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ORIGINAL ARTICLE

Bond characteristics of reinforced TMT bars in Self Compacting Concrete and Normal Cement Concrete

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Abstract In its simplest form, it can be said that the resistance to separation of mortar and concrete from reinforcing steel (or other materials) with which it is in contact is called bond strength. These days different kinds of concrete are manufactured, all with different properties. But bond strength is something which is essentially a well sort after quality for any RCC structure or element. Bond strength can be easily found out by standard pull-out test machine. But in this work, the bond strength was measured using Universal testing machine (UTM) with some modified arrangements. The bond between the concrete and steel reinforcement was investigated for two different kinds of concretes. Using reinforcing bars bond strengths were measured using Self Compacting Concrete (SCC) specimen and Normal Cement Concrete (NCC) specimen. Castings of SCC specimens were carried out without compaction, while the normal concrete specimens were casted with substantial compaction and vibration. The study revealed that SCC specimens generated higher bond to reinforcing bars in comparison with NCC specimens. Secondly, the correlation between bond strength and compressive strength of NCC is more consistent. Thirdly, the results obtained with UTM were compared with the results obtained with standard pull-out test machine and they were found in permissible limits.

1. Introduction

Concrete is the structural material that is extensively used globally. Generally plain concrete system does not have the ability to carry load in tension, once the cracks develop in its cement matrix. To improve the tensile cracking and prevent concrete failure, reinforcement using steel bars is carried out within the concrete mass. Concrete reinforcement increases the flexural behavior and loading capacity of concrete and Thermo Mechanically Treated (TMT) bar enhances the bond strength between reinforcements and concrete. Steel works well as reinforcement for concrete because it bonds well with concrete and this bond strength is proportional to the contact surface of the steel to the concrete. The bond strength greatly varies with changes in mix design and grade of cement used and by providing intensive heat curing, high early bond strength can be achieved [1]. There is strong influence of

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various types of surface preparation such as wire brushed, acid etched, grooved, grooved-wire brushed and grooved-acid etched on bond strength [2]. Moreover, concretes compressive strength, bar diameter, concrete cover, embedded length, and pre-flexural crack length also affect the bond strength [3]. There are 3 ways in which cement concrete is bonded to a steel reinforcement: (i) adhesion between concrete and steel bars, (ii) mechanical Interlock through ribs of steel bar and (iii) chemical reaction between steel and concrete [4]. There are several other factors that directly or indirectly influence the bond strength. A comparative study of the bond strength of reinforcing steel between a high-volume fly ash concrete (HVFAC) and conventional concrete (CC) has revealed that HVFAC possesses comparable bond strength as CC [5].

Studies show [6,7] that TMT bar is the appropriate material for reinforcing concrete structures and has the ability to bond well with concrete. Generally the design of RC structures is based on the assumption of full interaction through concrete and reinforcement interface that is without physical slip and it is reasonable in load bearing capacity analysis, however becomes unacceptable when serviceability of RC structures is considered [8]. A study [9] represents exponential bond stress distribution function and developed an analytical procedure for prediction of deformation and progressive cracking of tensile RC specimens. There is size effect on crack spacing in RC elements using the concept of stress transfer [10] and stress transfer algorithm can be used for parametrical analysis of tension stiffening in tensile RC members. The bond between concrete and development length of reinforcing steel is essential for composite action in reinforced concrete construction.

In the present study, to evaluate the advantages of SCC quantitatively, an experimental program was conducted to measure the bond strength of reinforcing bars in SCC as well as in normal concrete. Several variables are examined, including age of concrete, size and shape of reinforcing bars, (W/C) ratios and type of concrete materials. In the experimental program, the SCC specimens were cast by non-vibration practice, while the Normal Cement Concrete (NCC) specimens were cast by conventional procedures with substantial amount of compaction. To investigate the characteristics of bond development, reinforcing bar pull-out tests were conducted at various ages of concrete, starting from the setting time of concrete to 28 days. Further study also demonstrates to carryout pull-out test using UTM machines. Generally Universal Testing Machine (UTM) is available in majority of the laboratories. The method of using UTM for pull-out test has been explained here in this paper. Samples with various parameters were first tested with the standard equipment and then were tested on UTM for the pull-out test. Results were compared. It is explained, how the UTM can be modified and used for testing the bond strength between steel and concrete up to a fairly accurate degree.

2. Significance of the work

This work has major significance in construction works related to reinforced concrete and selection of materials and their specification. The experiments performed for measuring the bond strength of reinforcing bars can be used for the evaluation of the feasibility using SCC in place of normal concrete. Moreover there are several other relevant structural performances, but in this paper, more emphasis has been given on bond strength and investigation is made in view of the extension of design rules from Normal Cement Concrete (NCC) to SCC.

2.1. Materials and methods

The bond properties of reinforcing bars in SCC were studied by conducting direct pull-out test of reinforcing bars embedded in SCC specimens and also in NCC specimens and the results are compared. UTM was modified to conduct the pull-out tests.

2.1.1. Materials

OPC 33 grade cement (IS: 269-1989) and silica fume (IS: 15388-2003) were used as cementitious materials. Tables 1 and 2 show the chemical and physical properties of OPC 33 grade cement used in the study. Natural River sands (Yamuna River, New Delhi) and crushed gavels (Faridabad, Haryana) were used as fine and coarse aggregates respectively. The characteristics of the aggregates are given in Table 3. The super-plasticizer used was polycarboxylic acid-based with relative density of 1.5 and the mixture proportions of SCC and NC are summarized in Tables 4 and 5 respectively.

2.1.2. Pull-out test using UTM machine

Pull-out tests were carried out using the Universal Testing Machine by changing the position of the cube. Cube was placed in such a manner that pull-out test can be performed effectively. Cube was placed below the deck as shown in Fig. 1. The length of reinforcement was increased to 600 mm where 150 mm was embedded in the cube. The bars were passed through the hole present in the deck and then clamped at the jaws present at the top. Hence proper tensile forces were transferred uniformly through the cube.

Table 1 Chemical properties of cement OPC 33 grade.

S. no.	Composition	Amount
1	L.S.F.	0.66–1.02
2	SO3	Max 3.5%
3	L.O.I	Max 5.0%
4	MgO	Max 6.0%
5	Insoluble residue	Max 5.0%
6	Chloride	Max 0.1%
7	Alkali content	Max .05%

Table 2 Physical properties of cement OPC 33 grade.

S. no.	Property	Value
1	$f'c$ (3 day)	Min 16 MPa
2	$f'c$ (7 day)	Min 22 MPa
3	$f'c$ (28 day)	Min 33 MPa
4	Fineness	Min 225 m^2/kg
5	Autoclave Expansion	Min 0.80%
6	Setting Time-Vicat	Min 30 min

f′c = Compressive strength.