BONDING STRENGTH BEHAVIOR OF CONCRETE USING GRANULAR WASTE PLASTIC AS A PARTIAL REPLACEMENT OF SAND

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ABSTRACT

Concrete is one of the most common materials used in the construction industry throughout the world. Excessive extraction of natural aggregates, due to the rapid growth of concrete construction resulted in the search for alternative source of concrete aggregate. The aim of the study is to investigate the influence of plastic waste granular on the bonding between steel and concrete. Also to observe the variation of compressive strength of concrete using granular waste plastic compared to the conventional concrete. The test specimens were made from concrete of grade 20 MPa and granulated waste plastic were used as partial replacement of 0%, 5%, 10% and 15% by weight of natural fine aggregate (sand). For pull out loading test 12mm, 16 mm, 20 mm and 25 mm Ø rebar were used incorporating 0%, 5%, 10% and 15% plastic granular. From the study, it was observed that the variation of compressive strength is very little up to 5% replacement level. Beyond 5% replacement level compressive strength reduces rapidly with the increment of granular plastic replacement. The bonding stress between steel and concrete decreases for 12mm, 16mm, 20mm and 25mm bars respectively as about 5 to 7% with 5% replacement level, 15 to 20% with 10% replacement level and 20 to 30% with 15% replacement level. The variation is less for small Ø bars and it increases for higher Ø bars.

Keywords: *Recycling plastic waste, Bonding strength, Pull out test, Waste management, PET fiber.*

1. INTRODUCTION

Due to rapid industrialization & urbanization all over the world, lots of infrastructure developments are taking place. This process has thrown questions to mankind to solve the problems generated by this growth. One of the important problem is the acute shortage of constructional materials. Big attention is being focused on the environment and safe guarding natural resources and recycling of waste materials (Thosar, Husain, 2017). For solving the disposal of large amount of recycled plastic material, reuse of plastic in concrete industry is considered as the most feasible application (Yadav, 2008). Plastic waste is one of the fastest growing waste products throughout the world. Every year more than 500 billion plastic bags are used all over the world (Thosar, Husain, 2017). According to World Watch institute (2015) about 299 million tons of plastic waste were produced in 2013.Disposal of plastic waste in environment is considered to be a big problem due to its very low biodegradability and presence in large quantities. In recent time use of such industrial waste from polypropylene (PP) and poly ethylene terephthalate (PET) were studied as alternative replacements of a part of the conventional aggregates of concrete. If plastic wastes can be mixed with the concrete mass in some quantity Orin some form, without affecting the fundamental and other properties of concrete with slight negotiation in strength, large quantities of plastic waste can be consumed to solve disposal problem of plastic waste.

Reinforced concrete is an integral part of construction work all over the world. It behaves as a composite member when reinforcing bars and concrete residing together and they offer better stiffness and durability than conventional concrete. These fundamental properties depend on the bond behavior between steel and concrete (Paul et al., 2013). If plastic waste granular is to be used in reinforced concrete then the bonding between steel and plastic is of great concern. The main objectives of this study are to investigate the influence of plastic waste granular on steel-concrete bonding and to observe the variation of compressive strength of concrete made by adding plastic granular. Ultimately, the aim of this project is to explore the possibility of recycling plastic waste material to check the variation of the mechanical properties of Reinforced Concrete.

2. METHODOLOGY

At first Literature review was completed from Journals, Books and internet. Then primary estimation for materials was made and required materials were collected. Various properties of the materials were tested and according to that mix ratio was calculated using ACI mix design. Then the specimens were cast and cured for specified curing period. After that compressive strength test and pull out test were executed.

2.1 Materials

Ordinary Portland Cement (OPC), locally available fine sand was used for casting the specimens. Brick chips made from first class bricks were used as coarse aggregate. Plastic waste products were collected, washed thoroughly and then dried. Then these were shredded and grinded to achieve required fineness.

2.1.1 Coarse aggregate

First class brick chips were used as coarse aggregate. Specific gravity, Unit weight and absorption capacity were found 2.08, 1200 kg/m^3, 12% respectively. Maximum aggregate size was 20mm.

2.1.2 Fine aggregate

Local sand (fine sand) was used as fine aggregate. Specific gravity, Unit weight, absorption capacity and fineness modulus were 2.48, 1600 kg/m^3, 3.26% and 1.36 respectively.

2.1.3 Binder

Ordinary Portland Cement (OPC) was used as binding material. Specific gravity, initial setting time and final setting time were found 3.15, 48 minutes and 240 minutes respectively.

2.1.4 Plastic granular

Specific gravity, Unit weight and Fineness Modulus of plastic waste granular were found 0.93, 593 kg/m^3 and 2.74.

2.2 Concrete mix design

The ACI Standard 211.1 was followed for reference mix design of M20 grade concrete. The mix ratio was found 1:1.37:2.92 with w/c ratio of 0.59.

Table 1: Mix Proportion for each m^3 of concrete

Plastic (%)	Water (kg)	Cement (kg)	Sand (kg)	Brick chips (kg)	Plastic Granular (kg)
0	183.62	346.49	476.39	1010.89	0
5	183.62	346.49	452.57	1010.89	23.82
10	183.62	346.49	428.75	1010.89	47.64
15	183.62	346.49	404.93	1010.89	71.46

2.3 Test specimens

For compressive strength test, cylindrical specimens of dia 150mm (6") and height 300mm (12") were used. Three specimens were used for each of the percentage of sand replacement (0%, 5%, 10% and 15%). Twelve groups of concrete cylinder of same size were used for pull out test. 12mm, 16mm, 20mm and 25mm deformed bars were used as reinforcement. For each diameter of rebar four groups of cylinder with plastic level of 0%, 5%, 10%, 15% were used. Embedded length of the bars were $12xd_b$ (bar diameter). All the tests were conducted after a curing period of 28 days.

2.4 Bond stress & Direct pull out test

The transfer of axial force from reinforcing steel bar to the surrounding concrete produced from the development of tangential stress components along the contact surface. The stress acting parallel to the bar along the interface is called bond stress. For the reinforced concrete material, it is necessary to create suitable bond between steel bars and surrounding concrete. Bond ensures that there is little or no slip of the steel bars relative to the concrete and the means by which stress is transferred across the steel-concrete. Bond resistance is made up of chemical adhesion, friction and mechanical interlock between the bar and surrounding concrete.

The direct pullout test was conducted using Universal Testing Machine. This method was adopted in this study to evaluate the bondperformance of steel-reinforced concrete for various diameters (12 mm, 16 mm, 20 mm and 25 mm) and degrees of plastic granular (0%, 5%, 10% and 15% replacement of sand). This testing set up and procedure is different from ASTM C900-15 setup. However, the test was adopted in this study because it is simpler, more convenient andcosts less compared with other tests. This test setup is also practical as it represents the main longitudinalreinforcement, which is mostly subjected to tensile forces in a reinforced concrete beam (Rakib, Morshed, 2016).

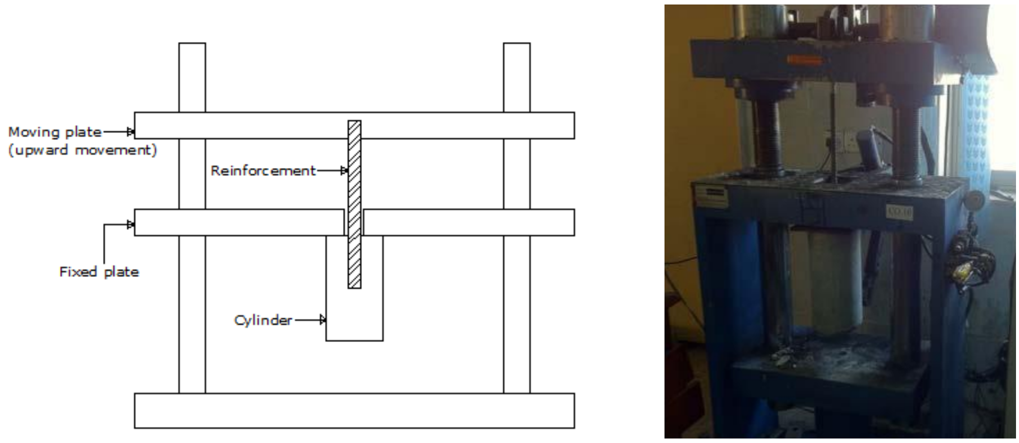


Figure 1: Schematic diagram of direct pull out test.

The schematic diagram of the test is shown in Figure 1. In the test conducted, the specimens were positioned in a Universal Testing Machine. Concrete cylinder was kept below the fixed plate that has a hole in the center where the bar can pass through. The reinforcement was entered through the hole of the fixed plate and reached to the moving plate where it was gripped by clamp. Force was applied by the upward movement of the moving plate and force was measured using the scale of Universal Testing Machine.

2.4.1 Bond stress calculation

Bond stress is calculated as average stress between the reinforcing bar and the surrounding concrete along the embedded length of the bar. In general, the bond stress corresponding to the maximum pull out load can be regarded as the bond strength or the ultimate bond (ACI Committee 2002). The criterion of ultimate bond strength is characterized by its clear definition and simplicity in bond strength interpretation (Hadi, 2008). For uniform bond, the bond stress S can be expressed as:

$$S = P_{max} / (\pi \times L \times d_b) \quad (1)$$

Where, P_{max}= maximum pull out load
d_b=diameter of the bar
L =Embedded bar length = 12 d_b

Equation (1) was employed in present calculation of bonding stress between the embedded steel bar and the surrounding concrete for the specimen.

3. RESULTS & DISCUSSIONS

3.1 Results and Graphs

3.1.1 Uniaxial Compressive Strength test

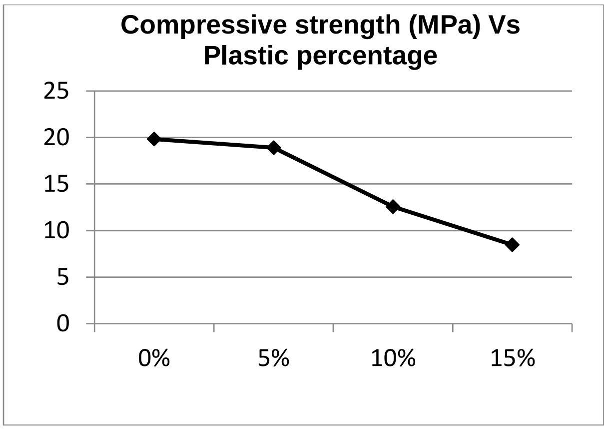
The compressive strength results are shown in the Table 2 below. All the strengths are average of three values of compressive strength for each plastic level. All the specimens were made from concrete of grade 20 MPa and tested after 28 days curing period.

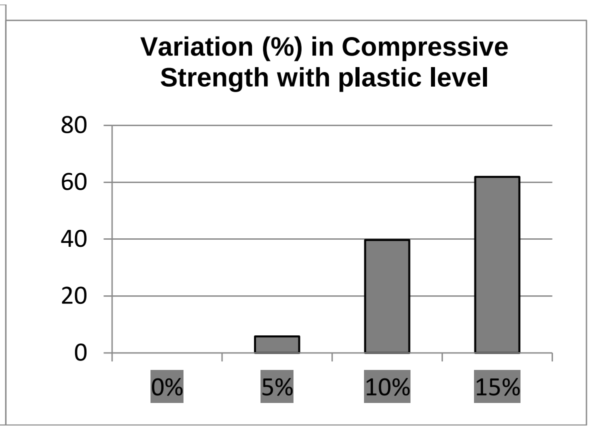
3.1.2 Table 2: Compressive strength test data

% of sand replaced	Average compressive strength (MPa)
0%	19.83
5%	18.91
10%	12.58
15%	8.47

Figure 2: compressive failure at 15% replacement level

Figure 2 shows the failure of concrete specimen under compressive load at replacement level of 15%. From figure this is evident that incorporation of plastic makes the concrete ductile. The specimen deformed significantly before failure. Figure 3 shows that the compressive strength of concrete reduces gradually with the increment of plastic granular as fine aggregate. Up to 5% replacement level the reduction is within 5%. But beyond 5% compressive strength decreases significantly up to 60%. This is due to poor bonding between plastic granular and cement paste.





- Figure 3: Variation of compressive strength with plastic level.

3.1.3 Direct Pull out test

Bond stress between steel and concrete for different bar diameters (12 mm, 16mm, 20 mm and 25 mm) incorporating various plastic levels (0%, 5%, 10% and 15%) are tabulated in Table 3 below. All the specimens were made from concrete of grade 20 MPa and tested after a curing period of 28 days.

Table 3: Direct pull out test data

Bar diameter	**Average Bond stress (MPa) for various replacement levels**			
	0%	5%	10%	15%
12 mm	14.64	13.26	11.91	10.47
16 mm	10.24	9.6	8.59	7.83
20 mm	8.05	7.56	6.76	6.09
25 mm	6.52	6.04	5.47	5.13

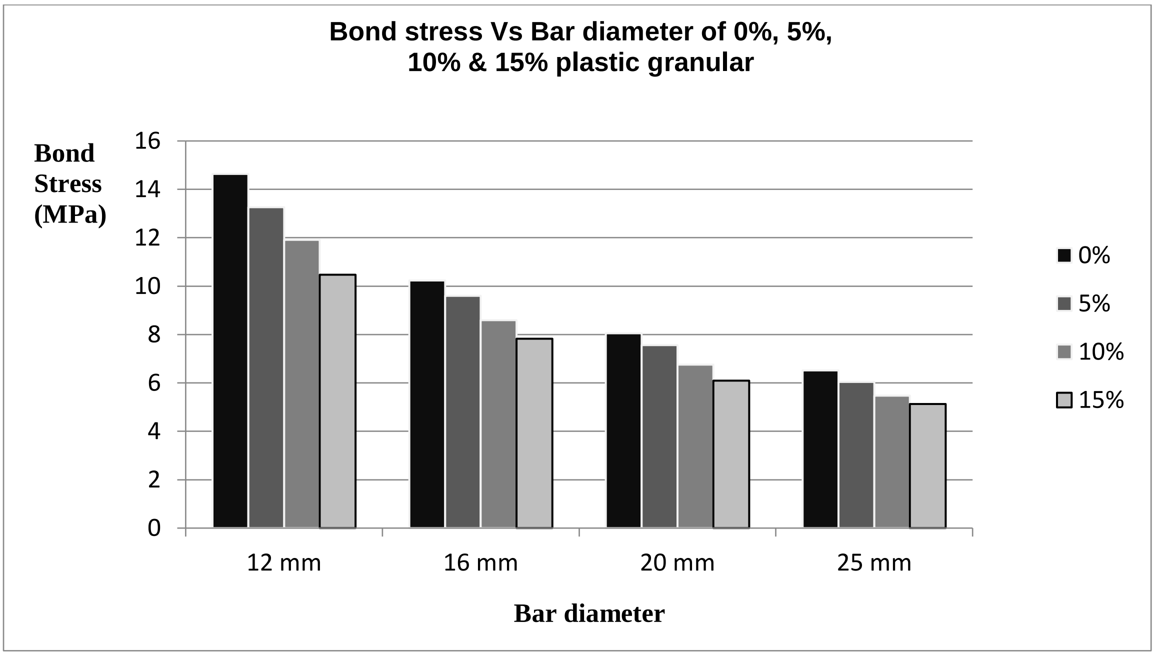


Figure 4: Bonding stress Vs Bar diameter of 0%, 5%, 10% & 15% plastic granular.

Figure 4 shows the variation of bond stress of specimens with different bar diameters for sand replacement level of 0%, 5%, 10% and 15%. Bond stress decreases with the increase in diameter of steel bar. From graph, it is clear that plastic granular has influence on the bonding between steel and concrete. All the specimens failed by splitting or crushing of concrete. For all diameter bars the bond stress reduces with the plastic level. The possible reason behind this reduction is the poor bonding between steel and plastic material. Chemical adhesion is completely absent in this case. So the mechanical interlock is very poor.

4. CONCLUSIONS

Following conclusions can be drawn based on the results observed from this study:-

- The value of compressive strength of concrete is observed to decrease 5% up to are placement level of 5%. But beyond that it decreases rapidly by 40% and 60% for 10% and 15% plastic granular.
- The bonding stress between steel and concrete decreases for 12mm, 16mm, 20mm and 25 mm respectively as about 5 to7% with 5%replacement level, 15 to 20% with10% replacement level and 20 to 30% with 15% replacement level.
- Bond stress decreases significantly with plastic granular used as partial replacement of sand. So introduction of plastic granular in Reinforced concrete is not safe and should not be recommended.
- Introduction of plastics in concrete tends to make concrete ductile, hence increasing the ability of concrete to significantly deform before failure. This characteristic makes the concrete useful in situations where it will be subjected to harsh weather such as expansion and contraction, or freeze and thaw.

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