 200 – 250 kN/mm². Density - 1.8 g/cm³. Tenacity - 3000 N/mm².</td>
</tr>
<tr>
<td>Aramid filaments</td>
<td>12</td>
<td>1000-2000</td>
<td>Modulus of Elasticity - 60-130 kN/mm². Density - 1.4 g/cm³. Tenacity - 700 N/mm².</td>
</tr>
<tr>
<td>Ploypropylene filaments</td>
<td></td>
<td></td>
<td>Density - 0.92 g/cm³. The fibre is prone to alkali degradation, proper coating should be realized. Tenacity - ~2000 N/mm².</td>
</tr>
<tr>
<td>Basalt filaments</td>
<td>12-16</td>
<td>600 – 1500</td>
<td>Modulus of Elasticity - 70 – 90 kN/mm². Density - 2.8 g/cm³.</td>
</tr>
</tbody>
</table>

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**Fig.1**—Geometrical architecture of commonly used textiles for application in concrete.
the shape to be constructed soon after the production, and it adapts to the specific configuration. The process incorporated in this technology can also be tailor made depending on the structural and non-structural applications that are aimed at. Also, scale up and down of this technology is possible for in-site applications. This method also helps to increase the speed of manufacture of textile reinforced concrete products in order to achieve economical mass production. To manufacture TRC sheets, the ingredients of the fine grained concrete are mixed in a mixing unit and transferred to the hopper of TRCPT apparatus. A controlled flow of binder is allowed to cast the first layer of TRC sheet. A leveling action is performed to level the first layer to maintain the uniformity of binder. Next, the textile or fabric is fed and stretched above first layer of binder. Again levelling is done to ensure the proper placement and bonding of textile. Subsequently final layer of binder of required thickness is applied and levelled. To maintain the desired thickness of TRC product, a pulling action is performed. These sheets can be cut both in wet and dry condition. The TRC sheets cut in wet condition are prototyped to produce various products. For example, TRC sheet is placed over an existing cold form steel sheet and TRC roofing sheets are produced. To achieve the desired properties for TRC sheet, the number and type of textile used and the binder ingredients can be modified. Another products such as wind turbine blades, which can act as sacrificial elements, flower shaped concrete basin, wash basin, manhole cover etc. are also demonstrated here. The TRC strips prefabricated in this manner are also used for retrofitting. In wet condition, it can be directly attached to the reinforced concrete beam for strengthening without the use of any additional adhesive or anchoring methods. Another application is canal lining. The TRC sheets produced through TRCPT are transported to the site and placed in the existing canal configuration. In brief, the Textile reinforced concrete products using TRCPT can be used as standalone components like roofing sheets, slabs, shells, prefabricated elements and in repair and rehabilitation applications, tunnel lining, jacketing around columns, fire protection, structural strengthening, masonry strengthening, in underground construction, composite pipe construction and also in wind energy sector.

Advantages

The various advantages of TRCPT are such as, it is a single technology to produce multiple products with increased production rates, simple set up with scale up and scale down possibilities, tailor made possibilities of manufacturing methods according to product requirements, uniform production, both pre-fabricated and in-site applications are possible with TRCPT, Smooth surface and aesthetically appealing final products, Less variability for mechanical properties from point to point and structure to structure, Minimal manual effort- 95% automation and remaining 5% manual effort for the production, Production of high performance textile/fabric cement composites, Minimization of material wastage by avoiding the excess mortar application on the fabric/textile contributing to a faster and more energy efficient overall production process, Increase in the speed of manufacture of textile reinforced concrete products in order to achieve economical mass production, Huge economic benefit possible from technology TRCPT, if used in large scale construction sites to produce various custom made structural and non-structural components of textile reinforced concrete. Depending on the resource availability, the textile can be chosen appropriately for various applications to produce textile reinforced concrete products

Applications

The Textile reinforced concrete products using TRCPT can be used as standalone components like canal lining, sandwich panels, façade elements, industrial flooring, street furniture – for institutional complexes and also residential complexes, canopy structures for bus-stands roofs/cycle stands roofs/ railway station roofs, partition walls in housing/offices, sound barriers along the high speed motor-ways and railways, roofing element- Outer shells for stadiums/sports complexes, non-structural applications (wash basin, landscaping). TRC can also be used as a repair, rehabilitation and retrofit material. It has very well proven its efficiency in repair and strengthening of concrete beams/slabs, repair and strengthening of masonry structures, as repair material for offshore concrete structures. The non structural components such as flower pot, wash basin, door and window frame, door panel etc. can also be made using TRC.
Details of a canal lining done for a small stretch of damaged canal is shown in Figure 2. After producing the TRC sheets using TRCPT, those were transported to the nearby site and directly adhered to existing brick canal, which was in a damaged condition. In order to level the surface a lean mix of 1:6 (cement: sand) was applied on the brick surface. The various steps of the application are given in Figure 2. The performance of an RC beam strengthened with TRC that are produced through TRCPT is shown in Figure 3. The TRC strips produced were applied in wet condition to the RC beam as soon as it is produced and in another beam, the 28 days water cured strips were attached to RC beam using an epoxy. In both the cases, there is an improvement in the structural behaviour seen compared to control beams. The load versus displacement behaviour is shown in Figure 3.
Conclusions

A novel pre-fabrication technology developed to produce textile reinforced concrete products are discussed in this paper. The pre-fabrication technology uses the prototyping concept to produce structural and non-structural components. This technology completely avoids the use of mould that is used in conventional concrete applications and provides an all-in-one kind of solution to produce multiple TRC products. The various possible applications of TRC and the applicability of the technology for the same is highlighted. Practical feasibility of the technology is also demonstrated using examples.

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