A REVIEW ON DURABILITY AND MECHANICAL PROPERTIES OF STEEL, PROPYLENE AND HYBRID FIBRE REINFORCED CONCRETE

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Abstract: Concrete is the most extensively used structural material in the world with an yearly production of over seven billion tons. For a multiplicity of reasons, much of this concrete is cracked. The reason for concrete to undergo cracking may be endorsed to structural, ecological or economic factors, but most of the cracks are formed due to the natural weakness of the material to resist tensile forces. Concrete normally shrinks and force crack when it is controlled. It is now well-known that steel fibre reinforcement offers a solution to the problem of cracking by making concrete tougher and more yielding. It has also been proved by wide investigation and field tests carried out over the past three decades, that addition of steel fibres to plain or reinforced concrete members at the time of mixing and production improves a number of properties of concrete, particularly those related to strength, performance and durability. Also the change in fibre type like propylene fibre and hybrid fibre also affects the various properties of concrete. This review paper is an evaluative report of studies established in the recent years. It describes and gives a theoretical basis for the research.

Keywords: cracking, durability, mechanical properties, steel fibre reinforcement, propylene fibre, hybrid fibre

1. INTRODUCTION

In modern years Fibre reinforced concrete is cement based composite material has been developed. It has been successfully used in construction with its outstanding flexural tensile strength, resistance to splitting, impact resistance and outstanding permeability and frost resistance. It is a successful way to raise toughness, shock resistance and resistance to plastic shrinkage cracking of the mortar. Fibre is added as a reinforcing material possessing certain characteristic properties. Hybrid is based on the fibre constitutive response, in which one fibre is stronger and stiffer and provides strength, while the other is more ductile and provides toughness at high strains. Hybrids are based on fibre size, where one fibre is very small and it provides micro crack control at early stages of loading and the other fibre is larger, provides a bridging mechanism across macro cracks. Hybrids are also based on the function of fibre, where one type of fibre provides strength or toughness in the hardened composite, while the second type provides fresh mix properties suitable for processing. The PP fibres are actually man-made synthetic fibres resulting from research and development in the petrochemical and textile industries. These fibres are derived from organic polymers which are available in a variety of formulations. The FRC, is a composite material made of hydraulic cement, water, fine and coarse aggregates, and a dispersion of discontinuous fibres.

2. LITERATURE REVIEW

For the purpose and to defend the research work, a number of research papers are analyzed. Following are the excerpts from the different research work performed by number of academicians and researchers.

The strength properties of hybrid nylon-steel fibre reinforced concrete were investigated by **Yew et al.** in comparison to that of polypropylene-steel FRC, at the same volume fraction (0.5%). The content of the high performance macro structure steel fibres is at 0.4% of volume fraction, and the content of micro nylon and polypropylene-fibres is at 0.1% of volume fraction. The investigational results showed that the compressive strength, splitting tensile strength and modulus of rupture of the nylon-steel fibre concrete was improved by 3.2%, 8.3% and 10.2%, respectively, over those of the polypropylene - steel fibre reinforced concrete. With regard to the impact resistance, the first-crack and failure strength, and the percentage increase in the post first-crack is improved more for the nylon-steel-fibre concrete than for its PP - steel fibre concrete counterpart. The above mentioned improvements of the hybrid nylon-steel fibre register a higher tensile strength, possibly due to its better diffusion in concrete, and they are bonded with mixture as well (**Yew et al. 2011**).

A total of 504 concrete specimens were tested by **Faisal et al. (1992)** to study the effect of including hooked-end steel fibre reinforcement on the mechanical properties of high-strength FRC. Fibre content ranges from zero to 1.5 percent by volume, and the compressive strength of concrete was about 94.0 MPa. The influence of fibre content on the compressive strength, modulus of rupture, toughness, and splitting tensile strength was presented. Addition of 1.5 percent by volume of hooked-end steel fibres resulted in a small increase of 4.6 percent in the compressive strength, while the modulus of rupture and the splitting tensile strength increased by 67.0 and 159.8 percent, respectively. The fibre reinforced concrete can deliver a convenient, practical and cost-effective method for overcoming micro-cracks and other deficiencies of similar types. Since concrete is weak in tension, some measures must be adopted to overcome this deficiency. Human hair is strong in tension hence it can be used as a reinforcing material. Hair fibre (HF), an alternate non-degradable matter, is available in abundance and is inexpensive. It also creates ecological problem for its decompositions. This investigation has been undertaken to study the effect of human hair on plain cement concrete on the basis of its compressive, crushing, flexural strength and cracking control to economize concrete and to reduce ecological problems.

Experiments were conducted by **Jain et al. (2012)** on concrete beams and cubes with various percentages of human hair fibre, i.e., 0%, 1%, 1.5%, 2%, 2.5% and 3% by weight of cement. The ability of a concrete structure to resist aggressive environments is directly related to the continuity and permeability of the concrete cover protecting the reinforcing steel bars from being corroded. This can be accomplished by preventing the concrete from being cracked with the addition of fibres in the concrete.

The cover concrete should limit the ingress of aggressive agents, such as chlorides, that can cause damage to the structure, while remaining crack free. Typically, when low permeability is desired, supplementary cementitious materials are added to the concrete mixture; however, this can result in an increase in plastic, drying and autogenous shrinkage cracking **(Cohen et al. 1990; Bloom and Bentur 1995 and Almussalam et al. 1999).**

Soroushian et al. (1995) have studied the effect of PP fibres on the initial and final setting time of concrete and found that the initial and final setting times were decreased by 9 and 27 percent, respectively, with the addition of PP fibres. This reduction is expected to reduce the period of exposure prior to setting of fresh concrete to the dry environment, which is responsible for plastic shrinkage cracking. The amount of bleed water for plain and fibrous concretes was also reduced. Due to the addition of PP fibres, there was an 18 percent decrease in the amount of bleed water of concrete; the fibres possibly reduce the settlement of heavier mix constituents (e.g., aggregates), thereby reducing the upward movement of water (bleeding) in concrete.

Stanish et al. (1997) stated that the RCPT method was originally developed by the Portland Cement Association, under a research program sponsored by the Federal Highway Administration (FHWA).

The test method, **AASTHO T277 and ASTM C1202,1997** have reported that many concrete structures have been built today with specifications insisting low-permeability of concrete. In the present scenario, the construction industry accepts this test procedure as a measurement for determining chloride permeability.

The paper by **Jain et al. (2012)** has stated that for each combination of proportions of concrete one beam and three cubes were tested for their mechanical properties. By testing of cubes and beams they establish that there was an increase in the properties and strength of concrete by the addition of human hair as fibre reinforcement. For use in fire resistance calculations, the relevant thermal and mechanical properties of steel FRC at elevated temperatures were determined. These properties included the thermal conductivity, specific heat, thermal expansion, and mass loss, as well as the strength and deformation properties of steel fibre reinforced silicious and carbonate aggregate concretes.

Ann et al. (2009) stated that the workability of fibre reinforced self-consolidating concretes with two steel fibres of different aspect ratio and one synthetic fibre using standard Slump Flow and J-Ring Test. The test results showed that 40 kg/m^3 (2.5 lb/ft^3) steel fibres and 4 kg/m^3 (0.25 lb/ft^3) plastic fibres can be the upper bound of the fibre content regarding the workability of SCC.

In general, reinforced concrete structures are at times exposed to the effects of horizontal loads such as those generated by seismic activity and wind. For this reason, the bond behavior under cyclic loading for reinforced concrete members is much more significant. The most important factors influencing bond behavior under cyclic loads are concrete compressive strength, cover, bar size, anchorage length, steel yield strength, loading type **(Rehm and Eligehausen 1979 and Harajli 2009).**

The mechanical properties are specified in the form of stress - strain relationships for the concrete at elevated temperatures. The results show that the steel fibre has slight influence on the thermal properties of the concretes. The influence on the mechanical properties, however, is relatively greater than the influence on the thermal properties and is expected to be useful to the fire resistance of structural elements constructed of FRC **(Lie and Kodur (1996)).**

Fume Concrete (SFC) produced with hybrid fibres is a relatively new and advanced material of construction. A typical SFC with Hybrid Fibres mixture consists of coarse aggregate replaced by fine sand used in conventional concrete. The Portland cement plays the role of fine aggregate and the silica fume that of the cement. SFC has no large aggregate and contains small steel fibres that provide additional strength and in some cases can replace traditional reinforcement. The strength and ductility characteristics of SFC may be improved by using hybrid fibres. The different combinations of hybrid fibres like (steel + galvanized iron), (steel + PP), (steel + waste coiled steel fibres), (steel + HDPEF), can improve the characteristics properties of SFC. In their paper, **(Deepak et al. 2011)** described experimental investigation carried out to study the effect of temperature attack on the strength properties such as compressive strength, tensile strength, flexural strength and impact strength of SFC prepared with Hybrid Fibres. Results were compared with strength properties of SFC without Fibres and SFC with Mono Fibres.

Chandramouli et al. (2010) stated that an experimental investigation was conducted on cylinders of 150 mm diameter and 300 mm long with M20 grade concrete cast with addition of glass fibres of varying percentages of 0.03, 0.06 and 0.1 by volume of cement. The RCPT was conducted for a period of 90, 180, 365 and 720 days. The test results showed that the addition of glass fibres exhibited better performance.

One of the primary causes of plastic shrinkage cracking is the loss of water from evaporation that leads to a built-up of tensile shrinkage stress when concrete is subjected to sufficient restraint. When the rate of water loss due to evaporation exceeds the rate at which the bleed water is supplied to the surface, negative capillary pressures form that result in volume changes in the concrete. Tensile stresses in the paste form due to the negative capillary pressure and the development of strength in the concrete. Cracking occurs if the tensile stresses are greater than the tensile strength of the concrete. It is suggested that **(Naaman et al. 2005 and Voigt et al. 2004).**

Corrosion-induced cracks also accelerate the ingress of detrimental ions, resulting in further cracking. The introduction of fibres into concrete has been considered effective in reducing cracking and enhancing durability in cement-based composites **(Mu et al. 2002; Poon et al. 2006).**

The research **b\ _XED Horbanova et al. (2010)** focuses on the properties of PP concentrates and fibres modified by inorganic additive. The PP staple fibres are assigned as reinforcement of concrete to transform and absorb deformation energy. Modification of PP fibres is necessary to ensure more intense anchoring of fibres in cement matrix. In this work the impact of inorganic additive on the rheological properties of PP and PP concentrate as well as on thermal, thermo mechanical and mechanical properties of composite PP fibres was investigated. At rheological properties the index pseudo plasticity of PP and PP concentrates were comparable. Thermo mechanical analysis showed, that temperature of fibre deformation was higher at higher drawing ratio of composite PP fibres containing inorganic additives. Mechanical properties of modified fibres without stabilization and stabilized at 95°C for 1 minute achieved higher values at drawing ratio 4.0. Surface modification of fibres containing inorganic additives was noticeable.

Lie and Kodur (1996) have concluded that the compressive strength at elevated temperatures of FRC was higher when compared to that of plain concrete. The addition of steel fibres resulted in an increase in the ultimate strain and improvement in the ductility of a FRC member. At elevated temperatures, steel FRC exhibited mechanical properties that were more beneficial to fire resistance than those of plain concrete and also thermal properties that were similar to those of plain concrete. The proposed relationships for thermal and mechanical properties of steel FRC at elevated temperatures could be used as input data in mathematical models for the calculation of the fire resistance of concrete structural members..

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