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A Review – Shear and Pullout behaviours of steel Fiber Reinforced Concrete on Elevated Temperature

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Abstract— This paper presents the study of the shear and pullout behaviours of steel fiber reinforced concrete (SFRC) with partial replacements of fine aggregate with copper slag subjected to elevated temperature. Since the shear failures are catastrophic and sudden without any warning, the shear failure of structures to be avoided. The flexural strength in RCC and Prestressed concrete members are influenced by the bond between steel and concrete. Therefore this paper is focused to study these behaviours. The study is formulated to test the shear and pullout behaviours in the elevated temperatures on the specimen of Steel Fibre Reinforced Concrete with partial replacement of fine aggregate with 40% of copper slag with different volume fraction of steel fibers of 0%, 3% and 4% randomly oriented in the concrete.
Keywords— Copper slag, Elevated temperature, Pullout (bond) Strength, SFRC, Shear strength

I. INTRODUCTION

Interest in the behaviour of concrete at a high temperature mainly results from the many cases of fires taking place in buildings, high-rise buildings, tunnels, and drilling platform structures. Some important structures like Nuclear Power Plant concrete Structures, structures near jet aircraft engine blasting, Chemical Processing units, refractory, building affected by fire accidents , etc are subjected to elevated temperatures. During a fire, the temperature may reach up to 1100ºC in buildings and even up to 1350ºC in tunnels, leading to severe damage in a concrete structure. To a large extent, damage to concrete is caused by cracking, which occurs arising due to mismatched thermal strains between the coarse aggregates and the matrix. The elevated temperature adversely affects the mechanical properties of concrete like compressive strength, flexural strength, tensile strength, shear strength, bond strength, etc, consequently overall changes in dimension, functions and behavior of the concrete structures.

Now a days in the modern constructions like Nuclear Power Plants, multiplex complex, the bonded reinforcements are often used in conjunction with prestressed steels and in the composite structures the shear connectors are invariably provided, for which the bond (pull out) strength of concrete is predominant factor.

Many research efforts are focused towards the evaluation of concrete properties in compressive strength , flexural strength, tensile strength but only a few efforts to evaluate the shear and pullout strengths behaviors of concrete in the elevated temperatures which also the vital properties to be evaluated.

II. REVIEW OF LITERATURE

Jonas Gustafsson (1997) investigated the steel fibre as shear reinforcement in high strength concrete beams. He tested twenty beams of different sizes and various % of steel fibers some with shear reinforcement and some without shear reinforcement but with steel fibers. He had concluded that the use of 1% by volume of 6/0.15 steel fibers in the concrete, increases the ultimate shear capacity of 30% than the nominal shear reinforcement used beam sections. In general, a mix of short, straight fibers, 6/0.15, and longer fibers, 30/0.6, that were hooked in the ends, provided the best contribution to the shear resistance of the beams.

Nguyan Van Chan H (2002) investigated the properties of steel fiber reinforcement and the effects of the quantity and aspect ratio of steel fibers in the concrete. He explained that steel fibers are little effect on the compressive strength but considerable effects on tensile strength, flexural strength and workability. It was concluded that the tensile strength increases 133% and flexural strength increases about 100% when admixing of 5 % of steel fibers to the concrete. The higher the aspect ratio reduces the workability but increases the direct tensile strength and flexural strength.

Leema Rose A & Suganya P (2015) have tested the concrete cubes of M30 Grade with different proportion of copper slag 10%, 20%, 30%, and 40% are partially replaced as fine aggregate and studied the properties of compressive strength. The study concluded that addition of copper slag in concrete increases the density up to 20%, self weight of concrete and the compressive strength. The addition of copper slag up to 30% increases the compressive strength and beyond that the compressive strength decreases.

Binaya Patnayak. et.al (2015) have conducted experiments to investigate the strength and durability of concrete having copper slag as partial replacement of sand as fine aggregate. It have been tested two types of concrete grade (M20 & M 30) with different proportions of copper slag of 0% to 50% replacement. The experiments have concluded that Flexural strength, Acid resistivity, and Sulphate Resistivity have improved when the copper slag used as partial replacement of fine aggregate up to 40% in the concrete. Beyond this replacement percentage there is reduction of flexural and compressive strength of concrete.

Deepak Gowda. B & Balakrishna H B (2014) have done the experimental studies on the Flexural Behaviour of Reinforced Concrete Beams by replacing Copper Slag as Fine Aggregate. The M30 grade of concrete mix with water-cement ratio of 0.45 is used to determine the various mechanical properties. This research work mainly consist of two parts , In the first part, substitution of natural sand partially by copper slag in concrete is done with replacement of 0%, 35%, 40% and 45%. The optimum level of replacement of copper slag was found to be 40% and the results were better than that of control Mix. The compressive strength gradually increases from 0%, 35%, 40% replacement of copper slag and decreases for 45% replacement of copper slag. The concrete incorporating copper slag exhibits good mechanical properties and therefore up to 40% by weight of natural sand can be replaced by copper slag.

Sherif Yehia & Ghanim Kashwani (2013) have analysed the properties of the common construction materials such as concrete, steel, and composite structures under high temperature. It has been explained that the spalling of concrete during elevated temperature could affect the mechanical properties of concrete due to the increase of vapour pressure. This pressure leads to internal cracks and stress which exceeds the tensile strength of the concrete and also explained that the concrete does not spall if the moisture content was kept below 3% by weight.

Anand N & Arulraj G (2011) have presented the studies on literature review on the Effect of Elevated Temperature on Concrete materials. Through this presentation it has been reviewed the methods used by various investigations for testing concrete at elevated temperature and concluded that, the strength of concrete, type of cement, type of aggregate, water cement ratio, density of concrete, percentage of reinforcement, cover to the reinforcement etc are some of the important factors that affect the performance of concrete at elevated temperature. Among their review it has been chosen the necessary literature useful for this presentation.

Gai-Fei Peng. et.al.(2006) carried out an investigation to explore the relationship between occurrence of explosive spalling and residual mechanical properties of fibre toughened high performance concrete exposed to high temperatures. The residual mechanical properties measured includes compressive strength, tensile splitting strength, and fracture energy. A series of concretes were prepared using ordinary Portland cement and crushed limestone. Steel fibre, polypropylene fibre, and hybrid fibres were added to enhance fracture energy of the concretes. After exposure to high temperatures ranged from 200 to 800 °C, the residual mechanical properties of fiber toughened high performance concrete were investigated.

Chan. et. al. (1999) carried out an investigation on the fire resistance of normal strength and high-strength concrete, with compressive strengths of 39**,** 76**,** and 94 MPa respectively. After exposure to temperatures up to 1200°C, compressive strength and tensile splitting strength were determined. The pore structure in HSC and in NSC was also investigated. Results indicated that HSC lost its mechanical strength in a manner similar to that of NSC. The range between 400 and 800°C was critical to the strength loss. High temperatures had a coarsening effect on the microstructure of both HSC and NSC. On the whole HSC and NSC suffered damage to almost the same degree, although HSC appeared to suffer a greater worsening of the permeability-related durability.

Amit Rana (2013) had studied the properties of steel fiber reinforced concrete and investigated the optimum quantity of steel fibers required to achieve the maximum flexural strength for M25 Grade concrete. It had been tested 30 beams of size 15x 15 x 70 cm casted with hook end steel fibers in the concrete, to determine the flexural strength . The beams were tested after 28 days of curing in two point load system. From This study it was concluded that, adding steel fibers of 3% to 4% by volume , it increases the flexural strength considerably up to 4 to 5 N/ mm2 , beyond that there is only a little effect of steel fibers in increasing the flexural strength of the concrete.

Joris Fellinger. et. al. (2005) has investigated the shear and anchorage behavior of fire exposed hollow core slabs. They have presented a FE model for the shear and anchorage behaviour of fire exposed hollow core slabs, comprising new constitutive models for concrete and bond of prestressing strands at high temperatures. It has been concluded and recommended that, Current design codes like the new Eurocode 2 do not adequately take into account the shear and anchorage failure of fire exposed HC slabs. On the basis of 25 new fire tests and an in-depth investigation into existing fire test data on HC slabs, is was demonstrated that the shear and anchorage behaviour can lead to premature failure. Therefore, these failure modes should be considered in the fire design of HC slabs.

Sallal Rashid Al-Owaisy (2007) investigated the effect of exposure to elevated temperatures up to (500º C) on shear transfer strength of concrete experimentally by using push-off specimens. From this investigation it was concluded that, shear transfer strength was affected significantly after exposure to elevated temperatures, where the percentage loss in strength ranged from (18.3 to 41.8 %) after exposure to temperatures from (150 to 500 ºC).

M.K.Marolia,(2012) investigated the shear strength on the fibre reinforced RPC by conducting direct shear test on inverted L shape moulded RPC concrete specimens with various proportion of the steel fibres. From this investigation it has been concluded that the ultimate single shear strength for RPC with inclusion of fibers considerably more than the plain RPC. With addition of fibre the specimens do not fail suddenly and the failure load is more than the first crack load.

Nipun Verma and Anilkumar Mishra (2014) investigated the bond characteristic of reinforced TMT bars in Self Compacting Concrete and Normal Compacting Concrete by conducting Pullout Test in the concrete cubes of NCC and SCC specimens in which the TMT bars were embedded. The UTM was used to conducting the Pull out test . The test revealed that the SSC specimens have more bond strength than the NC C.

III. NEED FOR STUDY

Although a large number of experimental and analytical research programs were conducted on the fire resistance of reinforced concrete, the majority of these research works focused on their compression and flexural performance. There is lacking of experimental work addressing the shear capacity and pull out (bond) strength of reinforced concrete elements during fire conditions. Shear failure is catastrophic as it occurs suddenly without sufficient warning. The bond strength between reinforcement and concrete influences the flexural strength, shear strength and ductility of the reinforced concrete sections and reduction of loss in prestressing force in the prestressed concrete members. Therefore, it is essential to adequately evaluate the shear resistance and pullout strength of reinforced concrete elements during fire conditions to avoid such disastrous mode of failure.

IV. CONCLUSION

This study is carried out with addition of steel fibres in the concrete specimens and exposed to elevated temperatures and subjected to shear and pull out tests. This study is concluded that the addition of steel fibres resists the brittle failure of the concrete specimen and increases the bond strength. The randomly oriented steel fibres resists the propagation of random shaped cracks and the cracks occurs mostly through the shear planes which is mostly ductile cracks. Therefore the sudden collapse of the structure due to shear during the fire accidents can be avoided. However more detailed studies with various structural members instead of simple cubes. The replacement of copper slag up to 40% as fine aggregate is the environmental and cost effective of concrete preparation.

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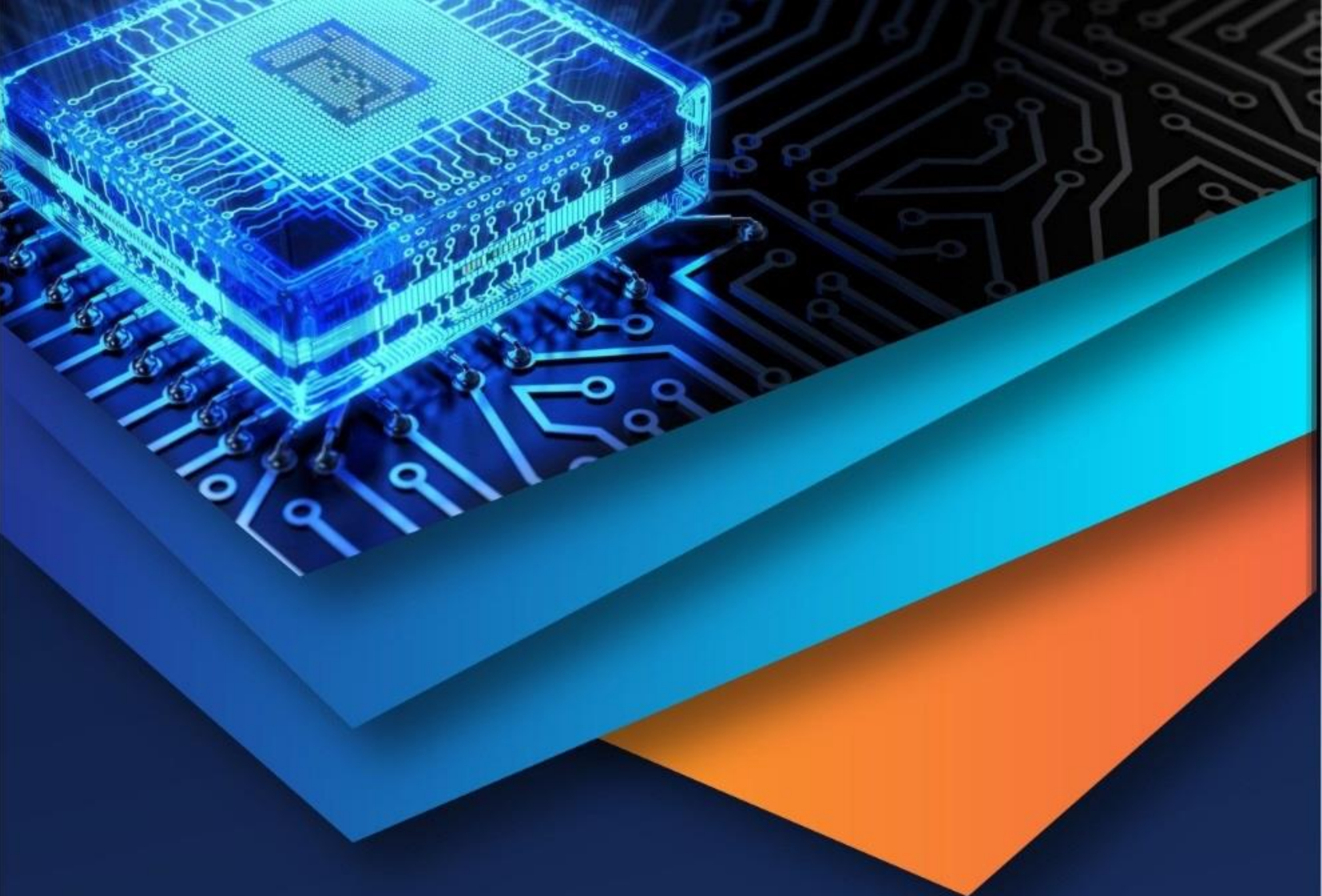

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