A Review on Experimental Investigation of Macro Synthetic Fiber Reinforced Concrete

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Abstract: The Structural Polypropylene fibre reinforced concrete (SPFRC) contains randomly distributed short discrete Polypropylene fibres which act as internal reinforcement to enhance the properties of the cementitious composite (concrete). The principal reason for incorporating short discrete fibres into a cement matrix is to increase the flexural tensile strength and increase the toughness and ductility and effect on properties of the fresh concrete and fracture properties of the resultant composite. These properties of SPFRC primarily depend upon length and volume of fibres used in the concrete mixture.

***IndexTerms* – SPFRC, SPF, FRC.**

I. Introduction

The addition of the fibres to concrete has been shown to enhance the toughness of concrete. The ability of fibre-reinforced concrete composites to absorb energy has long been recognized as one of the most important benefits of the incorporation of fibres in plain concrete. Fibers bridge a crack and provide resitance to crack opening which imparts post- cracking ductility to the cementitious composite which would otherwise fail in a brittle manner.

A concrete beam containing fibres suffers damage by gradual development of single or multiple cracks with increasing deflection, but retains some degree of structural integrity and post-crack resistance even under considerable deflection. A similar beam without fibres fails suddenly at a small deflection by separation into two pieces. The toughening effect is the result of several types of fiber/matrix interactions, which leads to energy absorption in the fiber-bridging zone of a fiber-reinforced concrete (FRC). These processes include fiber bridging, fiber debonding, fiber pullout (sliding) and fiber rupture as a crack propagates across a fiber through the matrix.

There are many kinds of fibers, both metallic and polymeric, which have been used in concrete to improve specific engineering properties of the material. Steel fibres are used in a wide range of structural applications, in general, when the control of concrete cracking is important such as industrial pavements, precast structural elements and tunnel linings. Steel fibers have high elastic modulus and stiffness and produce improvements in compressive strength and toughness of concrete. Improvements in flexural strength of the material are also obtained using steel fibres in concrete. Increase in flexural strength is achieved with increasing fiber aspect ratio (length to diameter ratio) and fiber volume fraction; significant improvements are obtained at high volume fractions. In general, addition of steel fibers influences the compressive strain at ultimate load and ductility in flexure more significantly than the improvements in strength. Steel fibers, however, increase structure weight of concrete and exhibit balling effect during mixing, which lowers the workability of the mix. In addition, steel fibers easily basset and rust, and it also has the problem of conductive electric and magnetic fields.

Synthetic fibres are usually smaller than steel fibres and are most typically used in industrial pavements to reduce the cracking induced by shrinkage. Polypropylene fibers have good ductility, fineness, and dispersion so they can restrain the plastic cracks. Synthetic fibres are mainly effective in reducing crack formation, particularly at an early stage of the cast and in severe weather conditions (e.g. in dry climatic zones), when hygrometric shrinkage brings along some weak tensile stress which is yet too high for the fresh mixture to withstand.

Improvements are being made to optimize fibers to suit applications. Recently, macro- synthetic fibres have been produced with the aim of substituting steel fibres in structural applications. There has been a growing interest on synthetic fibres, owing to some substantial advantages over metallic ones, such as strong chemical stability in alkaline and generally aggressive environments, exemption from oxidation, lightness and, in turn, convenient stocking and handling, a-toxicity and electromagnetic transparency. This latter aspect is relevant, for instance, when either dealing with special equipment (ranging from mobile phones to CT diagnostics) or in industrial buildings wherein, say, automated toll collection booths employing electromagnetic vehicle detectors are planned. The availability of a structural synthetic fibre, capable of contributing to the load carrying capacity of an element while increasing its toughness and durability at a reasonable cost, is an important asset for an improved building technology. The knowledge on the mechanical behavior of concretes reinforced with these fibres is still limited.

II. Objectives

The broad objective of the work reported in this paper is to investigate the influence of macro synthetic fibers on the mechanical behavior of concrete. Specific objectives of the paper include

1) To evaluate the influence of macro-synthetic polypropylene fibers on the workability and compressive strength of

concrete.

2) To evaluate the influence of macro-synthetic polypropylene fibers on the toughness and ductility of concrete.

3) To provide an interpretation for the observed tension response of fiber reinforced concrete in flexure in terms of crack propagation and toughening mechanisms in the composite.

III. LITERATURE REVIEW

Fibers have been used as discrete randomly distributed reinforcement to strengthen a material weak in tension. Fibers have been shown to improve the toughness and the post crack ductility in tension, which is achieved by the reinforcement effect across a crack in the material matrix. The use of fibers results in an enhancement in the load carrying ability which is achieved due to stress transfer after cracking. The earliest documented use of fibers has been the incorporation of chopped hay and camel hair in adobe bricks by the Egyptians. Since then different types of fibers have been developed, which can broadly be classified as metallic, synthetic, glass, and mineral. Properties of the different fibers commonly available today.

Table: Typical Properties of Fibers

Fiber	Diameter	Specific gravity	Tensile strength	Elastic Modulus	Fracture strain
	(mm)		(GPa)	(GPa)	(%)
Steel	5-500	7.84	0.5-2.0	210	0.5-3.5
Glass	9-15	2.6	2.0-4.0	70-80	2.0-3.5
Fabricated Polypropylene	20-200	0.9	0.5-075	5-77	8.0
Cellulose		1.2	0.3-0.5	10	
Carbon (high strength)	9	1.9	2.6	230	1
Cement matrix (For comparison)		2.5	3.7 X 10^3	10-45	0.02

IV. METHODOLOGY

Standardized test methods for quantifying improvements in material behavior and obtaining specific material properties have been developed. In these tests material parameters which quantify ductility and toughness of the material are obtained from measured load response. The quantities derived from these tests allow for comparison of material behavior. Standard test procedures for evaluating the response of FRC are available in ASTM 1609, UNI 11039-2, ASTM 1018, EN 14651 and JSCE SF 24.

Additionally, researchers have proposed methods for obtaining fracture or material parameters from the measured test response from the standardized test procedures. The test procedures and the different data reduction procedures are reviewed in this section.

1. ASTM C1609/C1609 M-05 provides a standardized test procedure to establish the flexural toughness, the flexural strength and the residual strength factors of the fiber reinforced concrete from the load-deflection curve through testing of a simply supported beam under third-point loading. The loading and support system capable of applying third point loading the specimen without eccentricity or torque in accordance with ASTM C78-02 is shown. Test is performed measuring the applied load and the beam net deflection (i.e. the absolute mid-span deflection minus the support deflection) at a constant deflection rate. The beam midpoint deflection between the tension face of the beam is measured in relation to the neutral axis of the beam at its support. First peak deflection, toughness and Equivalent flexural strength are derived from the measured response. The standard load-displacement behaviors of fiber reinforced concrete beams. The peak load is determined as that value of load corresponding to the point on the load-deflection curve that corresponds to the greatest value of load obtained prior to reaching the end-point deflection. The first-peak load is defined as that value of load corresponding to the first point on the load-deflection curve where the slope is zero, that is, the load is a local maximum value. In specimens, which exhibit an increase in load after the load drop produced by cracking, the first peak load is the distinctive point in the load response associated with load drop. Strength corresponding to each peak load, f_P is determined following formula for modulus of rupture.

2**.**ASTM 1018 *provides standardized measures of toughness indices taken as the area under the load-deflection curve up to the first crack to area under the load-deflection curve up to certain specified deflection from the load-defection curves of specimens. From the load- deflection curves obtained using the loading procedure specified in ASTM 1609, toughness indices are calculated at three level of deflection 3δ, 5.5δ and 10.5δ,* corresponding to 3, 5,5 and 10.5 times the deflection at first crack, Deflection values greater than 10.5δ can also be chosen for composite that can carry considerable loads at large deflection. The three suggested indices called I_5, I_{10} and I_{20} are defined by following equations. The deflection values of 3δ, 5.5δ and 10.5δ were chosen using elastic perfectly plastic behavior as the datum. Residual loads at specified deflections, the corresponding residual strengths and determination of specimen toughness based on the area under the load-deflection curve up to a prescribed deflection and the corresponding equivalent flexural strength ratio are also obtained.

$$I_{10} = \frac{Area\ under\ the\ load - deflection\ curve\ up\ to\ 5.5\delta}{Area\ under\ the\ load - deflection\ curve\ up\ to\ \delta}$$

$$I_{20} = \frac{Area\ under\ the\ load - deflection\ curve\ up\ to\ 10.5\delta}{Area\ under\ the\ load - deflection\ curve\ up\ to\ \delta}$$

3.UNI 11039-2 bending test is a four-point loading test on a prismatic beam. UNI test specifically prescribes the specimen absolute dimensions; the UNI test employs a notched beam with a specimen which is 150 mm deep, 150 mm wide and the span length is 450 mm. The notch is sawed at mid-span with a depth, a_0 equal to 0.3 times the overall specimen depth (a_0 = d/3). The test is performed measuring the load, P and the Crack Tip Opening Displacement (CTOD), while increasing the Crack Mouth Opening Displacement (CMOD) at a constant rate equal to 0.05 ± 0.01 mm/min. A schematic diagram of the UNI test setup. The first-crack load which required subtracting the contribution due to matrix cracking is obtained by determining the value of CTOD corresponding to the peak load value obtained by performing four-point bending tests on plain concrete beams is determined (CTOD0). In The absence of concrete specimens of the base is allowed the value of CTOD0 can be assumed equal to 25 mm.

V. TEST CONDUCTED

1 Compressive strength
2 Flexural test results as per ASTM C 1609 (For unnotched beam)
3 Flexural test results as per EN 14651-2005 (For notch beam)

VI. CONCLUSIONS

1) To evaluate the influence of macro-synthetic polypropylene fibers on the workability and compressive strength of concrete.
2) To evaluate the influence of macro-synthetic polypropylene fibers on the toughness and ductility of concrete.
3) To provide an interpretation for the observed tension response of fiber reinforced concrete in flexure in terms of crack propagation and toughening mechanisms in the composite.

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