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FLEXURAL STRENGTH VS STRAIN OF REINFORCED RAC RICH MIX BEAMS WITH HIGHER WATER-CEMENT RATIO

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ABSTRACT

This research paper presents laboratory investigations for the effect of higher water-cement ratio on the flexural strength of reinforced concrete beams cast with 50% dosage of recyclable aggregates from demolished concrete. 12 reinforced concrete beams were cast using rich mix (1:1.5:3). Additionally, six reinforced concrete beams were also cast using rich mix and all-natural aggregates. Water-cement ratio of 0.6 is used to study its effect on flexural strength, strain, deflection and cracking. Equal number of the beams was cured for 7- and 28-day. The test results show that increasing water-cement ratio has positive effect on flexural strength. However, deflection and strain remained higher than control specimen. The failure mode of the beams is observed shear failure.

KEYWORDS: Green concrete, water-cement ratio, demolished aggregates, recyclable aggregate concrete, flexural strength.

1. INTRODUCTION

Construction of skyscraper, medium height structures and associated facilities in almost every major city of the world has become the need of the day. It is mainly done to meet the socio-economic trends and to facilitate the increasing population particularly in developed area. Lack of the space available for new construction force the construction industry to opt demolishing of old or short height buildings to create space for new construction. Demolishing of the structures on other hand give rise to waste management and environmental issues. Clean and green environment being need of the day demands such ways and means; particularly with respect to construction and associated materials and equipment; which reduces environmental pollution. A possible measure to this end is the reuse of demolishing waste in new concrete. This will not only save the natural sources of the construction materials but also help in reducing the environmental pollution as less quarrying of aggregates and less cement generation will be required. Therefore, attempts are being made since couple of decades by different scholars to evaluate the possibilities of reusing the demolishing waste in new concrete by studying its properties and behavior.

Coarse aggregate being large constituent (by volume) of concrete body, if replaced fully or partly by the demolishing waste will help in increased consumption of demolishing waste in new concrete. In this regard Memon[1] has reviewed recent developments. In this review study, the authors highlighted use of demolishing waste as coarse aggregates in new concrete and challenges associated with it. Liew et al[2] also reviewed prospects and challenges of using green concrete. The authors reviewed the topic with respect to environmental aspects and advantages. They concluded their work with remarks that public awareness and cross-disciplinary collaboration is required in use of green concrete at large-scale. Pandey et al[3] also discussed the similar issues but with respect to benefits of green concrete over conventional concrete and reduction in global warming.

Reinforced concrete beam is the basic structural element used to study various parameter. The flexural stress-strain behavior of the same but made with 50% replacement of natural coarse aggregates with aggregates from demolished concrete has been studied by Oad el al or normal mix[4] and rich mix[5] concrete. Based on the outcome of the research the authors observed that the behavior of recycled aggregates concrete is similar to that of conventional concrete but reduction in peak load lead to the reduction in flexural capacity. However, the reduction recorded is minimum for both normal and rich mix reinforced concrete beams.

Proper monitoring of concreting process from batching to placing play key role in ensuring the strength and durability of the product. However, it is general observation that except in batching plant, the use of water to mix the concrete ingredients has got several issues particularly quantum of water. Generally, higher quantity of water is used. Indeed, it is due to the illiteracy of the labor involved which assumes more water will ease concrete mixing and machine maintenance. But it produces adverse effect of the strength of concrete as water-cement ratio increases beyond the required one. To this end effect of w/c ratio along with different curing methods has been addressed by Chan et al[6] The authors designed biosand filter mix concrete to study its strength, shrinkage and slump. The authors used w/c ratio from 0.51 to 0.76 along with wet and dry curing methods. Based on the test results of 28-day cured cylinders, authors observed that water cement ratio from 0.51 to 0.59 yield maximum strength. Reverse to this Choong et al[7] designed the research work to study the effect of recycled aggregate on water-cement ratio. The authors used recycled aggregates from different sources and different dosages. Based on the test results authors concluded that higher water-cement ratio is required when recycled aggregates are used. However, they did not find any relationship or effect due the source of demolished concrete aggregates. Effect of water cement ratio on reinforced recyclable concrete beams cast with equal dosage of natural and recyclable aggregates has been studied by Oad et al.[8] The authors used four different w/c ratios from 0.45 to 0.7 to cast reinforced concrete beams with 50% replacement of natural coarse aggregates with demolished concrete as aggregates to study its effect on flexural strength. 7- and 28-day curing were used in the study. The authors observed decrease in flexural capacity with increase in water-cement ratio. From the test results authors observed that normal mix reinforced recyclable aggregate beams cast with water-cement ratio from 0.6 to 0.65 produced approximately same flexural capacity as that of the same beams cast with all-natural coarse aggregates.

The above discussion motivates the research presented in this article. Considering the need of green concrete and irregularities in use of concrete mixing water in field, this paper presents experimental evaluation of effect of higher water-cement ratio on reinforced rich mix concrete beams cast with equal proportion of natural and demolished concrete aggregates. The rich mix is commonly used in construction industry; particularly in compression members. Therefore, the outcome of the research will prove beneficial in understanding the behavior of green concrete at higher water cement ratio.

2. MATERIALS AND MODEL

In the following details of the materials used and prepared models is given.

2.1 Conventional materials: Ordinary Portland cement, hill sand and natural coarse aggregates were obtained from local market and used in preparation of the specimens. The mixing water to be used in concrete mix was obtained from the main water supply scheme of the city. pH of the water was evaluated and found equal to 6.9. The value falls in the range of potable water, hence confirms with the standard requirement regarding the water to be used in concrete mix.

2.2 Recycled aggregates: For recycled aggregates used in the preparation of proposed specimen, old demolished concrete was obtained from demolishing of reinforced concrete slab of a school building about 50 years old. The large blocks were manually reduced to size approximately equal to 20mm, followed by sieve analysis of both natural and recycled aggregates in standard fashion to have well graded aggregates in concrete mix.

2.3 Model Beams: Total of 18 reinforced concrete beams were cast using above mentioned ingredients in rich mix (1:1.5:3 ratio) with 0.6 water-cement ratio. The size of all beams is kept equal to 900 mm x 150mm x 150 mm. Out of above-mentioned beams 12 beams were prepared with 50% dosage of recycled aggregates from demolished concrete. Remaining six beams were cast with all-natural aggregates. To reinforce the beams 4#4 deformed bars with 50% in each tension and compression zones were provided. #3 deformed bars were used as shear reinforcement at 150 mm center-to-center, throughout the length.

The concrete ingredients in required proportion along with water were mixed in concrete mixer, followed by casting of the specimen in standard manner. After casting fifty percent of the beams were cured for 7- and remaining 50% for 28-day by fully immersing in water.

3. Specimen Testing

After elapse of required curing time beams were allowed to dry at room temperature for 24-hour in laboratory. Dumec pads then installed along the central line of the beams for strain measurement. All the beams were then tested in universal load testing machine till failure under gradually increasing central point load (Figure 1) in accordance to ASTM standards.[9]

Figure 1: Beam testing.

During testing, load, deflection, strain and cracking were monitored at regular intervals. The strain values obtained at different locations along the central line of the beam were then averaged. Flexural strength was computed from recorded load and dimensions of the beam by numerical expression given in ASTM C293.[9] The recorded and computed results for maximum values of the parameters for 7-day cured of reinforced concrete beams cast with recyclable aggregates are given in Table 1. The same for 28-day cured reinforced concrete beams cast with recyclable aggregates are given in Table 2. Table 3 and Table 4 give the results of the parameter for reinforced concrete beams cast with all-natural coarse aggregates and cured for 7 and 28 days respectively.

Table 1: 7-day curd reinforced concrete beams with recyclable aggregates.

#	B #	Load	Deflection	Flexural Strength	Strain
1	B13	65276	4.125	26.110	0.00307
2	B14	70173	4.294	28.069	0.00291
3	B15	71751	4.337	28.700	0.00291
4	B16	72136	4.405	28.854	0.00298
5	B17	71960	4.412	28.784	0.00298
6	B18	72145	4.291	28.028	0.00295

Table 2: 28-day curd reinforced concrete beams with recyclable aggregates

#	B #	Load	Deflection	Flexural Strength	Strain
1	B19	75520	4.578	30.208	0.00302
2	B20	78806	5.014	31.522	0.00301
3	B21	76215	4.812	30.486	0.00318
4	B22	77085	4.817	30.834	0.00312
5	B23	78056	4.657	31.222	0.00303
6	B24	78090	4.682	31.236	0.00313

Table 3: 7-day curd reinforced concrete beams with all-natural aggregates

#	B #	Load	Deflection	Flexural Strength	Strain
1	B67	67334	4.322	26.934	0.00275
2	B68	66980	4.419	26.792	0.00277
3	B69	66270	4.311	26.508	0.00274

Table 4: 28-day curd reinforced concrete beams with all-natural aggregates.

#	B #	Load	Deflection	Flexural Strength	Strain
1	B70	70646	4.588	28.258	0.00292
2	B71	70160	4.523	28.064	0.00304
3	B72	70060	4.599	28.024	0.00306

4. RESULTS AND DISCUSSION

The flexural strength and strain for 7-day cured beams is plotted in Figure 2, whereas the same for 28-day cured beams in plotted in Figure 4. It may be observed from these figures that the trend of the parameter for both groups of beams; 50% recycled aggregate and all-natural aggregates; is almost similar except maximum values. Therefore, the concrete with recycled aggregates in comparison to conventional concrete has good behavior of flexural strength and strain.

The average values of the group of beams are computed and are given in Table 5. The control specimens (beams with all-natural aggregates) were used for comparison of the results of proposed beams. Additionally, the similar results of reinforced concrete beams cast with 50% dosage of recycled aggregates but with 0.54 water cement ratio published by Oad el al are also reproduced in table 5 for comparison of the results of present research outcome.

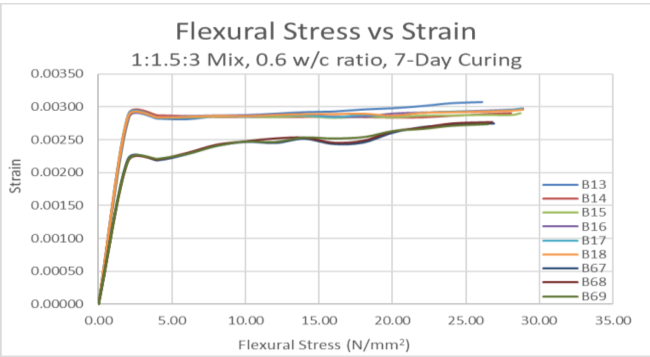

Figure 2: Flexural strength vs strain (7D curing).

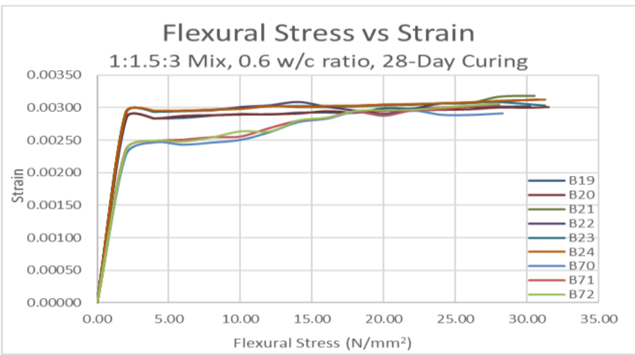

Figure 3: Flexural strength vs strain (28D curing).

Table 5: Average values of flexural strength, strain, load and displacement.

#	RCA (%)	w/c Ratio	Curing (Days)	Average values of			
				Load	Deflection	Flexural Strength	Strain
1	0	0.6	7	66861.33	4.351	26.745	0.00275
			28	70288.67	4.570	28.115	0.00300
2	50	0.6	7	70573.50	4.311	28.091	0.00297
			28	77295.33	4.760	30.918	0.00308
3	50[5]	0.54	7	63361.00	4.150	25.34	0.00321
			28	69694.67	4.970	27.88	0.00325

It may be observed from above table that flexural strength of reinforced concrete beams cast with water cement ratio equal to 0.6 is better than control specimen with same water cement ratio and the beams results from literature.[5] 7-day cured beams with 0.6 w/c ratio observed 5.55% and 11.38% increase in flexural strength than control specimen with 0.6 w/c ratio and beams with 0.54 w/c ratio. The same for 28-day cured beams is recorded equal to 9.97% and 10.91%. Average deflection in the proposed showed fluctuation. For 7-day cured beams with recycled aggregates 0.01% decrease is observed whereas, in comparison to beams with 0.54w/c ratio 13.26% reduction is noted. The same for 28-day cured beams is observed equal to 4.15% higher and 4.22% less. However, all the deflections recorded remained less than the approximate allowable deflection by ACI-318.[10]

The strain recorded for reinforced concrete beams with recyclable aggregates and 0.6 water-cement ratio is observed higher than control specimen with same water-cement ratio but less than the strain observed by the beams cast with 0.54 water-cement ratio.

Figure 4: Cracks in reinforced concrete beams.

During testing of the beams cracking was also observed. At peak load the cracking pattern was observed diagonal cracks initiating from middle of the beam and propagating towards the supports. Few beams also showed arching action. Therefore, the failure mode of the beams is concluded as shear failure. Few snap shots of cracks in beams are shown in Figure 4.

5. CONCLUSION

The aim of the research presented in this article is to evaluate the effect of water-cement ratio equal to 0.6 on the flexural behavior of the rich mix reinforced concrete beams cast with 50% dosage of recycled aggregates from demolished concrete. The comparison of the results with control specimens and those from literature but with 0.54 w/c ratio shows that the flexural capacity of 7-day cured beams was almost equal to the flexural capacity of control specimen and higher than the beams cast with 0.54 w/c ratio. Whereas, the same of 28-day cured beams; remained higher than both groups of the beams. Deflection and strain of the proposed beams was observed higher than control specimen and beams cast with w/c ratio equal to 0.54. But the deflection results were less than those allowed by ACI 318. Therefore, it is concluded that when recyclable aggregates from demolished concrete are used then higher water-cement ratio equal to or nearly equal to 0.6 gives better results for rich mix concrete.

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