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Behavior Of Reinforce Fibrous Self Compacting Concrete Beam Strengthening With Externally Bonded Hybrid FRP System

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ABSTRACT: *In recent years, self-compacting concrete (SCC) has gained wide use for placement in congested reinforced concrete structures with difficult casting conditions. SCC offers several economical and technical benefits; the use of fibers extends its possibilities. Adjustment of the water/cement ratio and super plasticizer dosage is one of the main key properties in proportioning of SCC mixtures. Several tests such as slump flow, V-funnel, L-box were carried out to determine optimum parameters for the self-compatibility of mixtures. In this article Nylon 300-e3 micro synthetic fiber and Nylon Tuff macro synthetic fiber has used in combination and the effect of fiber inclusion on the compatibility of hybrid fiber reinforcement concrete are studied. Both the Nylon fiber hybrid with SSC and compared to Plan SSC, Hybrid SSC. The behavior of Reinforced Concrete (RC) beams strengthened in flexure by means of different combinations of externally bonded hybrid Glass and Carbon Fiber Reinforced Polymer (GFRP/CFRP) sheets has also studied.*

Keywords: *Concrete; externally bonded sheets; Carbon; Glass; Fiber Reinforced Polymer ;hybrid systems; Reinforced Concrete; Self-compacting concrete.*

I. Introduction

Self-compacting concrete (SCC) can be considered as a concrete which has little resistance to flow so that it can be placed and compacted under its own weight with little or no vibration effort, yet possesses enough viscosity to be handled without segregation or bleeding[2].

SCC was first introduced in the late 1980's by Japanese researchers. However, to design a proper SCC mixture is not a simple task. Various investigations have been carried out in order to obtain rational SCC mix-design methods. Okamura and Ozawahave proposed a simple mixture proportioning system. In this method, the coarse and fine aggregate contents are kept constant so that self-compatibility can be achieved easily by adjusting the water/cement ratio and super plasticizer dosage only [3, 10].

Concrete is one of the principal materials for structures and it is widely used all over the world. However, the heterogeneous structure of concrete results some undesirable effects. The modern concrete can be designed to have a high workability that allows the concrete to flow in the congested reinforcement areas and fill complicated formwork without segregation [4, 5].

There are many advantages of using SCC, especially when the material cost is minimized. These include.
Eliminated problems associated with vibration.

- Less labour involved.
- Faster construction.
- Improved quality and durability.
- Higher strength And SCC mixes must meet three key properties:
- Ability to flow into and completely fill intricate and complex forms under its own weight.
- Ability to pass through and bond to congested reinforcement under its own weight.
- High resistance to aggregate segregation [10].

However, the character and performance of FRC changes, depending on the properties of concrete and the fibers. The properties of fibers that are usually of interest are fiber concentration, fiber geometry, fiber orientation, and fiber distribution. Use of fibers into SCC mixes has been presented by many researchers. Depending on many parameters such as maximum aggregate size, fiber volume, fiber type, fiber geometry, and fiber aspect ratio, fiber inclusion to concrete reduces the workability of concrete.

However, the combination of hybrid FRC and SCC together can provide a way of producing a hybrid fiber reinforced self-compacting concrete (HFR-SCC) with superior properties in not only hardened state but

also fresh state. Slump flow, V-funnel, and J-ring tests are performed to assess workability. Both L-box and U-box tests may be used as a passing ability Indicator. Moreover, the mechanical properties, namely the compressive and tensile strengths, of HFR-SCC mixtures are also determined at various ages [2, 3].

The use of externally bonded Fiber Reinforced Polymer (FRP) systems has been proven to be an effective technique to rehabilitate and strengthen deficient and deteriorated structural member. The FRP materials are known to have high stiffness, high strength to weight Ratio, resistance to corrosion and ease of installation. It should be noted that the externally bonded systems were produced in the early 1940s.

However, the introduction of FRP materials showed better performance than the conventional methods due to the several mechanical advantages of the FRP materials. Many experimental programs and numerical studies investigated different strengthening techniquesin which multiple arrangements of FRP plates and sheets were used. Among them, experimentally investigated the performance of continuous high-strength reinforced concrete beams externally strengthened with CFRP and GFRP sheets. It was concluded that as the number of CFRP sheets increases, the load carrying capacity of the tested specimens increases, while the moment redistribution and ductility decrease along with a decrease in the CFRP ultimate strain at failure. Similarly, for the specimens strengthened with GFRP sheets [9].

Externally bonded CFRP/GFRP sheet method is a suitable repair and strengthening method that is becoming an accepted practice for rehabilitating existing structures in the civilian sector.

The main advantages of CFRP/GFRP may be summarized in the following points:

- Availability in any length and ability to be transported in rolls and Light weight.
- Reduced maintenance cost and construction periods.
- Outstanding fatigue strength [10].

Fig 1.1 Fibermesh 300-E3 Micro Synthetic Fiber

Fig 1.2 Fiber Tuff Macro Structural Synthetic Fiber

II. Review Of Literature

2.1 Self-Compacting Concrete

N. Bouzoubaa M. Lachemi et al. in 2002 has conducted experimental program. The fresh concrete must possess high fluidity and good cohesiveness. The use of fine materials such as fly ash can ensure the required concrete properties. The initial results of an experimental program aimed at producing and evaluating SCC made with high volumes of fly ash has presented and discussed. Nine SCC mixtures and one control concrete were investigated in this study. The content of the cementitious materials has maintained constant (400 kg/m3), while the water/cementitious material ratios ranged from 0.35 to 0.45. The self-compacting mixtures had a cement replacement of 40%, 50%, and 60% by Class F fly ash. Tests were carried out on all mixtures to obtain the properties of fresh concrete in terms of viscosity and stability. The mechanical properties of hardened concretes such as compressive strength and drying shrinkage were also determined. The SCCs developed 28-day compressive strengths ranging from 26 to 48 MPa. The results show that an economical SCC could be successfully developed by incorporating high volumes of Class F fly ash.

Burak Felekoglu, Selcuk Turkel, Bulent Baradan et al. in 2006 has studied various experimental setups.The use of self-compacting concrete (SCC) with its improving production techniques has increasing every day in concrete production. However, mix design methods and testing procedures are still developing. Mix design criterions had mostly focused on the type and mixture proportions of the constituents. In this study, five mixtures with different combinations of water/cement ratio and super plasticizer dosage levels were investigated. Several tests such as slump flow, V-funnel, L-box were carried out to determine optimum parameters for the self-compatibility of mixtures. Compressive strength development, modulus of elasticity and splitting tensile strength of mixtures were also studied

2.2 Self compacting hybrid fiber concrete

Mustafa Sahmaran, Alperen Yurtseven, I. Ozgur Yaman et al. in 2004 has comparative studiedto fiber reinforced concrete (FRC), self-compacting concrete (SCC) has a relatively new type of concrete with high flow ability and good cohesiveness. It offers very attractive economical and technical benefits, which can be further extended when combined with FRC. In this article two different types of steel fibers were used, in combination, and the effects of fiber inclusion on the workability of hybrid fiber reinforced self-compacting concrete (HFR-SCC) has studied. The effects of fibers are quantified based on the fiber volume, length, and aspect ratios of the fibers. It has concluded that in addition to the above-mentioned quantifiable three properties, other properties of fibers such as shape and surface roughness has also found to be important.

Abdulkadir Cuneyt Aydin et al. in 2007 has comparative studied to self-compacting concrete and conventional concrete. SCC has a relatively new type of concrete with high flow ability and cohesiveness when compared to conventional concrete. In this article carbon and steel fibers were used in combination, and the effects of fiber inclusion on the compatibility of hybrid fiber reinforced concrete had studied. The effects of fibers had quantified based on the fiber volume and type of the fibers. It has concluded that in addition to the above-mentioned quantifiable properties, other properties of fibers such as strain sensing, shape, and surface roughness has also found to be important.

Eethar Thanon Dawood and Mahyuddin Ramli et al. in 2011 has studiedthe hybridization of different types of fibers may play important roles in arresting cracks and thus achieve high performance of concrete. Therefore, this study has conducted to investigate the use of different percentages of steel fiber (0, 1.0, 1.25, 1.5, 1.75 & 2%) as vol. %. Consequently, the hybridization of the steel fiber and palm fiber as 2% volumetric fractions on the high strength concrete has applied and determine the density, compressive strength, and flexural strength and toughness indices for all the mixes. The results show that the use of 1.0 % of steel fibers increases the compressive strength by about 13%. The hybrid fibers can be considered as a promising concept and the replacement of a portion of steel fiber with palm fiber can significantly reduce the density, enhance the flexural strength and toughness. The results also indicates that the use of hybrid fiber (1.5% steel fiber + 0.5% palm fiber) in specimens increases significantly the toughness indices and thus the use of hybrid fiber combinations in reinforced concrete would enhance their flexural toughness & rigidity and enhance their overall performances.

2.3 self-compacting concrete with CFRP sheet

Abdulaziz I. Al-Negheimish Ahmed K. El-Sayed Rajeh A. Al-Zaid Ahmed B. Shuraim and Abdulrahman M. Alh ozaimy et al. in 2012 has studiedone-way reinforced concrete joist floors with wide shallow beams (WSBs) has used widely in building construction throughout the Middle East. The short- and long-term behavior of WSBs externally strengthened with carbon fiber-reinforced polymer (CFRP) reinforcement has studied on isolated beams and as part of full-scale building. This paper presented the results of the experimental investigation on the flexural performance of isolated WSBs externally strengthened with CFRP reinforcement. A total of six full-scale beams were constructed and tested to failure. The test variables were the amount, type, configuration, and the elastic modulus of CFRP reinforcement. The test results were

presented in terms of deflections, ultimate capacities and modes of failure, crack width development, and strains in reinforcement and concrete. The test results showed significant improvement in the flexural performance of the strengthened beams with respect to flexural capacity, flexural stiffness, and crack width. All but one of the strengthened beams failed because of the debonding of CFRP reinforcement; however, the load carrying capacity of WSBs has more than that predicted by relevant design guidelines.

Arjan Fakhraldin Abdullah, Mazin Burhan Adeen, Alya'a Abbas Al-Attar et al.in 2014 hasresearch Studies the possibility of producing self-compacting concrete (SCC) containing Pozzolanic materials and reinforced with different types of fibers, 11% (by weight of cement) of silica fume were used and two types of fiber (Steel, Nylon) with different volume fraction, also it studies the structural behavior of the self-compacted reinforced T-section beams. The current study includes a practical program considers the effect of adding steel and nylon fibers to structural behavior of T-section self-compacting concrete such as compressive and tensile strength and flexural behavior represent by load-deflection curves, variables that which studied after obtaining the self-compacting has the volumetric ratios of fibers which used (0.2, 0.3 and 0.4) % ratios for steel and nylon and hybrid fiber. Also Rehabilitate the T-beams after failure in bending by strengthened it with carbon fiber strips (CFRP), and find out the effect of external strengthening by CFRP on the flexural resistance of concrete & reinforced concrete beams. The practical results of the current study indicated that when adding steel fiber to the self-compacted concrete it has shown a good effect of the increase in compressive, tensile and flexural strength, also it has effect of reducing deflection, this effect increasing by increase of the volumetric ratio of steel fiber. While adding hybrid fiber in all ratios lead to an improvement in hardened properties of self-compacted concrete. The results of repair by strengthening the beams with carbon sheets indicated that the carbon fibers had a noticeable effect in increasing the ultimate load in all beams and testing results showed that the flexural strength increased between (6.42%-29.62%) for concrete beams, and between (9%-33%) for rehabilitated damaged concrete beams.

2.4 self-compacting concrete with GFRP sheet

H. Mazaheripour J. A. O. Barros J. Sena-Cruz and F. Soltanzadeh et al.in 2013 has comparatively studied theoretical and experimental parameter. The objective of this study has to present a computational algorithm to analytically evaluate the bond behavior between glass fiber reinforced polymer (GFRP) bar and steel fiber reinforced self-compacting concrete (SFRSCC). The type of information to be derived has appropriate to study the flexural behavior of SFRSCC beams reinforced with GFRP bars in terms of serviceability limit states requirements; in fact, the bond between bars and surrounding concrete influences significantly the crack width and crack spacing. The proposed bond model has established by calibrating the parameters of a multi linear bond-slip constitutive law using the experimental results of pullout bending tests carried out by the authors, taking into account the experimental pullout force versus slip at loaded and free ends. According to the comparison between theoretical and experimental pullout force-slip, an acceptable accuracy of the model has observed. Additionally, by considering the proposed bond-slip relationship, a parametric study has carried out to evaluate the influence of the involved bond-slip law's parameters on the maximum force transferred to the surrounding concrete. Finally, the development length of two GFRP bars utilized in the experiments (deformed and smooth bars) has determined by means of the proposed model, and it has compared with the values recommended by codes.

2.5 self-compacting concrete with CFRP/GFRP sheet

Kian Karimi, A.M.ASCE Wael W. El-Dakhakhni, M.ASCE and Michael J. Tait, M.ASCE et al. in 2012 has studiedthis paper, the influence of slenderness on the behavior of steel-concrete composite columns encased in fiber-reinforced polymer (FRP) jackets. The composite columns have composed of steel I-sections that has partially encased by concrete and fully wrapped with epoxy-saturated glass and carbon FRP sheets. A total of nine specimens have tested with different slenderness parameters and heights ranging between 500 and 3,000mm. The confining pressure provided by the FRP jacket and the composite action between the constituent materials resulted in an enhanced compressive behavior of the composite columns. The compressive strength, elastic axial stiffness, and energy dissipation capacity of the composite columns increased by a ratio of up to 5.2, 2.5, and 14.0, respectively, compared with that of the bare steel columns counterparts. A capacity curve, which shows the compressive strength of the composite columns for various slenderness parameters, has developed based on the experimental results.

Rami A. Hawileh Hayder A. Rasheed Jamal A. Abdalla and Adil K. Al-Tamimi et al.in 2014 has studied this paper presented an experimental and an analytical investigation of the behavior of Reinforced Concrete (RC) beams strengthened in flexure by means of different combinations of externally bonded hybrid Glass and Carbon Fiber Reinforced Polymer (GFRP/CFRP) sheets. In order to obtain the mechanical properties of the hybrid sheets, multiple tensile coupon tests were conducted. In addition, an experimental program consisting of a control beam and four beams strengthened in flexure with GFRP, CFRP and hybrid FRP sheets

has conducted. The series of the RC beams were tested under four point bending to study the flexural effectiveness of the proposed hybrid FRP sheets. The load-deflection response, strain readings at certain locations and associated failure modes of the tested specimens had been recorded. It is observed that the increase in the load capacity of the strengthened beams ranged from 30% to 98% of the unstrengthened control RC beam depending on the combination of the Carbon/Glass sheets. It has also observed that the ductility at failure loads of the beams strengthened with glass and hybrid sheets has higher than that with a single carbon sheet. Hence, the selection of the optimum combination of hybrid sheets can lead to a strengthening material which provides an improved ductility and strength in beam behavior. Experimental and analytical results to investigate the behavior of RC beams strengthened in Flexure by means of different combinations of externally bonded hybrid GFRP and CFRP sheets has presented. Four beams externally strengthened in flexure with GFRP, CFRP, and hybrid combinations of GFRP/CFRP sheets, in addition to an unstrengthened reference beam were 17 tested under four point bending and the flexural effectiveness of the proposed strengthening technique with hybrid FRP sheets were investigated. It is observed that the ultimate load carrying capacity using close to the experimentally measured values. Also the analytical model predicts the behavior of the tested beams very accurately.

III. Conclusion

On the basis of the Review of Literature,

- Adding of Nylon fiber leads to an increase in compressive, tensile and bending strength; with increase in fiber contain compressive strength decreases.
- The use of high modulus carbon sheets in the hybrid system showed a largeincrease in the flexural stiffness, yielding load, ductility and reduction in the crack propagation within the RC beams.
- The ductility at failure for the beams strengthened with glass and hybrid sheets is higher than that with a single carbon sheet and the ductility at failure of the beam strengthened with a single glass sheet is the highest among all the strengthened beams.

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