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Influence of Surface Textures on Shear Capacity of High Strength Concrete Interfaces

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Abstract: ***Construction joints cannot be avoided in any type of construction when the size of a structure is too large or construction is carried out in stage-by-stage. As construction is made on stages, joints between concretes is formed and these interfacial joints play a major role in overall efficiency of the structural system which take part in transferring loads and stresses from one section to other section. Shear stress transfer mechanism between two concrete layers is a complex phenomenon. Several parameters like roughness of interfaces, dowel action due to aggregates used, compression resistance of weaker concrete and reinforcement crossing the interface influence the shear transfer mechanism. Performance of the joints should be studied since the sections connected by the joints may be of different properties. Concrete layers having difference in aggregate types, cement content and water cement ratio should be analyzed for interface shear. This paper reports tests in which direct shear forces are applied across the High Strength Concrete joints between concretes forming a composite action. Push-off specimens are used for experimental study. Specimens were cast with Manufactured sand (M sand) and river sand as fine aggregates. Surface textures are varied by imparting smoothness and roughness at interface and shear transfer mechanism is studied. Also effect of variation in shear transfer capacity due to fine aggregates used at interface is studied***

Index Terms**: *Construction joints, Dowel action, High Strength Concrete, Push-off, Shear transfer.***

I. INTRODUCTION

Concrete is a composite construction material composed of cement, coarse aggregate and fine aggregate bonded together which hardens over time when mixed with water. Workability, ease in moulding and early strength achievement are some of the efficient characteristics of concrete which make the concrete reliable in the era of fast growing construction industry. Various types of concretes are available today such as High Strength Concrete (HSC), High Performance Concrete (HPC), Ultra High Performance Concrete (UHPC) Fibre Reinforced Concrete (FRC) etc. and all made available due to the emerging researches in the field of concrete. Concretes with higher strengths and attributes superior to conventional concretes made the use of HSC for construction, especially for multi-story buildings in industrialized and developing countries. Reduction of column sizes, increasing column spacing thus increasing the floor space in lower floors,

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Increasing storey heights and number of stories are all made the use of high strength concrete. Uniform density and low permeability of High strength concrete imparts greater resistance to aggressive environment and disintegrating agencies and contributes durability to the structures. Construction joints cannot be avoided in any type of construction when the size of a structure is too large or construction is carried out in stage-by-stage. As the interfaces are potential failure sites, its performance of joints should be studied in detail since it is the major element in transferring shear stress from one section to the other. Also when elements cast at different times with concretes of different strength and constituents, to achieve composite action, interface shear strength must be sufficient to resist the sliding motion between the two concrete surfaces in contact. The main objective of the work is to study the effect of surface textures on shear capacity of HSC interfaces. For this purpose, Push-off specimens (size 300 x 520 x 125mm) are used to quantify the shear load vs. deformation of HSC interface. Control specimens were cast as monolithic and test specimens were cast as bi-lithic and interfaces were kept rough and smoothened for experimental study.

II. SHEAR TRANSFER

Shear forces induce inclined cracks in structural members. Shearing stresses can also cause sliding type of failure along a well-defined plane and this is denoted as Interfacial shear transfer or direct shear transfer . Shrinkage of concrete, external tension or accidental causes prior to external shear influence crack initiation in concrete. Shear transfer by aggregate interlock and dowel action is more dominant in construction joints. Sites of existing cracks, region of discontinuities are all potential areas of shear failure. Regions where two different types of concrete mixes are used to make construction joints, junction between flange and web in a beam are few examples for this type of failures. Shear transfer is quiet common in composite structures, corbels, deep beams etc. Push-off specimens (fig.1) are usually used in these types of experimental studies to measure the shear capacity of joints.

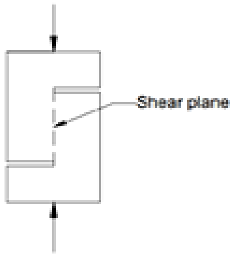

Figure 1. Specimen with Interface Shear Plane

III. EXPERIMENTAL INVESTIGATION

Experimental study is carried out to evaluate the effects of surface textures formed due to fine aggregates on shear capacity of HSC interfaces. Push-off specimens of dimension 300 x 520 x 125mm were cast for this purpose. Compressive loading is carried out until failure in Universal Testing Machine and corresponding load values were noted. Two LVDTs were used to measure the horizontal and vertical deflection on loading of push off specimens.

A. Materials

Materials used in the experiment are Ordinary Portland Cement (OPC), river sand and manufactured sand (Msand) as fine aggregates, coarse aggregate, super plasticizer and potable water. Coarse aggregate used are of size 6mm and 12mm conforming to IS 383 (part III):1970). M sand and river sand passing through 4.75mm sieve conforming to zone I were used as fine aggregate. Potable water free from impurities is used.

B. Mix proportion

HSC of grade M60 for the experimental study was developed using the recommended guidelines from ACI 211.4R-93. Optimum mix ratio of 1:1.36:2.14 adopted after various trial mixes.

C. Specimen description

Experimental work involved developing M60 mix and casting of push-off specimen of dimension 300 x 520 x 125mm .8mm diameter and 6mm diameter steel bars were used as main reinforcement and stirrups in order to eliminate failures other than interface shear failure. Specimen and reinforcement details are shown in Fig.2

Six types of specimens were cast and tested. Two of them were monolithic control specimens. Bilithic specimens were cast to idealize the joints made with variation in surface textures due to fine aggregates and mixes. Control specimens were cast with M sand and river sand (CSM & CSR) as monolithic specimen. Bilithic specimens included smooth interfaced specimens (SSM & SSR) and rough interfaced specimens (SRM & SRR). Specimen details are shown in table 1.

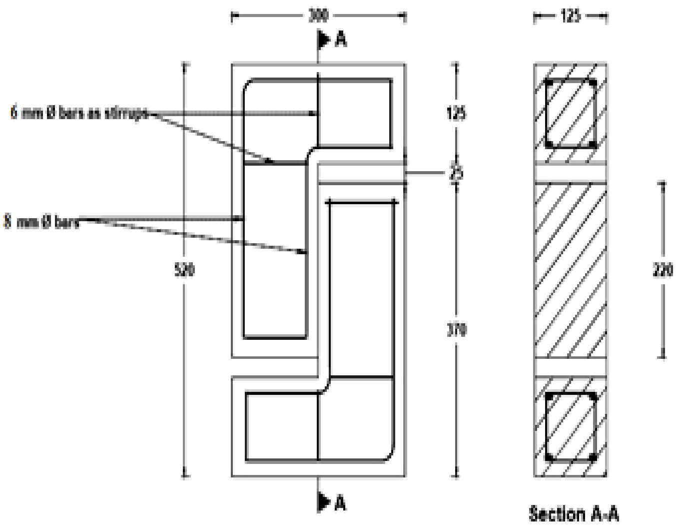

Figure 2. Reinforcement Details of Push-Off Specimen

Table 1. Specimen Description and Details

Sl. No.	Designation	Specimen description
1	CSM	Monolithic specimen with Msand as FA
2	SSM	Bi-lithic specimen with Msand
3	SRM	Bi-lithic specimen with River sand
4	CSR	Monolithic specimen with river sand as FA
5	SSR	Bi-lithic specimen with river sand and M sand
6	SRR	Bi-lithic specimen with river sand and Msand

D. Specimen Preparation

Steel moulds of size 300 x 520 x 125mm were used for casting specimens. Fig.3 shows steel mould and reinforcement arrangement. Reinforcement cages were placed in position and the moulds were filled with concrete mixes.. Entire arrangement was kept for 24 hours and demoulded later. These demoulded specimens were water cured for 28 days.

E. Testing of Specimen

Test setup was common for all specimens. Horizontal and vertical displacements were measured using two LVDTs attached to the specimen. Fig.4 shows test setup, loading condition and position of LVDTs.

Figure 3. Push-Off Specimen with Reinforcement

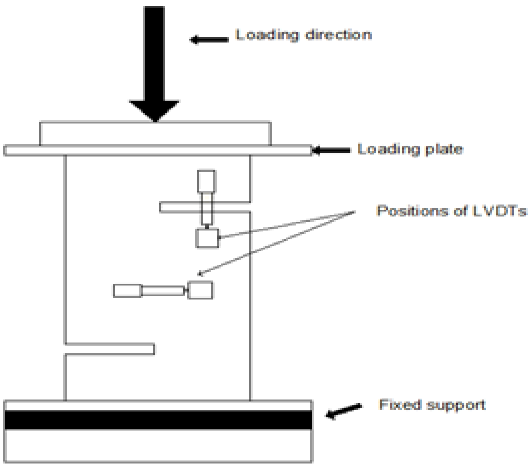

Figure 4. Schematic Diagram of Test Set Up

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All the specimens were subjected to direct compressive loading using 300 T UTM. Specimens were loaded till failure and horizontal and vertical displacements were noted for corresponding load intervals. Fig.5 shows the experimental setup.

Figure 5. Experimental setup

IV. RESULTS AND DISCUSSION

Experiments were carried out and results were obtained based on this experimental work. Discussion of test results based on the same are presented here.

A. Test Results.

From the direct shear test conducted on the specimen, loads and corresponding displacements were obtained. The horizontal and vertical displacements were recorded from LVDTs for each load increment until failure. Results obtained from the experiments are listed in table 2.

Control specimen showed high ultimate load and shear strength because of monolithic casting of control specimen. Specimens with smooth interface showed very low ultimate load and shear strength because interface is left as cast without any surface treatment. Specimen with rough interface showed considerably higher ultimate load and shear strength compared to specimen with smooth interface. Since this specimen is bi-lithic, it has lower values of ultimate load and shear strength compared to control specimen.

Table 1. Ultimate load and Shear Strength

Sl. No	Designation of specimen	Ultimate load (kN)	Shear stress (N/mm^2)
1.	CSM	186.4	6.8
2.	SSM	63.78	2.32
3.	SRM	93.2	3.4
4.	CSR	237.4	8.63
5.	SSR	89.3	3.24
6.	SRR	109.87	4

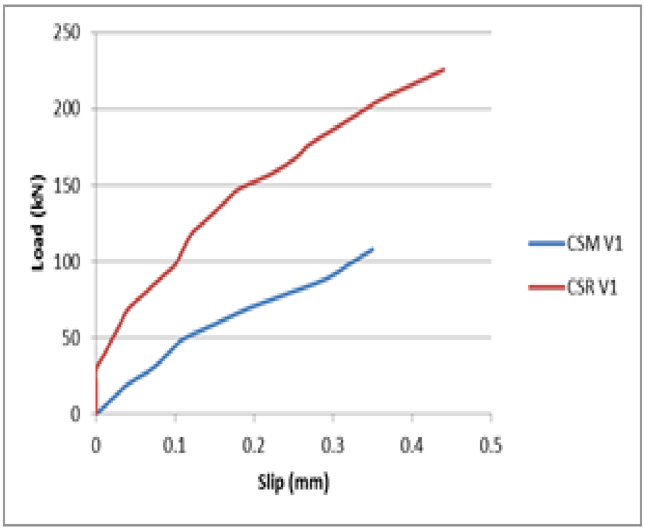

Figure 6. Load vs Vertical Slip for Control Specimen

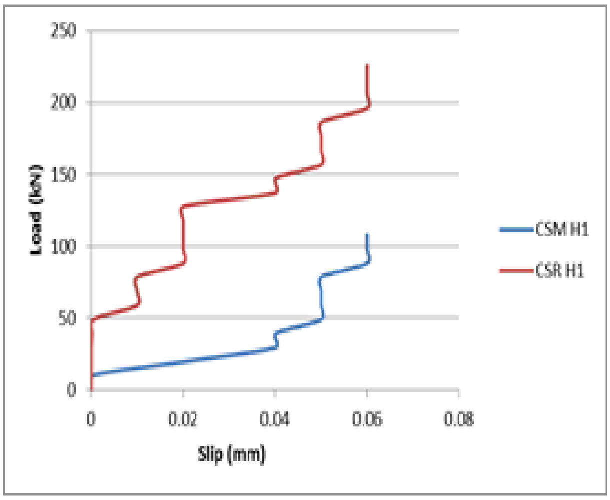

Figure 7. Load vs horizontal slip for control specimen

Control specimens showed larger ultimate load and shear strength both in the case of specimen with Msand and river sand. Larger values are obtained because of monolithic casting of specimens

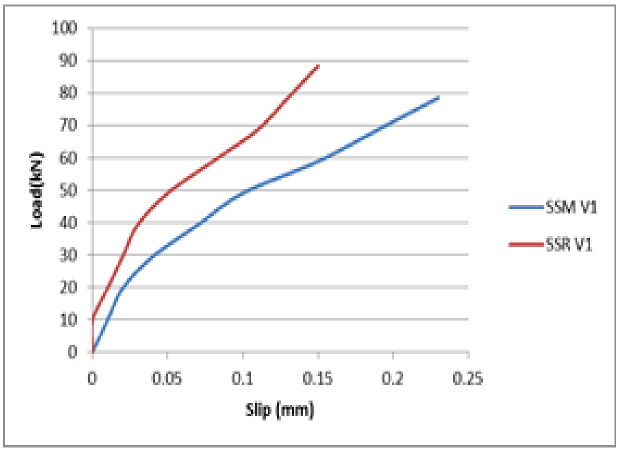

Figure 8. Load vs vertical deflection for smooth specimen

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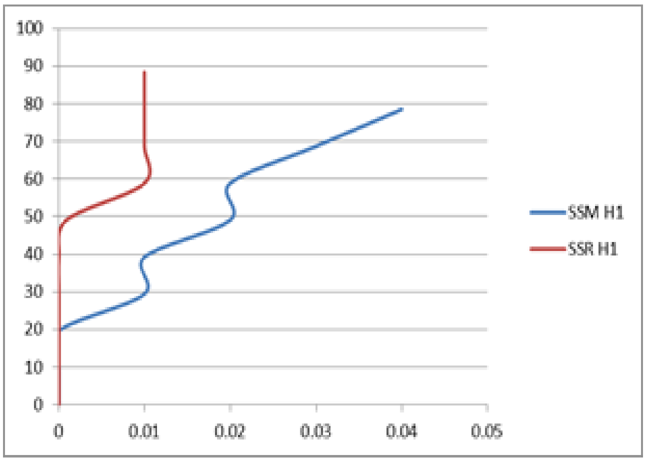

Figure 9. Load vs Horizontal Slip for Smooth Specimen

Specimen with smooth interface showed lower values for ultimate load and shear strength. Specimen got fractured into two pieces after reaching ultimate load. Fig.10 and Fig.11 shows load vs. vertical deflection and load vs horizontal deflection for rough specimen respectively.

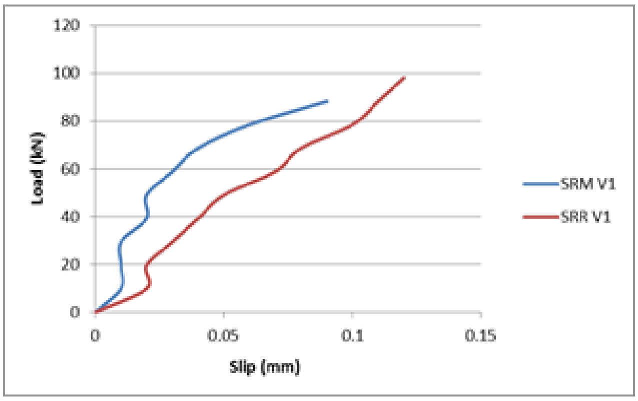

Figure 10. Load vs vertical slip for rough interfaced specimen

Control specimens fractured into two pieces after the ultimate load is reached .Specimen with roughened interface showed higher values for ultimate load and shear stress compared to specimen with smooth interface. Rough interfaced Specimen showed lower shear stress values compared to control specimen. This is due to the bi-lithic casting of the specimen. All specimens fractured into two pieces after reaching the ultimate load. Fig.12 shows the failure surfaces of three specimens

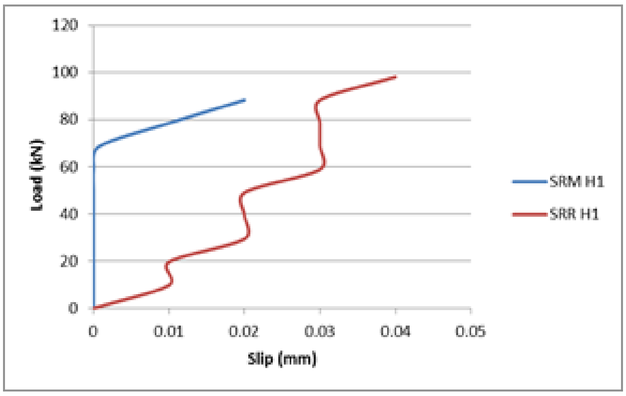

Figure 11 Load vs Horizontal Slip of Rough Specimen

CSM SSM SRM

Figure 12. Failure Modes of Interfaced Specimen

Table 3 Fracture Energy of Specimens

Specimen Designation	Fracture energy (N/mm)
CSM	1.51
SSM	0.33
SRM	0.47
CSR	2.39
SSR	0.34
SRR	0.45

Fracture energy of specimens were found out by calculating area from load vs slip graph of each specimen and these values are given in table 3. Monolithic specimens with river sand showed higher fracture energy and the energy on specimens with construction joints is less .This shows the need of special treatments at interfaces.

V. CONCLUSIONS

Experimental study involved casting of push-off specimens with varied surface textures. Control specimens were cast monolithic and others were cast bi-lithic with varied surface textures. Variation in shear capacity was studied and following conclusions were obtained:

1. Monolithic specimens showed higher shear strength than bi-lithic specimens and this lesser shear strengths may be due to the presence of joints.
2. Among the bi-lithic specimens, specimens with rough interface showed higher shear strengths. Shear strength of specimen with rough interface is 25% more than the specimen with smooth interface
3. Shear stress transfer mechanism between two concrete layers is to be improved. Interfaces should be roughened or reinforced in practical cases.
4. Further studies can be made with Fibre reinforced concretes at interface

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