Characterization of Reactive Powder Concrete with respect to its Bond Strength

Dipali S.Nagaonkar, Jyoti P. Bhusari

Abstract— This paper presents an experimental study conducted to evaluate the bond strength of Reactive powder concrete (RPC) between existing and fresh regular concrete. For this slant shear and Bi-surface shear test is used. According to obtained measured value bond strength is higher in fresh concrete to RPC rather than existing concrete to RPC. Analysis of results indicated that the highest value of bond strength was achieved in slant shear test than Bi-surface shear test. Various silica fume content ranging from 15% to 30% are used in the mixed proportion. Bond strength increases with silica fume content,the optimal silica fume content is between 20% and 25% , given the conditions of the experimental program.

Key words — Bi-surface shear test,Bond strength, Mix design,Reactive powder concrete, Silica fume, Slant shear test,Superplasticizers.

1 INTRODUCTION

Now-a-days there is tremendous development in the field of construction.As more skyscrapers are being built, the demand for the high strength concrete has been increasing year by year and also demand for materials with much higher strength will be far larger in the future, thus the use of supplementary cementitious materials and additives designed to enhance the properties of concrete has grown significantly As Low flexural tensile strength of concrete has a number of undesirable consequences for its performance. These include the necessity for auxiliary steel reinforcement and the requirement for thick-sectioned members, an emerging technology with the potential to overcome these limitations is Reactive powder concrete (RPC). . Thus the Advantage of the RPC is to improve higher compressive and shear strengths which lighten floor systems and reduce column cross-sections thus reducing inertial loads.The high energy absorption characteristics of RPC may also allow improved post-elastic response of columns, beam-column joints and shear walls. These can be difficult to execute using conventional concrete techniques due to congestion of the necessary reinforcing steel. Engineers are constantly looking for new materials to complex problems. Since RPC is a new material to tackle this problem.

Another major problem facing by civil engineers of today is to preserve, maintain, and retrofit these structures.RPC displays excellent repair and retrofit potentials on compressive and flexure strengthening and possesses high bond strength, bond durability as compared with other concrete.

Thus in this paper we presents an experimental study to evaluate the bond strength of RPC between existing and fresh regular concrete. We use RPC with various silica fume contents ranging from 15%, 20%, 25% and 30 % for the test. This paper also compare the bond strength measured by two different test methods for two different conditions i.e. existing concrete to RPC and fresh concrete to RPC. And methods for this are (1) bond under shear stresses – Bi-surface shear test and (2) bond strength under a state of stress that combine shear and compression – slant shear test. And for this experimental study was performed to find compressive strength of RPC by varying constituents such as Cement, Quartz sand, Silica fume, Admixture and water.

2 EXPERIMENTAL STUDY:

The objective of this report is to study the characterization of RPC for bond strength so that a better solution as a new material is available for to tackle the problem of congestion in towers and repair the concrete structure so that feasibility in bond strength will be improved. It also provides view for strengthing the concrete structure. For this experimental study is carried out for existing concrete with RPC and fresh concrete with RPC in different proportion of silica fume in RPC.

2.1 Test Program :

For validation of experiment 252 specimens is cast and testing is done for compression strength of RPC .From this cumulative average valued of suitable RPC grade compressive strength material is selected as shown in table.1 for further specimen casting. Now test are also done with regular concrete of M30 grade for different study with RPC of above grade.

Table 1 RPC mix proportion without steel fiber.

Mix	cement	Water/Cement ratio	Silica fume/ Cement ratio	Quartz sand/ Cement ratio	Super plastisizer	Comp. strength
T1	1.0	0.30	0.15	1.20	0.03	60-70 (62.50)
T2	1.0	0.30	0.20	1.30	0.03	70-80 (77.88)
T3	1.0	0.30	0.25	1.40	0.03	80-90 (79.91)
T4	1.0	0.30	0.20	1.50	0.03	> 90 (95.57)

Further experiments carried with above RPC grade with M30 concrete by following casting

For (1) **Existing concrete to RPC:**

(a)Bi-surface shear test : For test 16 cubes are casted with specimen (150 mm x 150 mm x 150 mm). The existing concrete and RPC correspond to two - thirds and one -third of the volume of the specimen respectively. Regular concrete was cast of size 100mm X 150mm X 150mm, when hardened, the substrate concrete was removed from the mould and stored under specific curing condition, this procedure was adopted to cast the substrate for all Bi-surface shear specimens when the substrate concrete reached 28 days of age the specimens were placed again inside the moulds and the added RPC cast occupying the remaining one third of the initial volume and tested latter reached 28 days of age.

(b)Slant shear test: the slant shear test according to ASTM C 882 measures the shear bond between the existing concrete and the RPC at an angle of 300. For test 16 cylinders are casted with specimen (75mm in diameter, 150mm in height with interface at 300 to vertical.). The bond strength is determined at the diagonal face by testing the composite specimen in compression.

(2)Fresh concrete to RPC

a)Bi-surface shear test: For test 16 cubes are casted with specimen (150 mm x 150 mm x 150 mm). The existing concrete and RPC correspond to two - thirds and one -third of the volume of the specimen respectively. Regular concrete and RPC were cast at the same time and stored under the same curing conditions for 28 days.

(b) Slant shear test : For test 16 cylinders are casted with specimen (75mm in diameter, 150mm in height with interface at 30^0 to vertical.). Regular concrete and RPC were cast at the same time and stored under the same curing conditions for 28 days.

time and stored under the same curing conditions for 28 days.

2.3 Experimental Results:

In Bi –surface shear test the bond strength of the inter face (table 2& table 3) is computed dividing the failure load of the composite specimen by the number of shear planes (2) and by the area of the bonded interface (150 x 150 mm^2), and in slant shear test the bond strength is calculated by dividing the maximum load at failure by the bond area (sloping area).

Table .2 Test results of specimen at the age of 56 days

specimen	SF/C ratio	Bi –surface shear test		Average stress (MPa)	Standard deviation (MPa)	Coefficient of variation (%)	Slant shear test		Average stress (MPa)	Standard deviation (MPa)	Coefficient of variation (%)
		Failure stress (MPa)	Failure mode				Failure stress (MPa)	Failure mode			
T1	0.15	1.04 1.24 1.14 1.58	Bond failure	1.25	0.20	16.25	7.29 6.51 7.08 6.95	Bond	6.96	0.285	4.00
T2	0.2	1.51 1.41 1.58 1.36	Bond failure	1.47	0.09	0.09	7.48 7.94 6.88 7.70	Bond	7.50	4.00	5.24
T3	0.25	1.69 1.50 1.40 1.39	Bond failure	1.50	0.055	3.67	8.99 8.48 8.84 9.31	Bond	8.91	0.298	0.298
T4	0.2	1.47 1.40 1.24 1.39	Mixed	1.38	0.08	6.15	7.39 7.77 7.07 7.58	Bond	7.45	0.26	0.26

Table .3 Test results of specimen at the age of 28 days

specimen	SF/C ratio	Bi –surface shear test		Average stress (MPa)	Standard deviation (MPa)	Coefficient of variation (%)	Slant shear test		Average stress (MPa)	Standard deviation (MPa)	Coefficient of variation (%)
		Failure stress (MPa)	Failure mode				Failure stress (MPa)	Failure mode			
T1	0.15	2.06 2.22 2.25 2.12	Bond	2.16	0.076	3.53	9.90 10.80 9.68 9.29	Non-Bond	9.92	0.55	5.59
T2	0.2	3.22 3.56 3.34 3.39	Bond	3.38	0.122	3.61	10.42 10.77 10.16 9.62	Non-Bond	10.25	0.422	4.16
T3	0.25	3.83 3.80 3.89 4.00	Bond	3.88	0.076	1.97	11.12 10.98 11.07 11.21	Non-Bond	11.10	0.08	0.75
T4	0.2	3.32 3.12 3.34 3.17	Mixed	3.24	0.094	2.91	9.79 10.19 9.54 9.30	Non-Bond	9.71	0.329	3.37

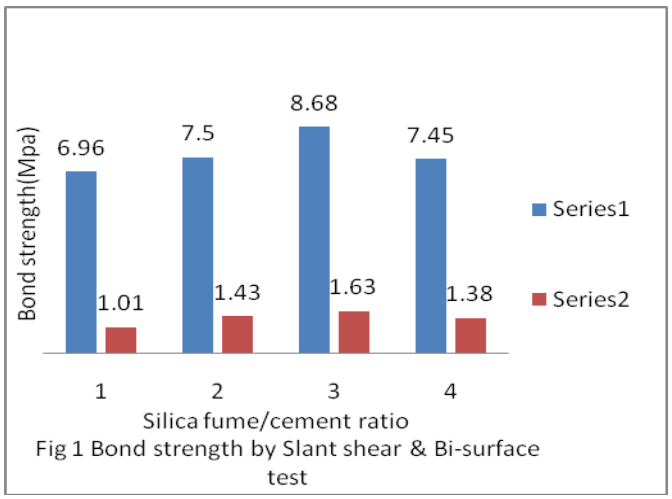

Fig 1 Bond strength by Slant shear & Bi-surface test

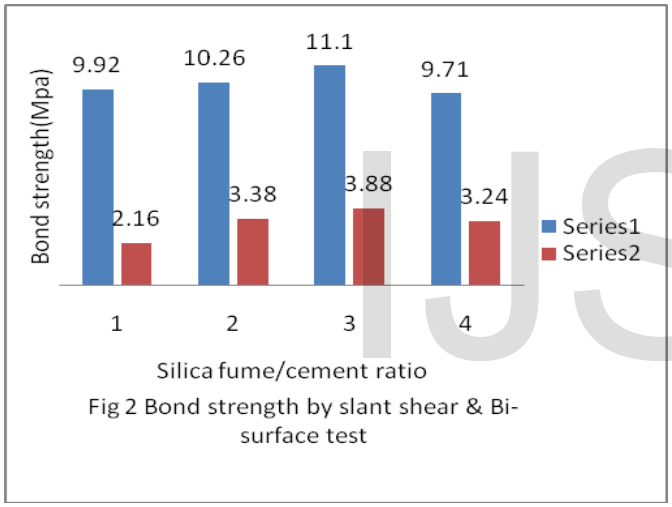

Fig 2 Bond strength by slant shear & Bi-surface test

3. Experimental Results and Discussion:

A) Failure mode:

(i) Slant shear test -

The failure modes were characterized by the location of the failure in the specimens. Bond failure is defined when the plane of failure is along the interface surface. Some of the specimens failed by partial failure of either regular concrete or RPC. Fig.3a. shows the slant shear specimen failed in bond and Fig. 3b shows a specimen in which the failure plane passed through a portion of interface and the existing concrete. Slant shear gave the highest bond strength for existing concrete to RPC and for fresh concrete to RPC.

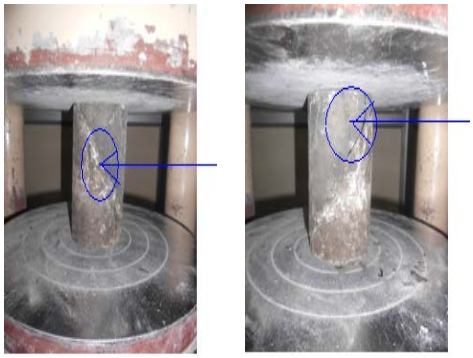
a) Non bond failure b) Bond failure

Fig. 3 Slant shear specimen after failure.

(ii) Bi –surface shear test –

After each test the specimens were carefully observed to identify the failure mode. Three distinctive failure modes were identified (1) bond failure with debonding at the interface.Fig.4a (2) Cohesive failure with concrete crushing.Fig.4b (3) mixed failure with debonding and concrete crushing.Fig.4c.

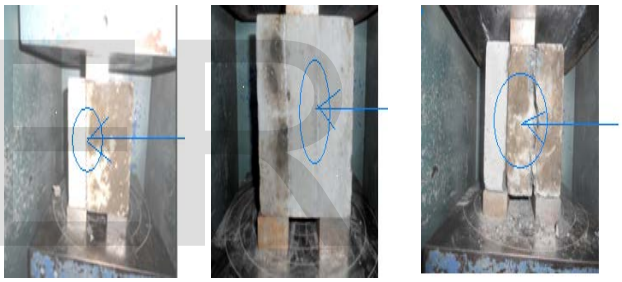
a)Bond failure b) Cohesive failure c) Mixed failure

Fig 4 Bi-surface specimen after failure

4. Conclusion:

I) The measured bond strength is higher in fresh concrete to RPC than existing concrete to RPC.

II) Bond strength is greatly dependent on the test methods used. It is higher in slant shear than in Bi-surface shear test.

III) Bond strength increases with silica fume content for both Bi-surface and Slant shear test methods. Based on the results the Optimal silica fume- cement ratio is found to be in between 20 % and 25 %.At this silica fume dosage, the bond strength is the highest among all cases.

IV) Bond strength does not depend on compressive strength, but increase in silica fume content bond strength increases.

Acknowledgements

I take this opportunity to express my deep sense of gratitude to my guide, Mrs. J. P. Bhusari for her continuous guidance and encouragement throughout the completion of this paper. I would also like to acknowledge with thanks to my husband and my friends for constant help and Co-operation given to me.

5. REFERENCES

1. Momayez, M.R. Ehsani, A.A. Ramezanianpour. H. Rajaie "Comparison of methods for evaluating bond strength between concrete substrate and repair materials" Cement and Concrete Research 35 (2005) 748–757.
2. Gengying Li A new way to increase the long-term bond strength of new-to-old concrete by the use of fly ash Cement and Concrete Research 33 (2003) 799–806.
3. Ming-Gin Lee , Yung-Chih Wang , Chui-Te Chiu "A preliminary study of reactive powder concrete as a new repair material" Construction and Building Materials 21 (2007) 182–189.
4. Yin-Wen Chan, Shu-Hsien Chu "Effect of silica fume on steel fiber bond characteristics in reactive powder concrete" Cement and Concrete Research 34 (2004) 1167–1172.
5. J.J. Chang, "Bond degradation due to the desalination process", Construction and Building Materials 17 (2003) 281–287.Pedro M.D. Santos, Eduardo N.B.S. Julio, Vıtor D. Silva, "Correlation between concrete-to-concrete bond strength and the roughness of the substrate surface" Construction and Building Materials 21 (2007) 1688–1695.
6. Eduardo N.B.S. Julio a, Fernando A.B. Branco b, Vıtor D. Silva a "Concrete-to-concrete bond strength.Influence of the roughness of the substrate surface" Construction and Building Materials 18 (2004) 675–681.
7. A.Cwirzen, V.Penttala, C.Vornanen "Reactive powder based concretes Mechanical properties, durability and hybrid use with OPC" Cement and Concrete Research 38 (2008) 1217–1226.
8. Huseyin Yigiter, Serdar Aydın, Halit Yazıcı, Mert Yucel Yardımcı, "Mechanical performance of low cement reactive powder concrete" (LCRPC) (2012).

.