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A STUDY ON FLEXURAL BEHAVIOUR OF RC BEAM REPAIRED USING TRC COMPOSITE

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Abstract–Reinforced concrete (RC) is a composite material in which concrete is relatively low in tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength or ductility. The steel reinforcement bars (rebars) is usually embedded passively in the concrete before the concrete sets. Textile-reinforced concrete is a type of reinforced concrete in which the usual steel reinforcing bars are replaced by textile materials. Instead of using reinforcement inside the concrete, this technique uses a fabric inside the same. Materials with high tensile strengths with negligible elongation properties are reinforced with woven or non-woven fabrics. Hence Textile reinforced concrete (TRC) is an innovative high performance composite material consisting of open multi-axial textiles embedded in a fine-grained concrete matrix. Initially literature survey is proposed are carried out, such that all the existing usage of Textile reinforced concrete (TRC) in the structural elements and its behaviour are covered and described. An attempt has been made in this thesis to repair and strengthen a damaged RC beam using Textile reinforced concrete (TRC) and its flexural behaviour has been experimentally studied and readily to be carried out.

Keywords: PVA fibres, compressive strength, flexural strength, deflection.

I. Introduction

Cement concrete (RC) is one of the most widely used building materials in the construction. Concrete is obtained by mixing together cement, sand, and aggregates with water. Fresh concrete can be locally made and moulded into almost any shape, giving it an inherent advantage over other materials. However, its limited tension resistance initially prevented its wide use in building construction. To overcome poor tensile strength, steel bars were embedded in concrete to form a composite material called reinforced concrete.

The use of reinforced concrete construction in the modern world stems from the extensive availability of its ingredients – reinforcing steel as well as concrete. Reinforced concrete fits nearly into every form, is extremely versatile and is therefore widely used in the construction of buildings, bridges, etc. The major disadvantage of RC is that its steel reinforcement is prone to corrosion. Concrete is highly alkaline and forms a passive layer on steel, protecting it against corrosion. Substances penetrating the concrete from outside (carbonisation) lowers the alkalinity over time (depassivation), making the steel reinforcement lose its protection thus resulting in corrosion. This leads to spalling of the concrete, reducing the permanency of the structure as a whole and leading to structural failure in extreme case.

Textile reinforcement is one of the alternative reinforcement material consisting of natural or synthetic singular technical fibres processed into yarns or roving which are woveninto multi-axial textile fabrics having an open mesh or grid structure. When textilereinforcement is incorporated into concrete, it is most often termed as Textile Reinforced Concrete (TRC) Research and development pertaining to this innovativehigh performance composite material is thought to have commenced at the end of the20th century.

Textile Reinforced Concrete (TRC) Development of a New Technology aim at the understanding the basic load bearing behaviorand at the development of technologies to facilitate the easy and economical application of TRC. The advantages of TRC lead to an entirely new application potential for concrete as a building material like thin structural elements and open up a new field for the application of concrete in the future.

TRC is composed of a high strength fine grained matrix and textileFabrics. Comparable to reinforcing steel the textile reinforcement carry the tensile forces occurring during the cracking of the concrete. Two-dimensional spacer fabrics are employed for reinforcement (Fig. 1.1).

These fabrics are woven of glass fiber bundles (rovings) which consist of up to several thousand glass filaments. The filaments of the textile which is shown in Fig. 1.1 have a diameter of around 27 µm, the roving consists of 1300 filaments and has an approximately effective cross sectional area of about 0,89 mm².

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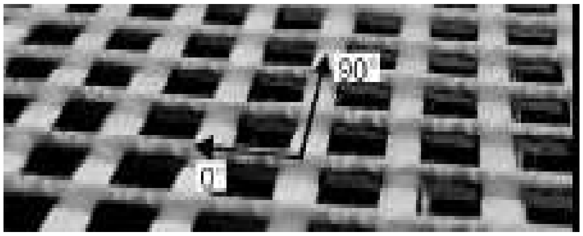

Bidirectional fabric

The woven fabrics and the open structure of the rovings provide an extensive surface and thus contact zone to the matrix. So the concrete has to fulfil certain requirements. To ensure sufficient penetration of the matrix into the textile, the aggregate has to be fine enough and the concrete must have a highly flowable consistence. Due to the specific bond conditions in TRC the occurring crack pattern under tensile load shows small crack distances and small crack widths. In contrast to steel glass does not tend to corrode. So there is no need for anyConcrete coverage. The thickness of structural elements of TRC can be kept limited to a few centimetres and thin and elegant structures are possible. Since TRC exhibits particular behavior after cracking extensive test series have been carried out to examine the load carrying behavior under different load conditions. On the basis of these findings design rules have been formulated and modelling approaches for numerical simulations have been formulated.

The textile made of treated coir, bamboo, jute, etc., are also the potential candidates for textile reinforcement. With excellent material properties, most notably freedom from corrosion, lightness and flexibility, textile reinforcements have made their entry into the modern concrete construction market with the potential to greatly transform the industry and extend design possibilities for architects, engineers and manufacturers of precast components. The advent of TRC requires approximately 60% less concrete than steel reinforced concrete, thereby promising a huge environmental advantage. Enhancing the ecological sustainability of building materials is beneficial not only in terms of cost and energy savings, but also help reduce maintenance and quantity of raw material extraction, as well as increasing the service life of a building.

TRC has a great potential in the construction of multitude structural and non-structural applications. Especially, with the diversity of raw materials available in India, possibility to manufacture technical textiles for structural applications is huge.

II. Overview of Literature

Truong et al. (2017) have investigated RC beams reinforced by TRC composites.His work aims to experimentally assess contributions of the strengthening and repair of slender reinforced concrete beams subjected to bending by applying the TRC composite in water tanks. reinforced and repaired by composite materials.The textile used in this study is a bidirectional AR glass mesh.. The test setup for the beams was four-point bending test and Digital image correlation measurement. The crack was observed and repaired. Two layers of matrix were placed in between the textile layer..The Result shows that the TRC composite materials by significantly improving the loading capacity of the ultimate load by 19 to 27%.

Kong et al (2017) have studied the durability behaviour of textile reinforced concrete subjected to both tensile and bending loads to compare its macroscale characterization. The instantaneous and long-term properties of composite TRC are found by tensile and flexural testing. TRC reinforced with 2 layers and 6 layers of fibreglass mat had been plotted as graph for natural ageing and accelerated ageing.The result states that the layers of glass fibre increased the strength capacity and the first macro crack strength of TRC in both tensile and bending tests.

Boxin et al. (2015) have investigated the crack resistance of concrete textile reinforced self-stressing concrete was prepared by combining self-stressing concrete and textile. The confinement effect of textile on the concrete matrix allows for the establishment of self-stresses in the matrix, which can highly enhance crack resistance.In this research, The textile and self-stressing concrete are found to work well together, and textile-reinforced self-stressing concrete can largely improve the crack resistance of concrete materials. A table was explained about mixture proportion of self-stressing concrete and normal concrete. Expansion deformation and 3 to 28 day expansion deformation.

Yunxing et al. (2017) have investigated the influences of textile layers, prestress levels and short steel fibers on the tensile behavior of basalt textile reinforced concrete (TRC). The tensile behavior of basalt TRC is considerably influenced by the number of textile layers. The TRC specimens with one or two textile layers demonstrate no reinforcement efficiency, prominent enhancement of tensile behavior and optimized cracking patterns.The cracking pattern achieves considerable optimization that features a higher number of cracks and reduced crack spacing with increasing number of textile layers. Tensile stress–strain curves of TRC specimens with different number of textile layers have been plotted in a graph.

Henrik et al. (2015) haveinvestigated onthin walled, high-strength concrete elements exhibiting low system weight and great slenderness can be created with a large degree of lightweight structure using the textile-reinforced load bearing concrete (TRC) slab and a shell with a very high level of sound absorption. a carbon warp knit fabric was modified and integrated into the fine concrete matrix a formwork system at prototype scale was designed enabling noise barriers to be produced with an application oriented approach and examined in practically investigations within the context of the project. Proof was also given of good post cracking strength, low creep and shrinkage deformation low susceptibility to cracking and excellent resistance to frost.

Saad et al. (2017) have investigated and compares the flexural performance of reinforced concrete beams strengthened with textile reinforced mortar (TRM) and fibre-reinforced polymers (FRP). The investigated parameters included the strengthening material namely TRM or FRP the number of TRM/FRP layers the textile surface condition (coated and uncoated)the textile fibre material (carbon, coated basalt or glass fibres) and the end anchorage system of the external reinforcement. Several parameters were examined namely the strengthening material (TRM and FRP) the number of FRP/TRM layers the textile surface condition the textile-fibre materials and the end anchorage system.

Natalie et al.(2017) have carried out the Bending Behaviour of Novel Textile Reinforced Concrete-Foamed Concrete (TRC-FC) Sandwich Elements design consisting of two facings made of carbon reinforced Textile Reinforced Concrete (TRC) a low density foamed concrete (FC) core and glass fibre reinforced polymer connecting devices was experimentally investigated according to quasi-static and cyclic quasi-static four point bending. The GFRP connecting devices are adequate connecting solutions for the TRC-FC composite elements as favourable load bearing capacity and partial composite action could be achieved. These sandwich elements demonstrated a highly ductile behaviour with multiple fine cracking in the TRC panels. In regard to the cyclic tests, the overall bending behaviour has a good agreement with that observed for the quasi-static test thereby proving that these elements have the ability to withstand such load cycling.

Zakaria et al. (2017) have investigated a numerical strategy for describing the textile concrete bond behaviour in textile reinforced concrete composites that separates the cohesive and coulomb friction contributions. It has been used to calibrate the textile concrete bond slip law of an existing TRC tested in tension by an innovative inverse approach thanks to its pull-out mode of failure.A simplified macroscopic numerical model for the TRC sandwich panel has been developed in this approach, TRC behaviour is based on the macroscopic constitutive law for the composite in which the enhanced TRC model is considered and the concrete textile bond law is integrated. Although time consuming, the multiscale results and the mode of failure. Disparity exists between the multiscale TRC sandwich panel model and the experimental investigation concerning the evolution of the crack opening damage after damage initiation which can be explained by the continuum crack damage approach used.

Lampros et al. (2017) have investigated on the bond behaviour between textile-reinforced mortar (TRM) and concrete substrates. The parameters examined include the bond length the number of TRM layers the concrete surface preparation(grinding versus sandblasting)the concrete compressive strength (15 MPa or 30 MPa)the textile coating and the anchorage through wrapping with TRM jackets. The results of for the investigation of the bond between textile-reinforced mortar (TRM) and concrete. Eighty specimens were fabricated and tested under double-lap shear. The poly parametric study included the investigation of the TRM bond lengththe number of TRM layersthe concrete surfacePreparationthe concrete compressive strength, the coating of the textile and the anchorage through wrapping.

Sharei et al. (2017) investigated the Structural behavior of a lightweight, textile-reinforced concrete barrel in a vault shellthe application of textile reinforcement in aggregate highperformanceconcrete has enabled the dimensioning of structural concrete in very small thicknesses. This possibilityAllows for the fabrication of thin-walled TRC shell structures with complex geometries. structural planning and construction require new modelling approaches to comprehend the structural behavior of such forms. In this studyon the sensitivity of the structural behavior and loadbearing capacity with respect to geometric imperfections in construction. The test setup described in this paper was designed with the aim of exploring the structural behavior with high degree of stress redistribution and damage propagation throughout the shell.

Regine et al. (2017) has studied about Textile reinforced concrete for strengthening of RC columns. The renovation and repair work or when buildings are to be adaptively reused, the planningengineer is frequently required to strengthen the load-bearing structure. This is the case, for example, if live loads will increase due to changes in use or if the structural integrity of a building has to be restored after a fire or earthquake. Columns are particularly vital components and elements of the static system of many buildings. Maximum increase of up to 85% in load capacity compared to non-strengthened columns. The individual components of the load bearing properties were analysed and a simple calculation model applied.

Funke et al. (2013) have investigated and developed a new hybrid material of textile reinforced concrete and glass fiber reinforced plastic. A new high-performance hybrid material has been developed by the combination of textile reinforced concrete (TRC) and glass-fiber reinforced plastic (GFRP).high strength, durability, surface quality and cost-efficient production can be implemented in one hybrid material.For the composite of GFRP and TRC the integration of an interlayer for the mechanical and thermal decoupling was indispensable. The developed interlayer, consisting of an epoxy resin and a polyester nonwoven, guarantees a high and sustainable detention compound between GFRP and TRC. The new GFRP-TRC-hybrid material has a tensile strength of 165 MPa and a density of 1.65 g/cm³.

Tetta et al. (2016) have proposed about shear strengthening of full-scale Reinforced concrete T-beams using textile-reinforced mortar and textile-based anchors. The effectiveness of TRM jacketing in shear strengthening of full-scale reinforced concrete (RC) T-beams focusing on the behavior of a novel end-anchorage system comprising textile-based anchors. The use of different textile geometries with the same reinforcement ratio in non-anchored jackets results in practically equal capacity increase. TRM jackets can be as effective as FRP jackets in increasing the shear capacity of full-scale RC T-beams. Finally, a simple design model is proposed to calculate the contribution of anchored TRM jackets to the shear capacity of RC T-beams.

Flavio et al. (2011) have focused on strain rate effect on the tensile behaviour of textile-reinforced concrete understatic and dynamic loading. The strength, deformation, and fracture behaviour of textile-reinforced concrete (TRC) subjected both to low and high-rate tensile loading ranging from 0.0001 to 50. High strain rates were achieved using a high-rate servo-hydraulic testing machine. and the microstructure of both composite and fibre was observed after the tests using anESEM. An increase in tensile strength, strain capacity, and work-to-fracture was observed for strain rates up to 0.1 s^{-1} with increasing strain rate. The tests at high loading rates showed a pronounced effect of the specimen length on the measured mechanical properties: with increasing gauge length the tensile strength and strain capacity decreased, while the work-to-fracture increased.

Maria et al. (2016) studied about the effect of accelerated aging on the interface of jute textile reinforced concrete. Double-sided pullout tests were performed on specimens reinforced withpolymer-coated and uncoated jute fabrics. Before testing, Microstructural analyses were performed to evaluate the degradation of the jute yarn and the fiber-matrix interphase using an environmental scanning electron microscope. Thermogravimetric analysis was carried out in order to evaluate the calcium hydroxide content. The pull-out results showed that coated fabrics formed a stronger bond than did the uncoated. For ordinary Portland cement matrices the maximum fiber pull-out force decreased up to 85% after six months of accelerated aging. In the MK matrix the degradation process was retarded substantially. Polymer coatings improved the bond between fiber and matrix and reduced fiber degradation.

Contamine et al. (2011) has investigated the Contribution of direct tensile testing on textile reinforced concrete (TRC) composites. His study aims to identify and propose contribution to direct tensile test for design purpose which is reliable, efficient and relatively easy to implement. The results obtained on the basis of a large series of experiments involving the laminating technique and the use of field measurements have permitted the validation, based on five criteria.The result proposed and described a protocol for direct tensile testing based on rectangular specimens and the provision of two displacement transducers (LVDTs) and hence it is important to be cautious when considering the spacing and the crack opening as intrinsic properties of the TRC composite without taking great care during the implementation particularly in the case of manualimplementation, such as laminating technique).

Dey et al. (2015) has investigated the Mechanical response of textile-reinforced aerated concrete sandwich panels was investigated using an instrumented three-point bending experiment under static and low-velocity dynamic loading. 0.5% volume of polypropylene fibers in the core, the flexural toughness however increased by 25%. Cracking mechanisms were studied using high speed image acquisition and digital image correlation (DIC) technique.It was found that textile reinforcement at the tension and compression faces of the beam element significantly improves the load carrying, flexural stiffness, and energy absorption capacity.

Thanh et al. (2015) has investigated the effect of simultaneous mechanical and high-temperature loadings on the behaviour of textile-reinforced concrete. The thermomechanical behaviour of two TRC composites has been studied and its nonlinear progressively evolves with the increase of the temperature level. The experiments show a clear difference between the thermomechanical responses of two TRC composites (CSM and GRI).The addition of the continuous long glass fibres in grid form in the TRC clearly has a positive effect on the thermomechanical by increasing the number of zones on the stress/strain curve, the ultimate tensile resistance, the stiffness of the post cracked composite of this material. This addition also increases the maximum thermomechanical axial strain of the TRC at elevated temperatures.

Antino et al. (2015) have investigated the results of the mechanical characterization of composite materials comprising high strength textiles embedded in inorganic matrices. These materials are commonly termed Textile Reinforced Mortars (TRM) or, when comprising cementitious matrices, Fabric-Reinforced Cementitious Matrix (FRCM – despite the fact that this term is often extended to composites with cement-free matrices). Different types of fibers were employed, namely carbon, glass, and basalt, as well as steel cords, which were embedded in lime- or cement-based matrices. Results of tensile tests on single fiber yarns and composite prismatic specimens with a rectangular cross-section are shown and discussed. The effect of fiber coating and stitch-bonded joints between warp and weft yarns on the tensile behavior observed is studied. The results obtained help to shed light on the different parameters that affect tensile testing of inorganic-matrix composites contributing to the appropriate mechanical characterization of these materials.

Chira et al.(2017) have investigated improvements of alkali resistant glass fibres/epoxy composite for textile reinforced concrete applications.The aimof work is to study the tensile, compressive and shear properties of textile rovings and also their matrix. He describes the sample preparations to obtain the tensile, compression and shear testing results for alkali resistant glass fibres (ARG) with epoxy composite. The effect of nanosilica particles on the mechanical properties of ARG with epoxy composite was studied. The results obtained for the rovings with nanosilica showed mechanical improvements for all tested properties. A numerical modelwas developed with the new obtained textile properties for a TRC facade panel to investigate the flexural behaviour.

Larbi et al. (2010) have proposed the Carbon epoxy composite materials are of considerable interest for reinforcement but they need to be improved and have constraints particularly in terms of cost and criteria of sustainable development. Alternative materials like textile reinforced concrete (TRC) should be seriously considered as substitutes for traditional composite materials. This experimental study focuses on the mechanical feasibility of this type of solutions by comparing them with traditional solutions such as CFRP. the materials have very similar behaviours, especially in the final stage. The truss model can be used with sufficient accuracy for the evaluation of the tensile strength, by considering a non-uniform stress distribution along the shear cracks that leads to failure.The results of this study particularly the significant increase in carrying capacity and bending stiffness.

Amir et al. (2012) have investigated the experimental and numerical study is related to the repair and strengthening of reinforced concretebeams with TRC (textile-reinforced concrete) and hybrid (TRC + carbon and glass rods) solutions that are positioned relative to the more traditional ones such as the CFRP (carbon fibre-reinforced polymer) solutions. Beyond the good performances highlighted experimentally, From a numerical perspective using numerical modelling (smeared crack approach) the overall behaviour of beams reinforced with TRC (or the hybrid solutions) based only on the textile efficiency factor (or the average contribution of the filaments) as a calibration coefficient was found to be significantly satisfactory. Numerical modelling performed on all the beams also highlighted the fact that the axial stiffness of reinforcements (even in the case of a cracking material) governing the overall behaviour of beams could, at least in part, explain the observed failure modes.

III. Conclusion

From the literature review it is clear that textile reinforced concrete TRC which is an innovative high performance composite material consisting of open multi-axial textiles embedded with a fine-grained concrete matrix. Many experimental methods improvements of alkali resistant glass fibres/epoxy composite for textile reinforced concrete applications. A numerical model was developed with the new obtained textile properties for a TRC facade panel to investigate the flexural behaviour. The Carbon epoxy composite materials are of considerable interest for reinforcement but they need to be improved and have constraints particularly in terms of cost and criteria of sustainable development. the materials have very similar behaviours, especially in the final stage. The truss model can be used with sufficient accuracy for the evaluation of the tensile strength, by considering a non-uniform stress distribution along the shear cracks that leads to failure. The experimental and numerical study is related to the repair and strengthening of reinforced concrete beams with TRC (textile-reinforced concrete) and hybrid (TRC + carbon and glass rods) solutions that are positioned relative to the more traditional ones such as the CFRP (carbon fibre-reinforced polymer) solutions.

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