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A Descriptive Review On Mechanical Properties Of Ultra High-Performance Concrete

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Abstract A research program is conducted to evaluate the mechanical properties of Ultra-High-Performance Concrete, with target compressive strength at the age of 28 days being more than 150 MPa. The methodology to develop such a mix has been explained. The material properties, mix design and curing regime are determined. The material attributes are understood by studying the stress-strain behaviour of UHPC cylinders under uniaxial compressive loading. The load–crack mouth opening displacement (mod) of UHPC beams, flexural strength and fracture energy were evaluated using the third point loading test. Compressive strength and split tensile strength results are determined to find out the compressive and tensile behaviour. Residual strength parameters are presented vividly explaining the flexural performance and toughness of concrete. Durability studies were also done to compare the effect of fiber to that of a control mix. For all the studies the Mechanical properties were evaluated by varying the percentage and aspect ratio of steel fibers. The results reflected that higher aspect ratio and fiber volume produced drastic changes in the cube strength, cylinder strength, post-peak response, load-mod, fracture energy, flexural strength, split tensile strength, residual strength and durability. Regarding the null application of UHPC in India, an initiative is undertaken to comprehend the mechanical behavior of UHPC, which will be vital in the longer run in the commercialization of structural applications.

INTRODUCTION

For the last decade, UHPC has been one of the keen interest areas for researchers. Conventional concrete is economical, but the problem posed is the low tensile and flexural strength. UHPC is a modified Reactive Powder Concrete having compressive strength generally more than 150MPa, and better resistance to failures occurring due to bending, tension, and compression. The selection of appropriate raw materials, micro- and macro-structural behavior, mechanical properties, durability, methodology for construction and design specifications have been still not clearly understood. They are developed for application in special structures which in the absence of coral provisions can only be practically implicated from the literature and past experimental investigations.

ii. LITERATURE REVIEW

M.M. Red et al (1999) produced innovative UHPC mixtures containing carbon fibers which had better strength and fracture toughness of the matrix with a more resilient post-cracking character. The examination of microcarbon fibers under SEM has shown these fibers to have no smooth surface, which Favors a better bond between these fibers and the cement. He also reported that mixes having both silica fume and silica flour possessed dense and uniform microstructure which was observed using SEM micrographs. No significant portlandite (CH) was detected by XRD. The thermal curing converted weak CH to strong C-S-H gel during hydration, the main hydration products identified had d-values in the range of 2.5 Å and 3.5 Å. Different phases of crystallized S-H were observed. Very strong and moderately permeable Xonotlite

(C6S6H) was a major product in mixtures. Qian Li Qian and Li (2001) observed the effects of integrating metakaolin on stress-strain relationships (tension and compression) and flexural strength for concrete at 0%, 5%, 10%, and 15% Metakaolin. The test results showed that the addition of Metakaolin is directly proportional to the increase in modulus of rupture, compressive strength, tensile strength and peak strain while tensile elastic modulus shows minor changes. The descending area of over-peak stress is enhanced with 5% and 10% of the replacement of cement by metakaolin. However, the brittleness of the concrete also increases with increasing metakaolin content.

Jianxin Ma and Jörg Dietz (2002) studied the self-compacting properties of UHPC with a strength of about 150MPa. They conducted flow tests with pastes constituting different water-to-powder ratios or different superplasticizer dosages with a flow cone similar to self-compacting concrete. He concluded optimal dosage of superplasticizer to be 2% of the powder mass. The slump flow of UHPSCC should be more than 700 mm instead of 650 mm, to reduce the air content to a minimum level which is done by increasing the paste volume in concrete rather than incrementing the SP dosage. The results also reflected that the compressive behavior of UHPSCC is not so strongly dependent on the slenderness of the test specimen as conventional high-strength concrete. This is the same case as in conventional self-compacting concrete. This phenomenon can be explained by the high powder content and the small size of the coarse aggregate.

O. Bayard, O. Pl (2003) studied the material modeling and did experimental investigations using the fracture mechanics approach on RPC. A linear approach was used to focus on the formation and the propagation of the crack. He explained the micro-structural stress and strain concentration, and a model for crack initiation and propagation based on the micro-plane method is obtained. Tensile tests in fiber-reinforced concrete showed the development of a pseudo-strain-hardening behavior associated with a given orientation of fibers. A relative influence of the local anisotropy induced by the process of casting was observed and can be used to optimize the mechanical behavior of RPC reinforced by fibers. Fehling (2004) studied the compressive and tensile properties of hardened Ultra High-Performance Concrete. The observations made were that the compressive strength of UHPC lay in the range of 150 to 220 MPa. Till 70 to 80 % of the compressive strength, UHPC showed a linear elastic Behaviour while the failure was explosive for those without fibers having no descending branch in the stress-strain-diagram. UHPC with fibers (UHPFRC) had pronounced descending branches depending on fiber content, fiber geometry (length, diameter), fiber length about maximum aggregate size, fiber stiffness (in case of fiber cocktails) and fiber orientation. Direct tension tests on UHPC without fibers delivered tensile strength values between 7 and 10 MPa failures being brittle while those with fibers had a tensile strength in the range of 7 and 15 MPa and failure being ductile.

Redaelli and Muthoni (2007) investigated the behavior of reinforced UHPC ties by conducting tests on unreinforced and reinforced UHPC beams, to investigate the effect of the amount and type of reinforcement. The paper describes the influence of the initial slope of the stress-crack opening relationship on the structural response in the first cracking stages predicting that the force in a reinforced tie continues to increase even during softening of the fibres. The differential equations of the cracking behavior of reinforced UHPFC are solved with a numerical technique to gain a better understanding of some governing physical parameters. The paper focuses on the pre-peak zone.

Marshall Davis (2008) This paper reports on a wide-ranging study on the properties of slurry infiltrated Fiber concrete containing fly ash, Metakaolin, and hook-ended steel fibers. Properties studied include the workability of fresh slurry-infiltrated fiber concrete, and compressive strength, flexural tensile strength, splitting tensile strength, dynamic elasticity modulus, the impact energy of hardened slurry infiltrated Fiber concrete. Fly ash and Metakaolin content used was 0%, 2.5%, 5.0%, 7.5%, and 10% in mass basis, and hook-ended steel fiber volume fraction was 0%, 2.0%, 3.0%, and 4.0% in volume basis. The laboratory results showed that steel Fiber addition, either into control concrete or fly ash, Metakaolin blend slurry infiltrated Fiber concrete; improves the tensile strength properties, flexural strength, impact energy, and modulus of elasticity. In this experimental study, the compressive strength improvement ratio is 33.60%, and Structural efficiency is 9.50 % higher in slurry infiltrated Fiber-concrete with Metakaolin as compared with fly ash-based slurry infiltrated Fiber concrete at the 4% replacement ratio of hook-ended steel fibers by volume.

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