

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

Bond Stress Equation for Unconfined Concrete

M.Veera Reddy

Professor, Dept. of Civil Engineering, Kakatiya Institute of Technology & Science Warangal, Telangana State, India

ABSTRACT: The purpose of this experimental work is to develop an equation for bond stress of unconfined concrete. The parameters considered in this study are content of silica fume, diameter of pull out bar and embedded length of pull out bar. Cubes and cylinders were cast and tested to meet the aim of this work. Using experimental data an equation is developed and compared with equations developed by research scholars.

KEYWORDS: Pull-out, Bond stress equation, mineral admixture, unconfined concrete, Silica Fume

I. INTRODUCTION

Concrete is an artificial material, which is made up of cement, fine aggregate, coarse aggregate and water. Mineral Admixtures like Ground Granulated Blast Furnace Slag (GGBS), Fly Ash (FA), Rice Husk Ash (RHA) and Silica Fume (SF) are using as additional ingredients of concrete to improve strength and durability properties of concrete [1]. But concrete is weak in tension and strong in compression, reinforcements are added to make it a composite material called Reinforced Concrete (RC), which can resist both tensile and compressive stresses. The behavior of RC structures depends up on the type of bond developed between the steel reinforcement and the surrounding concrete. Bond stress is the tangential shear or friction developed between the reinforcement and the surrounding concrete that transfers the force onto the reinforcement. To ensure the integrity of various constituent or composite action of concrete and steel reinforcement, sufficient bond should be developed by the surrounding concrete with the reinforcement. Adequate bonding between reinforcing bars and concrete is essential for the satisfactory performance of reinforced concrete structures. The simplest method to evaluate the bond strength is direct tension-pullout bond test. The use of deformed bars can enhance the steel-concrete bond capacity. Proper bond between the steel reinforcement and the surrounding concrete is also crucial for the overall strength and serviceability of RC members. The failure of RC structures may be due primarily to the deterioration of the bond. According to IS: 456-2000 [8], design bond stress is expressed for grade of concrete only. Very less literature is available on effect of mineral admixtures on bond stress. Hence an experimental work is taken up to study the bond stress in variation with Silica Fume. Based experimental data bond stress equation developed and compared with other bond stress equations developed by Orangun et al. (2), AS3600(3), Muhammad.N.S. Hadi (4) and IS: 456-2000 [8]

II. PREPARATION OF TEST SPECIMEN

The mix proportion of concrete for experimental investigations was arrived by designing as per Indian standard method [11]. The final mix proportion arrived was 1:1.9:3.4 with water/cement ratio 0.48. In this mix proportions cement was replaced with SF in 0%, 5%, 10%, 15% and 20% to get different compressive strengths in a particular grade of concrete. A mixer was used to mix pre-determined quantities. The cement, fine aggregate and coarse aggregate were first mixed in dry state, to obtain uniform colour and calculated amount of water obtained from workability test was added and the whole concrete was mixed for five minutes in wet state. The standard moulds used for investigation are 150mm*150mm*150mm for cubes and 150mm dia.*300mm height for cylinders. Cube moulds were used to cast test specimens for compressive strength. To cast test specimen with 150mm and 300mm embedded length of bar cylindrical moulds were used. The concrete after mixing was poured into moulds in three layers by poking with a tamping rod. The bars used for embedding are 16mm and 20mm HYSD. For each HYSD bar, 15 cubes, 15 cylinders with 150mm embedded length & 15 cylinders with 300mm embedded length were cast. The specimens were removed

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

from moulds in the next day and kept in water for curing, after 28 days curing period removed from water and allowed to dry under shade. Then the cube specimens are tested for compression, using 200T capacity CTM [10], all cylindrical specimens with embedded bar are tested to failure using 100T capacity Universal Testing Machine to get bond strength in tension [12]. After taking experimental data for all the specimens [5, 6], bond stress is calculated using equation-1 presented below.

$$\text{Bond Stress } (\mu) = \frac{P}{\pi d_b L_d} \text{-----(1)}$$

III. EXPERIMENTAL RESULTS AND ANALYSIS OF BOND STRESS

The Experimental results are presented in Table-1. It contains average cube compressive strength of concrete due to replacement of cement with SF and corresponding average bond stress values with different development length for 16mm and 20mm diameter bars.

The Bond stress equation developed by Orangun et al. [2] is given below as equation-2. And using this equation bond stress calculated and presented in column-7 of Table-2

$$\mu = 0.083045 \sqrt{f'_c} \left(1.2 + 3 \frac{C}{d_b} + 50 \frac{d_b}{L_d} \right) \text{-----(2)}$$

Australian Standard 3600 [3] recommends the following Equation-3 for bond stress between concrete and reinforcing steel. The Bond stress is calculated using this equation-3 and presented in column 8 of Table-2.

$$\mu = 0.265 \sqrt{f'_c} \left(\frac{C}{d_b} + 0.5 \right) \text{-----(3)}$$

Muhammad N.S. Hadi [4], proposed an equation for bond stress as given in equation-4. Using this equation bond stress is calculated and presented in column-9 of Table-2.

$$\mu = 0.083045 \sqrt{f'_c} \left(22.8 - .208 \frac{C}{d_b} - 38.212 \frac{d_b}{L_d} \right) \text{----- (4)}$$

The design Bond stress values according Clause 16.2.1.1 of IS: 456-2000[8], are estimated using linear interpolation and presented in column-10 of Table-2. Based on experimental data [7], an equation is proposed for bond stress and presented in equation-5. This proposed equation for bond stress is expressed in terms of cube compressive strength of concrete. The proposed Equation is similar to the Equation of Flexural strength for concrete as given in clause 6.2.2 of IS 456-2000. The values estimated using this equation is presented in column-11 of Table-2.

$$\mu = \sqrt{f'_c} \text{----- (5)}$$

To compare bond stress obtained using various equations and experimental data, a graph is drawn between analytical and experimental bond stress values for different SF content shown in figure-1. From the figure-1 it is observed that experimental and theoretical bond stress values are higher than the values stated in IS:456-2000. Hence the bond stress values obtained using IS 456 are under estimated.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

Table-1.The Experimental Results.

$d_b \rightarrow$		16 mm			20 mm		
$L_d \rightarrow$							
Strength $\rightarrow$ Mpa		Compression	Bond Stress	Bond Stress	Compression	Bond Stress	Bond Stress
S.No	SF (%)						
1	0	37.71	9.11	6.96	31.17	6.87	6.46
2	5	43.82	9.69	7.94	44.03	7.71	8.23
3	10	44.04	11.34	7.51	47.52	8.28	7.91
4	15	39.24	8.85	6.54	38.58	7.71	6.42
5	20	34.88	7.75	6.70	34.66	5.21	5.62

Table-2 Comparison of Bond stress values.

S. no	SF (%)	d_b mm	C Mm	L_d mm	Comp. Strength Mpa	Bond stress MPa					
						Expt. Values	Calculated			IS:456-2000 [8]	Proposed
							Orangun et al [2]	AS 3600 [3]	Muhammad.N .S. H [4]		
Col	1	2	3	4	5	6	7	8	9	10	11
1	0	16	67	150	37.71	9.11	9.74	7.63	9.10	2.89	6.14
2	5	16	67	150	43.82	9.69	10.50	8.22	9.81	3.04	6.62
3	10	16	67	150	44.04	11.34	10.52	8.24	9.84	3.04	6.64
4	15	16	67	150	39.24	8.85	9.93	7.78	9.29	2.99	6.26
5	20	16	67	150	34.88	7.75	9.37	7.34	8.76	2.71	5.91
6	0	16	67	300	37.71	6.96	8.38	7.63	10.14	2.89	6.14
7	5	16	67	300	43.82	7.94	9.03	8.22	10.93	3.04	6.62
8	10	16	67	300	44.04	7.51	9.05	8.24	10.96	3.04	6.64
9	15	16	67	300	39.24	6.54	8.55	7.78	10.35	2.99	6.26
10	20	16	67	300	34.88	6.70	8.06	7.34	9.76	2.71	5.91
11	0	20	65	150	31.17	6.87	8.17	5.55	7.90	2.28	5.58
12	5	20	65	150	44.03	7.71	9.71	6.59	9.38	3.04	6.64
13	10	20	65	150	47.52	8.28	10.09	6.85	9.75	3.04	6.89
14	15	20	65	150	38.58	7.71	9.09	6.17	8.78	2.95	6.21
15	20	20	65	150	34.66	5.21	8.61	5.85	8.33	2.7	5.89
16	0	20	65	300	31.17	6.46	6.62	5.55	9.08	2.28	5.58
17	5	20	65	300	44.03	8.23	7.87	6.59	10.79	3.04	6.64
18	10	20	65	300	47.52	7.91	8.18	6.85	11.21	3.04	6.89
19	15	20	65	300	38.58	6.42	7.37	6.17	10.10	2.95	6.21
20	20	20	65	300	34.66	5.62	6.98	5.85	9.57	2.70	5.89

IV.CONCLUSION

Following conclusions are drawn from the limited study

1. The SF is showing similar effect on compressive strength and bond stress of plain concrete. Hence the bond stress can be expressed in terms compressive strength of concrete.
2. The design bond stress According to IS: 456-2000, considering for development length is under estimated.
3. The proposed equation for bond stress can be used for estimation bond stress.
4. The specimens tested for bond strength in pull out and push out are failed in splitting.

Notations:	
u = Bond stress	P = Pull out Load (N)
d_b = diameter of pull out bar (mm)	L_d = embedded length of pull out bar (mm)
C = Concrete cover to pull out bar	f'_c = Cube compressive strength of concrete (N/mm^2)
Comp. = Compression.	Tens. = Tension

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly Peer Reviewed Journal)

Vol. 5, Issue 2, February 2016

REFERENCES

1. K. Gurunaathan and G. S. Thirugnanam., "Effect of mineral admixtures on durability properties of concrete" International Journal of Advanced Structures and Geotechnical Engineering, Vol. 03, No. 01, 2014
2. C. O. Orangun, I. O. Jirsa, and J. E. Breen., "A Reevaluation of Test Data on Development Length and Splices", ACI Journal, vol. 74, no. 3, pp. 114-122, 1977
3. Australian Standard for Concrete Structures AS3600., North Sydney, Australia, -1994
4. Muhammad N.S.Hadi., "Bond of high strength concrete with high strength reinforcing steel" The Open Civil Engineering Journal, Volume 2, pp 143-147, 2008
5. Sravanthi.M., "Effect of Silica Fume on Bond Strength and Compressive Strength of Concrete" Dissertation report to Submitted to Kakatiya University to Partial fulfillment for Award of M.Tech.-2015.
6. Sindhuja.P., "A study on Properties of concrete by using silica fume as partial replacement of cement" Dissertation report Submitted to Kakatiya University to Partial fulfillment for Award of M.Tech.-2015.
7. Veera Reddy.M., "experimental study on effect of silica fume on ultimate bond strength of unconfined concrete", International Journal of Scientific Research, Volume-4(Issue 12), Pp 406-408.2015
8. IS:456-2000, "Indian Standard Code of Practice for Plain and Reinforced Concrete" BIS, New Delhi
9. IS:383-1970, "Specification for Coarse and Fine Aggregates from natural sources for concrete" (2nd revision), BIS New Delhi.
10. IS:516-1959, "Method of test for strength of concrete", BIS, New Delhi, India
11. IS:10262-2009, "Recommended guidelines for concrete mix Design", BIS. New Delhi, India.
12. IS:2770-1997, "Method of testing bond in reinforced concrete part I-pullout test" BIS New Delhi.

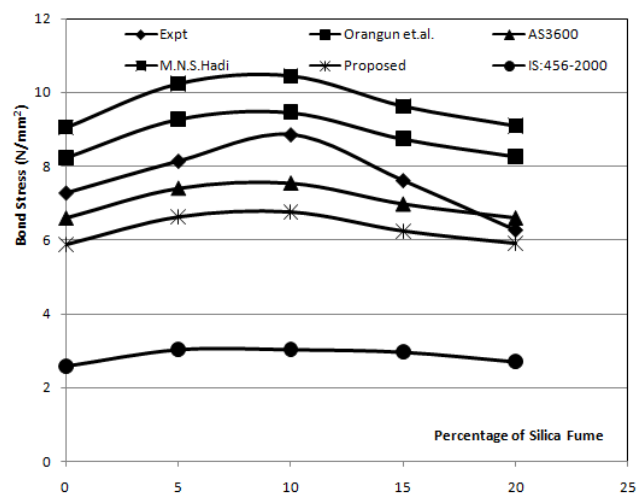


Figure-1. Shows Comparison of analytical and experimental bond stress values