

Study of the internal confinement of concrete reinforced (in civil engineering) with woven reinforcement

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Abstract: Concrete is generally the most used material in the field of construction. Despite its extensive use in structures, it represents some drawbacks related to its properties including its low tensile strength and low ductility.

To solve this problem, the use of steel reinforcement in concrete structures is possible. Another possibility is the introduction of different types of continuous fibre / staple in the concrete, such as steel fibres or synthetic fibres, to obtain "Concretes bundles".

Many types of fibre concrete, which have been developed and for many of them, the gain provided by the fibre was rather low and no significant improvement in tensile strength was really reaching. By cons, the ductility was higher than that of ordinary concrete.

The objective of this study is to examine concrete reinforcement by inserting reinforcements woven polyester. These are either woven bidirectional (2D) or three-dimensional woven (3D). So we will report the properties of each type of reinforcement and the influence of the method of weaving on the strength reinforcements and on the strength of concrete in which they are incorporated. Such influence should contribute to improving the sustainability and enhancement of reinforcement

Keywords: concrete structures, woven reinforcements

1. Introduction

The fibres, when added to concrete, could allow its strengthening opposing crack propagation and thus they increase its ductility. This solution provides a composite with superior traction capacity in ordinary concrete. With the random disposition of the fibres, the use of single fibres varies largely. This lack of order in the arrangement of the fibres causes some fibres become positioned perpendicular to the direction of the load while others are found in small sections solicited as shown in figure (Fig.1).

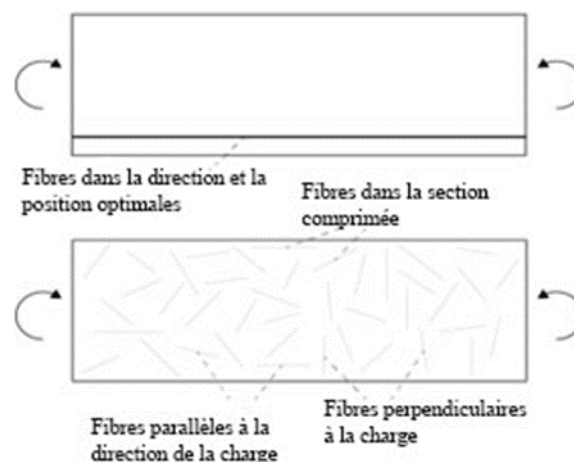


Figure 1. Fibres Arrangement

To remedy this, the use of textile structures to organize more orderly fibre has been studied and evaluated RWTH Aachen University and Dresden University of Technology [1]. This solution has therefore been developed in order to increase the load bearing capacity of the structure with the same amount of reinforcing or reducing the amount of reinforcement required for the same load capacity. In the same vein the use of woven reinforcements ("textile reinforced concrete" TRC) has been the subject of scientific research to produce high performance concrete composites with controlled geometry that could allow the construction of sustainable structures, more economical and more environmentally friendly.

Concrete reinforced with textile or textile-mortar composite (TRC) is a new class of sustainable building materials with high tensile strength, better toughness, higher ductility and good energy absorption under static and dynamic [2].

Resistance and improved ductility are governed mainly by the fibres which retard cracks in the matrix and to transfer loads, allowing the development of a micro-crack system distributed (Fig. 2)



Figure 2. Cracks distribution.

A comparative study between the tensile strength of a cement matrix reinforced with glass fabric and that of the same matrix reinforced by glass fibres revealed that the woven reinforcements provide the superior tensile strength [3]. (Figure 3). Subject to loads, these composites exhibit a better performance than the composite reinforced with short fibres (glass) (Fig.3) [5].

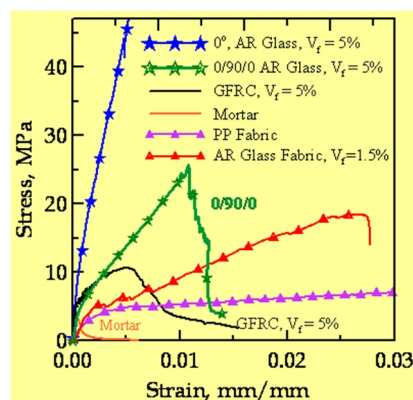


Figure 3. Response to static traction and dynamic loads.

The modern textile technology offers a variety of fabrics produced by different methods, which allows great flexibility in the design of the fabric. This flexibility allows precise control of the geometry and design of the fabric, thread geometry, orientation of the wire, and the combination of thread materials. These many options in designing the fabric create an opportunity to produce new building products that are structurally safe and durable.

Several publications [3] [4] discuss the state of the art on the subject of concrete reinforced by textiles (TRC). The following paragraphs present our own description of a bibliographic review of previous studies.

2. Mechanics characterization of woven reinforcements

The behaviour of a fabric is mainly controlled by three types of rigidities: stiffness voltage which is related to the extension of the fibre, shear stiffness that comes from the variation in angle between the strands and their crush on each the other, and the flexural rigidity which is very low compared to the other two forms of rigidities. One can determine the behaviour of a tissue either by experimentation, either by analytic methods or by simulation at the scale of representative unit cells (REC). [5] A REC is defined as a pattern for a simple translation to reconstruct the entire weaving

The diameters of fibers constituting the strands are very small in relation to their lengths. Therefore, the wicks cannot be subjected to tension in their longitudinal direction. The tension in the wicks depends mainly on two factors: stretching of the fibres, but also the shrinkage (corresponding to the difference between the actual length of a wick once extracted from the tissue and the length which it occupies in the fabric, expressed as a percentage).

The drawing a fibre in an orientation will lead to the withdrawal of the fibre in the other direction. Thus, the voltage in a wick will depend on the deformation of the wick, but also the deformation of the wick is located in the other orientation.

To characterize the behaviour of a tension fabric we use is experimental techniques, either finite element simulations at the mesoscopic scale. [6] For the experimentation, one of the techniques is to define the law of behaviour of the tissue using a biaxial tensile testing machine (Fig.4). This is to perform tensile tests in a direction while maintaining a constant deformation in the other direction. Thus, for each ratio k is obtained a traction diagram (Fig.5 (a)), and that finally allows to draw tension surfaces (Fig.5 (b)).

$$k = \frac{\varepsilon_{warp}}{\varepsilon_{weft}} \quad (\text{Eq. 1})$$

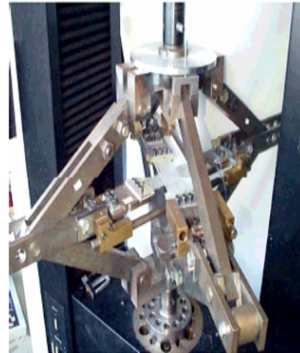


Figure 4. Biaxial tension to a fabric in Croix [7].

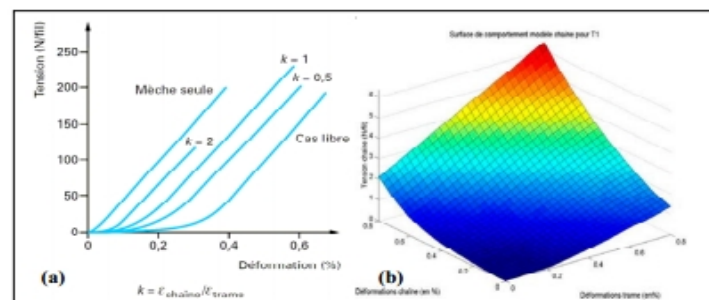


Figure 5. Biaxial traction surface [7].

The second method mentioned is to perform a 3D simulation of a REC at the mesoscopic scale (Figure 6), and further define once the tensile curves. The experimental results agreed well with the results from finite element.

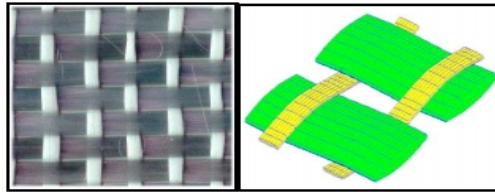


Figure 6. Representative unit cell of an unbalanced fabric.

The third method is, starting from the geometry of the weave profile to describe stress-strain curves analytically [8-9].

2.1 Concret

The requirements on the concrete may vary depending on the geometry and the textile mesh properties. Aggregates of sizes are often limited by the size of the mesh layer.

The cement matrix CRT is different from that generally used in reinforced concrete with steel bars. Concrete grained, also defined as mortar, is the type of concrete required for the TRC, where the maximum aggregate size is less than 2 mm. The fluid concrete is needed to adequately penetrate the openings of the textile reinforcing structure, to provide sufficient binding and to allow transfer of the load of the matrix to the reinforcement (Fig. 7).

In addition, the cement matrix must be chemically compatible with the selected textile reinforcement, while providing the desired load bearing capacity, mechanical characteristics and behaviour appropriate to the geometry of the specimen and the production method [2].

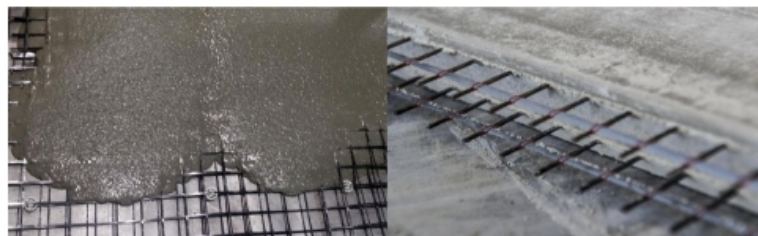


Figure 7. Overview of the textile composite mortar: casting process (left) and the cured TRC component (right)

2.2 Textile

There are a large number of variations of wicks constituting the reinforcing material. Various materials can be used such as carbon fibre, glass or basalt fibre. A textile thread consists of many single fibres in a range of 800 (typically glass fibre) to 24,000 (carbon fibres) [2]. A thread may vary in cross section, shape and circumference as well. Son these can then be arranged in the meshes of different types and sizes; 2D or 3D, sparse or dense, woven, glued or held together using additional son. How the stitches are arranged can affect mainly the ability to pull and the mechanical behaviour of the composite. [2]

In our study, we will use polyester fibres as a reinforcing material and we will discuss the different types of 2D and 3D weaving to identify, initially, their influence on the mechanical behaviour of the resulting fabric. The treated textile fiber is a synthetic fiber. She has good qualities of mechanical strength and is easily recyclable. Also, it is known for its fire retardant properties.

2.3 Mechanics of TRC

Many composite materials, such as polymer matrix have a strong adhesion matrix wire. Their behaviour laws expressed in tensile deformation, stress can then be modelled easily and accurately between the textile and the matrix. In this case, the intrinsic properties of the materials present sufficient to account for the behaviour.

In contrast, in the case of textile-mortar composites, filaments adhesion-matrix remains usually very limited. In addition, the impregnation of the thread (consisting of hundreds of filaments) is essentially restricted to filaments located on the periphery. The forces applied to the matrix are thus transmitted to the "external" filaments impregnated by the matrix (matrix adhesion filament) which themselves redistribute, in part, to the filaments 'internal' (membership filament-filament). Understanding these mechanisms of adhesion is thus required to take the behaviour of TRC traction. Given the complexity and importance of these mechanisms of adhesion between the textile and mortar, they were studied at different scales.

Also, in order to improve this adhesion, the thread can be pre-impregnated with various products. Their influence on the resistance to adhesion between the son and the matrix will also be considered. [11]

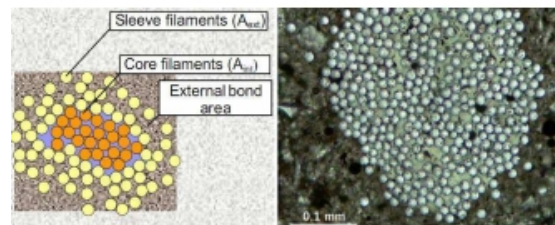


Figure 8. Illustration of a coated filament in its matrix. Viewing not impregnated and external inner filaments impregnated [12-13]

3. Conclusion

The literature review highlighted the growing interest of the scientific community for the textile-mortar composites (TRC) and thus their credibility in the performance-oriented terms (tensile strength of up to tens of mega Pascal, coupled with low openings cracks Service tenth of a millimetre). In addition, a general explanation of the two main constituents of the TRC namely the concrete matrix and the textile reinforcement, was exposed in this article. Also, experimental methods applied to characterize the mechanical properties on the textile reinforcement were also cited. In the end, other factors (membership, impregnating son, etc.) can affect the behaviour of textile-mortar composite, were mentioned and will also be considered in carrying out the tests

4. References

- [1] Orlowsky, J. and Raupach, M, Textile reinforced concrete from research to application. Cement WapnoBeton no. 16 (6), 2011, PP 323-331.
- [2] Bramehuber W., State-of-the-art report - RILEM, TC-TRC 201: textile reinforced concrete; 2006
- [3] Peled A. and MobasherB., Pultruded Fabric-Cement Composites, *ACI Materials Journal*, **102**(1), 2005, pp. 15-23.
- [4] Peled, A., "Textiles as Reinforcements for Cement Composites Under Impact Loading", Workshop on High Performance Fiber Reinforced Cement Composites (RILEM) HPFRCC-5, (Eds. H.W. Reinhardt and A.E. Naaman), Mainz, Germany, July 10-13, 2007, PP. 455-462.
- [5] BOISSE P, GASSER A, HAGEGE B, BILLOET J-L. Analysis of the mechanical behavior of woven fibrous material using virtual tests at the unit cell level. *Journal of materials science*, 2005, **40**, PP. 5955-5962
- [6] GASSER A, BOISSE P, HANKLAR S. Mechanical behaviour of dry fabric reinforcements. 3D simulations versus biaxial tests. *Computational materials science*, 2000, V17, PP. 7-20.
- [7] BUET-GAUTHIER K. Analyse et simulation du comportement mécanique des renforts composites tissés. Thèse de doctorat. Orléans : Université d'Orléans, 1998.
- [8] SUN Huiyu, PAN Ning, POSTLE Ron. On the Poisson's ratios of a woven fabric. *Composite structures*, 2005, **68**, PP. 505-510.
- [9] HIVET G, BOISSE P. Consistent mesoscopic mechanical behaviour model for woven composite reinforcements in biaxial tension. *Composites Part B*, 2007.
- [10] M PETTERSSON, PTHORSSON, FE-modelling of Textile Reinforced Concrete Façade Elements, MASTER'S THESIS, 2014.
- [11] R., CONTAMINE , A., SI LARBI, N. Q., THAN, P., HAMELIN; Numerical modeling of reinforced concrete beams under shear stress with and without external textile-reinforced concrete reinforcement; *Journal of Reinforced Plastics and Composites*, 2011.
- [12] KRÜGER, M., XU, S., REINHAR, Experimental and numerical studies on bond properties between high performance fine grain concrete and carbon textile using pull out tests; Beiträge aus der Befestigungstechnik und dem Stahlbetonbau (Festschrift zum 60. Geburtstag von Prof. Dr.-Ing. R. Eligehausen), Stuttgart; pp151-164; 2002.
- [13] JESSE, F.; Tragverhalten von filamentgarnen in zementgebundener matrix; Philosophy doctoral thesis, Technische Universität Dresden , 2005.