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Confinement Effect of Glass Fabrics Bonded with Cementitious and Organic Binders

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Abstract

Wrapping with advanced composite materials improve the behaviour of concrete structural elements in terms of increase in strength, ultimate strain and corresponding stress of confined concrete. This paper deals with the performance of concrete specimens confined with fabric reinforcement in cementitious binder (FABcrete) and in organic binder consisting of resins (FABpoly). Experiments have been conducted on plain and confined concrete cylindrical specimens under compression. It has been observed from the experimental studies that the specimen confined with FABcrete enhances the load carrying capacity and ductility similar to that of FABpoly confined specimen. Further, the failure of FABcrete specimen is observed to be vertical split, which is similar to that of plain concrete specimen. In the case of FABpoly specimen, failure has been initiated in the mesh region of fabric and ultimate failure is by spalling of concrete in the same region. Also, the failure of FABcrete specimen has been less abrupt and controlled as compared to the failure behaviour of FABpoly specimen. In comparison with FABpoly, FABcrete approximately has the same effectiveness in increasing strength and a slightly inferior ultimate strain. It can be concluded that FABcrete can also be used as a confining system for retrofitting applications.

KEYWORDS: Confined Concrete; Retrofitting; Glass Fabrics; Cementitious Binders; Organic Binder.

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1. INTRODUCTION

Reinforced concrete (RC) structures which are built only for gravity load shows very poor performance during several earthquakes. Concerns about the seismic response of existing structures grew considerably and poses significant challenges to manage the seismic risk by identifying a suitable strengthening material capable of enhancing the shear strength and ductility. Selecting new materials for strengthening RC structures requires proper understanding of the material behavior. The use of fiber reinforced polymers (FRP) in strengthening and seismic retrofitting has gained increasing popularity among structural engineers, due to numerous attractive features of these materials, such as high specific strength, corrosion resistance, ease and speed of application at minimal change of cross section etc. Despite its advantages over other methods, the FRP strengthening technique is not entirely problem free (Engindeniz et al. 2005; Coronado and Lopez, 2007). It is dependent on the bonding area of concrete, which is a function of the tensile capacity of concrete and the type of surface preparation used. Further, the organic resins used to bind and impregnate the fibers entail a number of drawbacks, namely poor behaviour at temperatures above the glass transition temperature, relatively high cost resins; potential hazards for the manual worker, non-applicability on wet surfaces or at low temperatures, lack of vapour permeability and incompatibility of resins and substrate materials.

One possible course of action aiming at the alleviation of the afore-mentioned problems would be the replacement of organic binders with inorganic ones, eg. cement-based mortars, leading to the substitution of FRP with fiber reinforced mortars (FRM) (Triantafillou and Papanicolaou, 2006; Bruckner etal. 2006; Ha and Lho, 2008). The problem arising from such a substitution would be the relatively poor bond conditions in the resulting cementitious composites as, due to the granularity of the mortar, penetration and impregnation of fiber sheets is very difficult to achieve. Fiber-matrix interactions could be enhanced when continuous fiber sheets are replaced by fabrics (also called as textiles). The latter comprise fabric meshes made of long woven, knitted or even unwoven fiber roving in atleast two (typically orthogonal) directions (Bruckermann etal. 2007). The quantity and the spacing of roving in each direction can be controlled independently, thus affecting the mechanical characteristics of the textile and the degree of penetration of the mortar matrix through the mesh openings. It is through this mechanical interlock that an effective composite action of the mortar-grid structure is achieved (Peled & Bentur 2000). For the cementations matrix, the following requirements should be met: non-shrinkable; high workability, high viscosity, low rate of workability loss, and sufficient shear strength in order to avoid premature debonding. During the past five years or so, the research community has put considerable effort on the use of fabrics as reinforcement of cement-based products, primarily in new constructions (Hegger 2006). However, studies on the use of fabrics in the upgrading of concrete structures have been very limited and there is a critical lack of coherent information and experimental/ numerical data available in the literature.

In this research work, an alkali resistant glass fabric is employed to wrap the concrete cylinders with organic and cementitious binders. Experimental studies have been carried out on plain and FABcrete and FABpoly confined cylindrical specimens and compressive strength and ultimate strain has been found out. It has been observed from the experimental studies that the specimen confined with FABcrete enhances the load carrying capacity and ductility similar to that of FABpoly confined specimen. Further, the failure of FABcrete specimen is observed to be vertical split which is similar to that of plain concrete specimen. In the case of FABpoly specimen, failure has been initiated in the mesh region of fabric and ultimate failure is by spalling of concrete in the same region. In comparison with FABpoly, FABcrete approximately has the same effectiveness in increasing strength and a slightly inferior ultimate strain. Further, this paper reports on the feasibility of the systems, using glass fiber reinforcement embedded in a cement-based matrix, and in resin. The goal of the feasibility study is to address the requirements of constructability and compatibility of the fiber/matrix system for retrofitting applications.

2. EXPERIMENTAL DETAILS

The experimental program was executed with three main purposes: 1) to explore different types of binding matrices along with a fabric architecture; 2) to assess constructability of the candidate strengthening systems; and 3) to evaluate system compatibility and effectiveness by testing confined concrete cylinders in pure compression.
A total of 7 (4 FABcrete, and 3 FABpoly) concrete cylinders, 150 mm diameter and 300 mm in height, were wrapped with one layer of alkali resistant glass fabric reinforcement along with five control (unwrapped) specimens. The cylinders were cast from a single batch and left to cure for 28-days. Experiments were conducted under displacement controlled loading.

2.1 Materials selection

Fabric Architecture

The alkali resistant mesh/fabric type of reinforcement (Figure 1) characterized by a mean tensile strength of 45kN/m in wrap and weft direction has been selected. The mesh size of the fabric is 25mmx25mm. The Mechanical properties of glass fabric is given in Table 1.

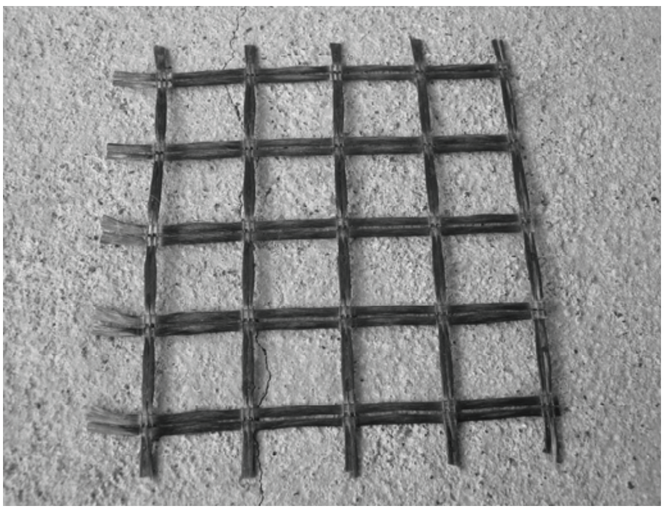

Figure 1: Architecture of glass fabric

Table 1: Details of glass fabric

Fabric name	Coated with	Elongational break (max)	(weight) mass/unit area (minimum)	Roll length	Roll width	Grid size	Tensile strength
SRG-45	Modified acrylic polymer	<3%	225g/m^2	45.7m	0.91m	25mmx25mm	45kN/m (Across width)
							45kN/m (Across length)

Binding material–Organic Resin

The resin polylite 721-800 is thixotropic accelerated and has a viscocity that ensures thorough glass fibre impregnation. It is easy to mix and can be applied by brush. The physical and mechanical properties of applied resins are given in Table 2.

Table 2: Physical and mechanical properties of resin

Polymer	*Tensile strength (MPa)*	*Elongation*	*Density (g/cm^3)*	*Heat Distorsion Temperature*
polylite 721-800	*72*	*4.5%*	*1.2*	*85^0*

Binding material– Inorganic Resin

The main parameters considered for cementitious binding material were based on their ability to:
a) permeate the fibers in the fabric and reach an adequate degree of "wettability", thus requiring relatively fine cementitious mortar; b) provide sufficient bond strength: though confinement is a contact-critical application, the need to bond with the concrete substrate is necessary to transfer load to the fibers, ensuring that good contact is maintained while the binder cures with the reinforcing fibers; c) allow sufficient curing time to ensure workability while preparing the samples; and d) ensure dimensional stability.
The cementitious binder is a fine grained concrete with a maximum aggregate size of 0.6mm that allow for complete penetration of glass fabric. Super-plasticizer was added to obtain an improved flowing capability. Silica fume and flyash were used to reduce the amount of alkali as compared to pure Portaland cements. A detailed description of the matrix composition is given in Table 3.

Table 3: Cementitious binder matrix for FABcrete

Cementitious binder Mix	*Quantity (kg/m^3)*
Cement (53 grade)	*490*
Fly ash	*175*
Silica fume, as slurry	*35=(17.5+17.5)*
Water w	*280*
Super plasticiser (Glenium 140)	*3.5*
Quartz Flour 0-0.2mm	*300*
Quartz sand 0.2-0.6 mm	*500*

Cubes of 70mmx70mmx70mm have been prepared to find out the compressive strength of cementitious binder mix used in FABcrete and is reported in Table 4. Further, cylinders of 75mmx150mm were cast to determine the split tensile strength of the cementitious binder in FABcrete and obtained as 6.25MPa.

Table 4 : Compressive strength of 70 x 70 x 70 mm cube cementitious binder for FABcrete

Day	*3*	*7*	*14*	*28*
Compressive Strength, MPa	*14.38*	*33.01*	*42.38*	*56.26*

2.2 Specimen preparation

In Figure 2(a), the specimen prepared with FABpoly has been shown and Figure 2(b) shows the specimen with FABcrete. Before testing the plain and confined specimens, sulphur capping has been done to ensure the uniform load transfer to the specimen.

Figure: 2(a) Cylindrical concrete specimen confined with FABpoly

Figure: 2(b) Cylindrical concrete specimen confined with FABcrete

The specimens were tested using MTS machine of 2500kN capacity. In each specimen, two LVDT's has been fixed and connected to data acquisition system to measure axial deformation. Test has been carried out under displacement controlled loading.

2.3 Test Results and Discussions

The stress-strain curves obtained from the experiments for each specimen are rendered in the form of representative normalized stress-strain graphs in Figure 3. The normalization has been done with respect to the ultimate stress and corresponding strain of a representative control specimen. The results of experiments indicate a) It was possible to evaluate adequate materials – both fiber architecture types and binding materials for the composite strengthening systems. b) Compatible strengthening systems were recognized. c) The strengthening systems based on fabrics embedded in inorganic matrices were verified to be feasible, showing increase in strength and significantly enhanced energy absorption.

Table 5 presents the details of average ultimate stress, ultimate strain and energy absorption for plain and confined systems. It is observed that there is about 7.5% and 4.5% increase in strength for FABcrete and FABpoly confined concrete specimens respectively compared to unconfined concrete specimen. Further, the energy absorption capacity of FABpoly is about 68% higher than that of plain concrete.

Table 5 : Comparison between plain and confined system

Specimen Type	*Ultimate stress (MPa)*	*Ultimate strain*	*Energy absorption ($x10^6$ J/m^3)*
Plain cylinder	*38.41*	*0.008*	*0.16*
FABcrete confined	*41.28*	*0.0086*	*0.18*
FABpoly confined	*40.08*	*0.014*	*0.27*

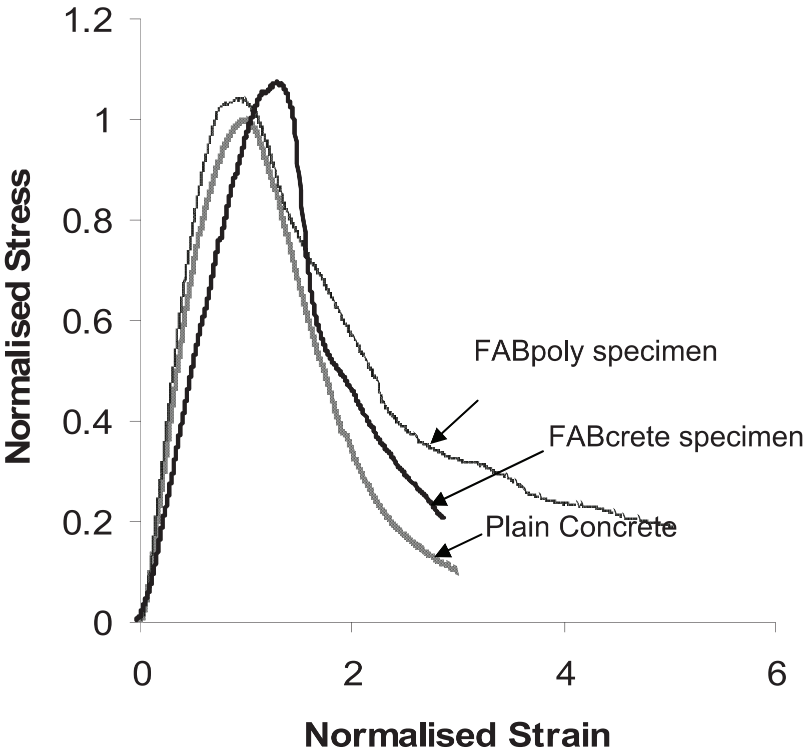

Figure: 3 Stress-strain behaviour of confined and unconfined specimens

Figure: 4 Compression failure of specimen confined with FABpoly

Figure 5: Compression failure of specimen confined with FABcrete

It is observed that specimens strengthened with FABpoly initiated failure in mesh region of fabric and ultimate failure has been by spalling of concrete in the same region. Whereas, if FABcrete is used as confinement, the failure is controlled and similar to that of plain concrete. Further, concrete surface preparation is not required when organic binder is replaced with cementitious binder due to its natural affinity to concrete. It is also observed that for fabric mesh, cementitious binder is effective compared to organic binders, because, the cementitious binder is capable of penetrating into the fabric architecture.

3. SUMMARY AND CONCLUSIONS

The present paper deals with strengthening systems for confinement effect using inorganic cementiious binders in fabric (FABcrete) and organic binder consisting of resins (FABpoly). It is observed that the cementitious binders can effectively contribute to increase the load carrying and energy absorption capacity of the structural components. In addition, the abrupt failure happening due to polymers in fabric can be avoided without compromising much on the load carrying capacity if organic binder is replaced by cementitious binder. This will help to have a controlled failure on the strengthened structural components. Also, usage of cementitious binder will lead to less compatibility and constructability issues compared to other strengthening system, which uses organic binders needing surface preparation. Further experimental studies involving varying the grade of core concrete, strength of inorganic binder and number of wrapping layers are required in order to substantiate the effectiveness of the FABcrete system.

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REFERENCES

[1] Bruckermann OI Hegger J and Sherif AG (2007), Modelling of textile reinforced concrete with inclined textile orientation, ACI material journal, 104(5), pp. 511-519.

[2] Bruckner A Ortlepp R and Curbach M (2006), Textile reinforced concrete for strengthening in bending and shear, Materials and Structures, 39(8), pp. 741-748.

[3] Coronado CA and Lopez MM (2007), Damage approach for the prediction of debonding failure on concrete elements strengthened with FRP, journal of composites for construction, ASCE, 11(4), pp. 391-400.

[4] Engindeniz M Kahn and Lawrence F (2005), Repair and strengthening of reinforced concrete beam-column joints: state of the Art, ACI structural journal, 102, pp. 187-197.

[5] Ha GJ and Lho CG (2008), Strengthening of reinforced high-strength concrete beam-column joints using advanced reinforcement details, Magazine of concrete research, 60(7), pp. 487-497.

[6] Hegger J (2006), Load-bearing behavour and simulation of textile reinforced concrete, Materials and structures, 39(8), pp. 765-776.

[7] Peled A and Bentur A (2000), Geometrical characteristics and efficiency of textile fabric for reinforcing composites,Cement and concrete research, 30, pp. 781-790.

[8] Triantafillou TC and Papanicolaou CG (2006), Fiber reinforced polymers (FRP) as strengthening materials of concrete structures versus Textile reinforced mortars (TRM), SP-230, FRPRCS-7, pp. 99-118.