International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: 6.614
Available Online at www.journalijcar.org
Volume 9; Issue 05(E); May 2020; Page No.22341-22344
DOI: http://dx.doi.org/10.24327/ijcar.2020. 22344.4402

Research Article

PERFORMANCE ASSESSMENT OF STEEL-CONCRETE COMPOSITE BONDED SPECIMEN UNDER SLANT SHEAR

Prashant[1], Pankaj Kumar[2] and Abhilash Shukla[3]

[1]Post Graduate Student, Department of Civil Engineering, Jaypee University of Information and Technology, Waknaghat-173234, Himachal Pradesh, India
[2]Assistant Professor, Department of Civil Engineering, National Institute of Technology Nagaland, Chumukedima, Dimapur-797103, Nagaland, India
[3]Assistant Professor, Department of Civil Engineering, Jaypee University of Information and Technology, Waknaghat-173234, Himachal Pradesh, India

ARTICLE INFO

Article History:
Received 4th February, 2020
Received in revised form 25th March, 2020
Accepted 18th April, 2020
Published online 28th May, 2020

Key words:

Bond Strength, Slant Shear, Composite

ABSTRACT

This paper investigates the bond strength between concrete and steel specimens which are bonded together to form a composite cylinder and observe the failure pattern and type of failure. The Slant Shear Test method, by ASTM C882 is used to check the bond strength between steel and concrete specimen. The steel and concrete specimens are bonded together on a slant elliptical plane at a 30° angle from vertical using epoxy based bonding agent. It is assumed that if the failure occurs on slant surface then the bond strength we obtain is true bond strength but on performing test the results shows that the bond strength obtained is not true bond strength i.e. failure don't occur on slant surface. The bond strength obtained is apparent bond strength. Thus, the slant shear test does not always provide true bond strength between the samples which are bonded together.

INTRODUCTION

As we know that concrete is a material which is used in many places for different purposes e.g. for construction of buildings, for maintenances purpose etc. We know that concrete is weak in tension and strong in compression. Also after some time concrete start to deteriorate because of which concrete is always in need of repair. Also we need to improve the strength of concrete in tension so concrete do not fail in tension. So, in this paper we have done research on the concrete-steel bonding and check the bond behavior between steel and concrete specimens using slant shear test. For that we made a composite cylinder specimen of concrete and steel in such a way that the composite cylinder shows monolithic behavior. Monolithic behavior in a structure is important because it helps the structure or any member within the structure to increase their efficiency and strength which helps in attaining an economical structural design. The slant shear test using ASTM C882 is used to check band strength due to reason that bonded surface is subjected to combine shear and compressive state of stress which is similar to the conditions in real structures (Clímaco and Regan, 2001)**[1]**. Also, there are two types of failure of sample can take place. One is adhesive mean interfacial type failure and second cohesive mean monolithic type failure (Santos 2009) **[2]**.

Corresponding author:* **Prashant
Post Graduate Student, Department of civil Engineering, Jaypee University of Information and Technology, Waknaghat-173234, Himachal Pradesh, India

Literature Study

Macdonald *et al*. (1982) **[3]**, has done his work on increasing the strength of the concrete structures by bonded them with steel plating. He said that sometimes to increase the structural performances of concrete, additional reinforcement of steel using epoxy adhesive can be bounded to hardened concrete for reasons like increasing load carrying capacity of structure, correcting n error in design or in construction, to stop cracking or to constraint it. He conclude that when steel plates were externally bonded to the beam in tension faces a fully composite action could be achieved in concrete beam which were tested in 4 point bending. Also, using a wide plate achievement of a soft failure can be done. Also, he find out that steel specimen which are exposed to environment than those which kept under controlled condition in laboratory attain slightly less strength due to corrosion because corrosion spread on all the steel interfaces which are exposed to environmental conditions.

Clímaco and Regan (2001) **[1]**, in choosing a basic point to check adhesive failure he select a critical angle for a Mohr-Coulomb failure model. About 223 numbers of tests were performed for three different types of angles. The three angles are 0°, 20°, and 26.7°. Despite of the fact that 20° angle was distinguished for always getting an adhesive failure type, cohesive type failure was also obtained. Also, when the angle is the lowest possible (0°), cohesive type failure was still observed. From this study, he finds out that:

1. The interface angle also play role in the mode of failure.
2. Adhesive type failure is not every time possible by defining this parameter.

Júlio *et al*. (2006) [4], he checks differential stiffness due to shear in concrete bond interfaces by casting SST samples. The samples of concrete were kept constant, at a 30 MPa compressive strength, whereas three same types of concrete samples with different grades of concrete were used in the layer to be added of concrete having compressive strengths of: 30 MPa, 50 MPa and about 100 MPa. The roughness in the surface were increased by different methods such as sand-blasting, being observed that specimens with the same concrete at both halves give out adhesive type failures whereas the other samples gives failure of cohesive type, proving a influence due to differential stiffness on the type of failure.

Santos *et al*. (2011) [2], in these literature two types of failure (adhesive as well as cohesive) are checked. Moreover, he finds out that the rate of failure in cohesive condition increase because of increase in the surface roughness. He also came to a conclusion that increasing in the differential stiffness the number of failures in cohesive state rises. The differential shrinkage condition was analyzed by using dissimilar conditions of curing and different ages between the added concrete layer and the substrate. He also came to conclusion that this parameter determines the type of failure.

Austin et.al (1999) [5] performs testing in bond of concrete repairing in shear. He said in application and performance of repair in concrete good adhesion between the material to be repaired and the concrete is required. He compares different methods and gets results of test of strength of bond that also include a tensile slant shear test. He find the failure of bond for repairs of concrete based on many tests such as pull off, Arizona slant shear etc test which shows stresses in compression and also state of pure tension. By utilizing this result compare to the previous tensile slant shear result, which are also in the different researches, we can find more logic in the failure shape of envelope in the regions of tension. In almost all the cases the mode of failure stresses are on the basis of the result analyze by peak FE. He find out that the polynomials curve of second order are best-fit because of exclude of the values of the pure tension which generate a cut off relationships which is given by the results of tension slant shear test. In an attempt to find an envelope of potential failures, it is useful to take in account the behavior of materials in a context wider compare to many theories which are established of failure. His engrossment in the combined as well as single shear/normal states of stresses leads instinctively to a approach known as Mohr-Coulomb. Also a classical alternative method to trafficking with the region in tension is done by applied Griffith fracture criteria's to the material which are brittle. Also, the addition in terms of shear to his theory from stress environments as well as normal stresses is in a parabolic relationship. He conclude that a study related to bond failure, which require cracking of the specimen at the interface of bond, may have a great chance of having natural empathy with respect to fundamentals failure of fractures criteria as compare to Mohr Coulomb relationships, which are distressed with the states of stress with in a materials preferably to the specimens which are bond together at the interface. Nonetheless, we can say that the purpose of this study is find an empirical bond failure case and to find out a common link to these two classical failure concepts. Issa *et al*. (2007) [6], Issa find out effect of epoxy repairing on cracks in concrete by doing experimental work. For the durability of concrete cracks always posed as a threat for the failure of concrete structures. Epoxy in crack can be filled either by gravity filling or injection method in order to restore structural integrity by bonding the crack. He had taken 15 samples out of which three samples with no cracks and six samples with cracks but without repair and another sic samples with repair done in cracks using epoxy by using method gravity filling. These samples were crushed by compressive loading and their compressive strength is find out.

He concluded that reduction caused in compressive strength of concrete by cracks is about 41%, where as the cubes in which epoxy in cracks is used is able to restore maximum strength loss due to cracks and the reduction in compressive strength is only about 8%. He concluded that with the increase in size of crack, there is progressively decrease in the strength of the concrete structures. Diab et.al (2017) [7], diab has find bond strength using slant shear between old type concrete material and self-compacting type concrete. He takes out a cylindrical specimen of 150mm dia and300 mm height having minimum COV. He find out that the roughness of the substrate having a notable effects on the strength of bond and also on specimen of prism which shows more reliability in bond strength. In these study first parts shows reasons that affect bond strength in old type and new type of concrete and effect of, roughness in old type of concrete, effect of bonding agent and effect of providing polyprepene fiber also latex to SCC. In the second half slant-shear tests study is carried out.

Gopala Krishnan (2005) [8], performed pull-out specimen test to find out effect on bond strength by replacing 50% fly ash with cement sample. The specimens contain 20mm diameter bars in a 150 mm cube of concrete. He finds out the same strength in the bond for the CC as well as HVFAC specimens. Arezoumandi *et al*. (2015) [9], replaces about Seventy percent of the fly ash of Class C with cement in a relatively excessive amount which is a highly cementitious (500 kg/m^3) mixture and he achieved the strength of bond higher for the HVFAC when it is correlate with CC in both of the splice beam and for the specimen in pull-out.

Zhang (2017) [10], He finds bond stress for various positions which are derive which are established on the strain in the reinforcement. The crest which are two in number of the stresses in bond appears in the area of the loading as well as the free ends, and also the distributions in the stresses in bond is further constant in the sample with a large induced corrosion cracks widthwise. The crests of bond stress with increase in the load have a moving trend in the free. Maragakis (2006) [11], he finds out that the strength of bond in concrete and FRP rises with compare to strain rates as logarithmic functions. Equations were also developing on the basis of regressions analysis done for the bonded result. Volz (2015) **[12]**, the consequences of corrosion in typical bond-slip relationships and also in different modes of the failure in bond are checked at different levels of corrosions. Three failure modes were shown by the deformed bar specimen which are: pull-out failures with the load-induced cracks, pull-out failures along corrosions cracks and splitting failure. Two types of failure were shown by the smoothed bar specimen, they are: pull-out type failures and splitting type failures. Induced cracks due to corrosions have effects in the etiquette of bond which are significant.

Materials and Laboratory Investigations

Cement: In construction field cement is the basic material to be used because it has the property to act as a binder between different materials. In this paper the cement used for experimental work is Pozzolona Portland Cement Fly Ash based. IS 1489 Part-1 (1991) code is used to check that all the requirements of cement are satisfied. The result obtained in laboratory by performing physical testing of cement are given below:

Table 1 Physical properties of cement

Sr. No	Experiment Name	Test Result	IS Code
1	Consistency of cement	33%	IS 4031-part4 (1988)
2	Initial Setting Time	82 minutes	IS 4031-part5 (1988)
3	Final Setting Time	573 minutes	IS 4031-part 5 (1988)
4	Specific Gravity of cement	2.81	IS 2720-part3
5	Fineness of cement(% retained)	3%	IS 4031-part1 (1996)

Aggregates: In concrete volume occupied by aggregates is maximum and Coarse and fine aggregates are taken from nearby sources and laboratory experiments were performed on them to find their physical properties. The range of size of fine aggregates lies between 4.75mm to 75 micron and coarse grain used are of 10mm to 12.5mm. According to IS 2386-1 (1963) sieve analysis of the aggregate is done and using IS 2386-3 (1963) specific gravity and absorption of the aggregates are find out. The results of physical properties of aggregates obtained are given below:

Table 2 physical properties of fine aggregates

Sr. No	Experiment name	Test Result
1	Specific gravity	2.65
2	Fineness Modulus	2.63

Table 3 Physical properties of coarse aggregates

Sr. No	Experiment Name	Test Result
1	Specific Gravity	2.69
2	Fineness Modulus	6.93
3.	Water Absorption (%)	1.9

Design Mix: Two grades M30 and M40 of concrete are prepared with the help of IS 10262 (2009) and IS 456 (2000). Six samples of concrete are prepared for both grades, three samples to check 7 days compressive strength and next three to check 28 days compressive strength for both grades. Mean value is taken of the three cubes to find out the value of 7 days and 28 days strength. Details of the grades of concrete samples are present below:

Table 4 Mix proportion of concrete mix

Grade of concrete	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)
M30	437.23	801	1034.89	175
M40	398.57	770	1054.34	139.5

Specimen Casting: For casting of the concrete mix we need all the materials require such as cement, sand as fine material and coarse aggregates. First we have to check there are no lumps in cement. Then taking the required amount by weight all the materials were put together then first dry mix them so cement, sand and coarse aggregate mix properly. Then if there is need to add additives to increase strength super plasticizer are mix in water in required amount and then water is added in dry mix and mixing is done in mixer for about 5min. All the samples were prepare using code IS 516 (1959). 150mm size cubes are taken and fill with concrete samples and after 24hrs de-mold them and put samples in water tank for curing and taken out at 7days and 28 days to find out 7days and 28 days compressive strength. The results of strength at 7 and 28 days for different grades are given below:

Table 5 compressive strength of samples

Grade of concrete	7 days strength (N/mm^2)	28 days strength (N/mm^2)	water/cement
M30	21.67	33.23	.4
M40	27.91	43.4	.3

Slant Shear Bond Strength: The strength of bond between steel concrete composite cylinder specimen is determine using slant shear test by using standard procedure given in ASTM C882. In this test procedure the concrete and steel samples are bonded on a slant elliptical plane which is inclined at an angle of 30° from the vertical with dimension of 50mm×100mm composite cylinder.

Figure 1 concrete mold and steel specimen for SST

In the figure 1 there are two materials, first one is mold in which concrete is placed and second is steel section. Both are cut slant making an angle of 30° from the vertical. Both are bonded together using epoxy based bonding agent using code ASTM C 881. The bonded composite material is shown in figure below:

Figure 2 Testing of Slant Shear Bond

The test was performed to find out at what compressive load the composite cylinder sample fail and using ASTM C882 we find out the bond strength between the composite cylinder. The bond strength given as [Max load]/[area of slant surface].

According to ASTM C882 there are two types of bond strength we can obtain on the basis of mode of failure. If the failure occurs on slant surface then the strength of bond obtained is true bond strength and if samples fail first than the strength obtain is apparent bond strength or minimum bond strength. The surface of concrete is prepared before bonding by dry brushing. We can also use various techniques like sand blasting, wire mesh etc. The slant shear test has a advantage that the bonded interface is subjected to combined compressive and shear stress state. The results obtain on composite cylinder using Slant shear test are given below:

Table 6 Results obtained using Slant Shear Test

Sr. No.	Grade of concrete	Compressive Strength (N/mm^2)	Apparent Bond Strength (N/mm^2) ASTM C882	Type of failure
1	M30	33.1	17.95	Cohesive
		32.6	17.67	Cohesive
		32.86	17.81	Cohesive
2	M40	43.31	23.48	Cohesive
		42.8	23.21	Cohesive
		42.54	23.06	Cohesive

CONCLUSION

Based on the experimental work I have performed following are the conclusion of results obtained by me which am written below:

1. There are many factors affecting bond strength such as curing conditions, cleanness at the specimen interface, cracks are present or absents, type of bonding agent used etc.
2. Different surface preparation techniques have different effect on the bond strength of the specimen.
3. The type of failure in the bond I have obtained is cohesive type of failure. This means that the concrete sample fails first and the bond did not break.
4. The type of failure is cohesive, so the bond strength obtain is not true bond strength. It is apparent or minimum bond strength between concrete and steel specimen.
5. For obtaining true value of bond strength we have to achieve higher strength in concrete or we have to prepare higher grade of concrete i.e. M45 and above.

Some more study is needed to be done on concrete-steel bonded specimen using SST, so that we can more accurately the limits of compressive strength within which a failure mode would occur.

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How to cite this article:

Prashant, Pankaj Kumar and Abhilash Shukla (2020) 'Performance Assessment of Steel-Concrete Composite Bonded Specimen Under Slant Shear', *International Journal of Current Advanced Research,* 09(05), pp. 22341-22344.
DOI: http://dx.doi.org/10.24327/ijcar.2020. 22344.4402

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