BEARING STRENGTH OF POLYETHYLENE TEREPHTHALATE (PET) FIBRE REINFORCED RECYCLE AGGREGATE CONCRETE

E. Aruna Kanthi[1], N. Venkata Ramana[2], C. Sashidhar[3]

[1]*Assistant Professor, Civil Engineering Department, JNTUA College Of Engineering, JNTUA Anantapur, Andhra Pradesh, (India)*
[2] *Associate Professor, Civil Engineering Department, UBDT College Of Engineering, Davangere, Karnataka, (India)*
[3] *Professor, Civil Engineering Department, JNTUA College Of Engineering, JNTUA Anantapur, Andhra Pradesh, (India)*

ABSTRACT

This article presents the Bearing strength behaviour of PET fibre reinforced recycles aggregate concrete. The Natural Aggregate (NC) was replaced by recycle aggregate (RA) in the proportion of 0, 25, 50, 75 and 100%. PET fibres were added to the Recycle Aggregate Concrete (RAC) by 1 and 2% volume. Total 90 cubes were cast and tested. The results showed that as the % of RA and volume fraction of PET fibre content increases the strength was decreased. For obtained experimental results Regression Models (RMs) were synthesized and the same are presented in this article.

Keywords- ***RAC, PET Fibres, Bearing Strength, Compressive Strength Regression Models.***

I. INTRODUCTION

The aggregates occupies about three fourth of the concrete volume and play a major role in different concrete properties such as fresh and harden concrete properties, dimensional stability and durability. Conventional concrete consists of sand as fine aggregate and gravel, limestone or granite in various sizes and shapes as coarse aggregate. There is a growing interest in using waste materials as alternative aggregate materials. In this context Demolished Waste Material (DWM) of building or any structure (after completing of its lifespan) or during modernization, waste is generated. This can be utilized in the concrete as RA. Many research works has been carried out on RAC. Now days the plastic is also is a waste and this waste is using for many works as recycle products. Among the plastics family Polyethylene Terephthalate (PET) is one of the major products using by the society in the form of various articles. In this connection a review is presenting below related to PET fibres and RAC. Marzouk et.al. [1] conducted the experimentation on concrete with plastic waste. The plastic material was used as sand substitution in the concrete. The results showed that the use of plastic bottle waste was effective and it attracts as low cost material. Siddique et.al.[2] investigated the effective utilization of waste products (tires, plastic, glass etc) in concrete. The study showed that the use of waste product in concrete not only makes it economical but also helps in reducing disposal problem. Kou et.al.[3] reported that splitting tensile strength of PVC concrete. From their study it is noticed that as PVC content increases the strength was decreased. Akcaozoglu et.al. [4] investigated the use of shredded waste polyethylene using two types of binders. The authors found that the compressive strengths of mortar with PET aggregate is higher with combination of binders. Kandasamy and Mrugesan [5] reported the behavior of composite material consisting of cement based matrix with an ordered or random distribution of fibre of steel, nylon, polythene. The results showed that the addition of fibres increases the properties of concrete. Baboo Rai et.al.[6] reported the concrete properties produced with waste plastic with and without plasticizer. The study showed that reduction in workability and compressive strength with inclusion of plastic. But they also specified that with addition of Plasticizer the strengths were increased marginally. Bhogayata et.al.[7] presents a comparative study of compressive strength of concrete made by mixing of plastic bags as concrete constituent. The results showed that as increase of plastic the compaction factor and compressive strength decreases. Jianzhuang Xial et.al [8] has given overview of study on recycle aggregate concrete. In this paper different properties and behaviour was described. Xiao.J.Zh. et.al [9] has shown relationships between mechanical properties of RAC. From literature it is observed that there is a little work has been focused on PET fibres concrete. So an experimental work planned to evaluate compressive strength (CS) and bearing strength of PET fibre recycle aggregate concrete. To find compressive and bearing strengths of PET fibre reinforced recycle aggregate concrete, 90 cubes were cast and tested in the laboratory.

II. MATERIALS USED

2.1 Cement: Ordinary Portland cement–53 grade was used. The specific gravity of cement was found as 3.15 and it satisfies the requirements of IS: 12269–1987 specifications.

2.2 Super plasticizer*:* To impart the additional desired properties, a super plasticizer (Conplast SP-430) was used. The dosage of super plasticizer adopted in the investigation was 0.85% (by weight of cement).

2.3 Sand: Locally available sand collected from river bed was used as fine aggregate. The sand used was having fineness modulus 2.96 and confirmed to grading zone-III as per IS: 383-1970 specification.

2.4 Coarse aggregates: The crushed stone aggregates were collected from the local quarry. The coarse aggregates used in the experimentation were 20mm.The aggregates were tested as per IS: 383-1970 and 2386-1963 (I, II and III) specifications. The specific gravity was observed as 2.65.

2.5 Recycle aggregate concrete: The Recycled coarse aggregate obtained by crushing demolished concrete mass (Fig.1) and the same was used as recycled coarse aggregate in the present investigation. To obtain a reasonably good grading, 50% of the aggregate passing through 20 mm I.S. sieve and retained on 12.5mm I.S. Sieve and 50% of the aggregate passing through 12.5mm I.S. Sieve and retained on 10 mm I.S. Sieve is used. The specific gravity was found as 2.48.

2.6 Water: Ordinary potable water, free from organic content, turbidity and salts was used for mixing and curing throughout the investigation.

2.7 PET Fibres: The waste PET fibres were obtained from unused drinking water bottles. The bottles were cut from wire cutter tool and it is labour oriented. The PET fibres were sieved and found that 10mm size are more in fiber content and the thickness was observed as 1mm. (Fig.2)

Fig.1 Collection of demolished concrete waste

Fig.2 PET fibres

III.TEST PROGRAMME

Concrete was prepared by a design mix proportion of 1:1.90:3.09 with a W/C ratio 0.45, which correspond to M20 grade of concrete. The entire mix was homogeneously mixed with calculated quantity of required materials. The standard cubes (150 x 150 x 150mm) were cast and tested after 28 days of curing to evaluate compression and bearing strengths of PET fibre recycle aggregate concrete. A total 15 mixes (90 cubes) were consider in the investigation and for each mix six cubes were cast (three cubes were taken for compression test and other three cubes taken for bearing test) and tested. The recycle aggregate was used in the concrete mixes with different proportions of 0, 25, 50, 75 and 100%. For each ratio of recycle aggregate concrete, the PET fibres were added in the proportion of 0, 1 and 2%. The average value of three specimens was taken as failure load for conducted test. The bearing test was conducted on cube with the help of steel plate (67.1x67.1x25.4mm (length x breadth x thickness)) in order to achieve the bearing area ratio as five. Here after in the forth coming discussion RAC indicates recycle aggregate concrete and RAC-0 considered as reference or conventional concrete.

IV.TEST RESULTS AND DISCUSSION

4.1 Compressive Strength

The compressive strength results are presented in Table 1and Figure 3. From this table and figure it is observed that as % of RA content increases the compressive strength decreases. For 25 to 75% of RA in content the strength decrement is about 2 to 14% compared to reference concrete. The reason may be the bond between recycle aggregate concrete and new cement mortar forms weak links, but it is vice versa for reference mix (RAC-0). These types of observations were made by Rasheeduzzafar, Khan [13] and Torben C Hansen [14]. From those articles it is observed that there is about 8 to 24% decrement in compressive strength when compared with natural aggregate concrete (NAC) or conventional concrete. The Compressive strength of RAC with fibres is in the range of 25 to 30 MPa. As the % PET fibre increase the compressive strength decreases. The design compressive strength of 20MPa is plotted in the Figure 3.0. This value touches the 2% of PET fibre RAC at 75% recycle aggregate (RA) content. This indicated that, RAC with 1% fibre volume and up to 100% of RA is effectively utilized, but the RAC with 2% fibre up to 75% is permitted for the designer/engineer in charge at site. The decrease in compressive strengths for RAC with PET fibres may be due to low bond strength between the surface of plastic waste and cement paste as well as the hydrophobic nature of plastic waste, which can inhibit cement hydration reaction by restricting water movement and another reason may be particle size and shape between natural and plastic fibre. Frigione [10] was also reported this type of trend for natural aggregate concrete with plastic waste.

Table 1: Compressive strength

Sl.No	Nomenclature	Compressive strength (N/mm^2) 0% fibre	Compressive strength (N/mm^2) 1% fibre	Compressive strength (N/mm^2) 2% fibre
1.	RAC-0	33.33	30.22	30.22
2.	RAC-25	32.13	28.75	28.75
3.	RAC-50	30.93	27.51	27.51
4.	RAC-75	29.19	26.54	26.54
5.	RAC-100	28.60	25.64	25.64

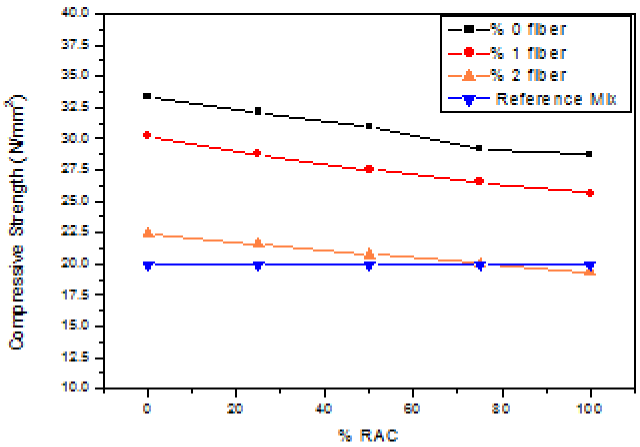

Fig.3: Compressive strength vs % of RAC

4.2 Bearing Strength

4.2.1 First crack (FC) stage

The bearing strength at first crack stage for all mixes is presented in Table 2 and Figure 4. From those it is observed that as the % of recycle aggregate is increases the bearing strength was decreased. For 0% of fibers, the bearing strength is decreased from 13 to 61% for 25 to 100% of recycle aggregate content, when compared with natural aggregate concrete. For 1% of fibre concrete mix, the bearing strength decreases as the % of recycle aggregate increases when compared with natural concrete with and without PET fibres. But the addition of 1%fibres for concrete mix, the bearing strength marginally enhances when compared with corresponding replacements with 0% fibre concrete. The mix with 25% of recycle aggregate along with 1% of fibre exhibits more strength (58.00N/mm^2) when compared with natural aggregate concrete without fibres i.e 0% fibre (52.00N/mm^2). But for mix with 50% of recycle aggregate along with 1% of fibre showed marginally more strength (55.20N/mm^2) of natural aggregate concrete without fibres i.e 0% fibre (52.00N/mm^2) For 2% of fibre concrete the bearing strength is decreasing as the recycle aggregate content is increasing. The % of decrease is about 7 to 30, when compared with natural aggregate concrete containing 2% of fibre (RAC-0 with 2%PET fibres). The mix with 50% of recycle aggregate along with 2% of fibre exhibits nearly the same strength of natural aggregate concrete without fibres i.e 0% fibre. From this it concluded that, as the fibre content increases the bearing strength may enhances for recycle aggregate concrete. In this mixes the fibres placing major role to enhance the strength. This type of trends were noticed by S.A.Al-Taan and J.A.Al-Hamdony[15) for steel fibre concrete. From the above results it concluded that the presence of steel fibres in concrete mix showed good performance up to 50% replacement i.e. it is as good as natural aggregate concrete. So the designer can be take the concrete mix with recycle aggregate up to 50% replacement with 1 and 2% of fibers.

Table 2: Bearing strength at first crack stage

Sl.No	Nomenclature	Bearing strength(N/mm^2) 0% fibre	Bearing strength(N/mm^2) 1% fibre	Bearing strength(N/mm^2) 2% fibre
1.	RAC-0	52.00	64.00	65.20
2.	RAC-25	45.00	58.00	60.50
3.	RAC-50	30.20	55.20	53.20
4.	RAC-75	28.50	50.20	50.30
5.	RAC-100	20.50	40.20	45.20

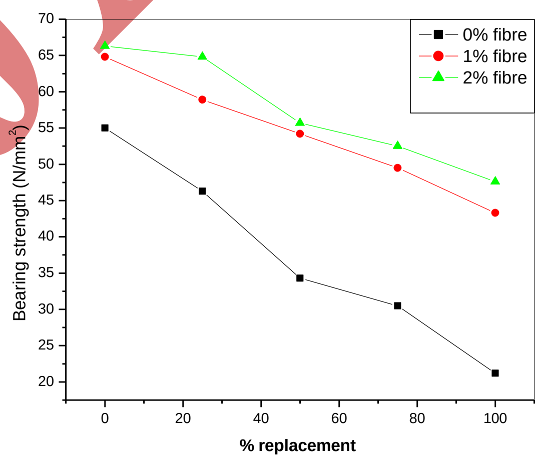

Fig. 4: Bearing Strength vs % replacement

4.2.2 Ultimate stage (US)

The bearing strength at ultimate state for all mixes is presented in Table 3 and Figure 5.From those it is observed that as the % of recycle aggregate is increases the bearing strength was decreased. The behavior at ultimate stage is similar to first crack stage. For 0% of fibers, the bearing strength is decreased from 8 to 41% for 25 to 100% of recycle aggregate when compared with natural aggregate concrete (RAC-0). For 1% of fibre concrete mix, the bearing strength decreases as the % of recycle aggregate increases when compared with natural concrete with and without fibres. But the addition of 1%fibres for concrete mix, the bearing strength significantly increased, when compared with corresponding replacements with 0% fibre concrete. The mix with 25% of recycle aggregate along with 1% of fibre exhibits more strength (75.31N/mm^2) when compared with natural aggregate concrete without fibres i.e 0% fibre (71.64N/mm^2). For 2% of fibre concrete the bearing strength is decreasing as the replacement recycle aggregate content is increasing. The% of decrease is about 10 to 46, when compared with natural aggregate concrete containing 2% of fibre. The mix with 50% of recycle aggregate along with 2% of fibre exhibits higher strength (79.20Mpa) of natural aggregate concrete without fibres i.e 0% fibre(78.15Mpa). From this it concluded that, as the fibre content increases the bearing strength may enhances for recycle aggregate concrete. In this mix the fibres placing major role to enhance the strength. This type of results were noticed by S.A.Al-Taan and J.A.Al-Hamdony[15] for steel fiber concrete. The presence of steel fibres in concrete mix show good performance up to 25% replacement. So the designer can be take the concrete mix with recycle aggregate up to 25% replacement with 1 and 2% of fibers while estimating the ultimate load. In the compressive strength results as the % of PET fibres content increases, the compressive strength was decreasing but whereas in the bearing strength test, as the % of PET fibres content increases the bearing strength is increasing, this may be due to, in compressive test the cube is loaded on the entire area (150mm x150mm), but in the bearing strength test the cube is loaded on the area of 67.1mm x67.1mm. The area beyond this plate size is not subjected to more stresses (less than critical stresses) and at the same time this area of concrete gives confinement to the loaded area.

Table 3: Bearing Strength At Ultimate Stage

Sl.No	Nomenclature	Bearing strength (N/mm^2) 0% fibre	Bearing strength(N/mm^2) 1% fibre	Bearing strength(N/mm^2) 2% fibre
1.	RAC-0	78.15	82.66	88.66
2.	RAC-25	71.64	75.31	79.20
3.	RAC-50	65.13	67.44	69.28
4.	RAC-75	57.38	60.53	58.82
5.	RAC-100	45.48	53.15	47.75

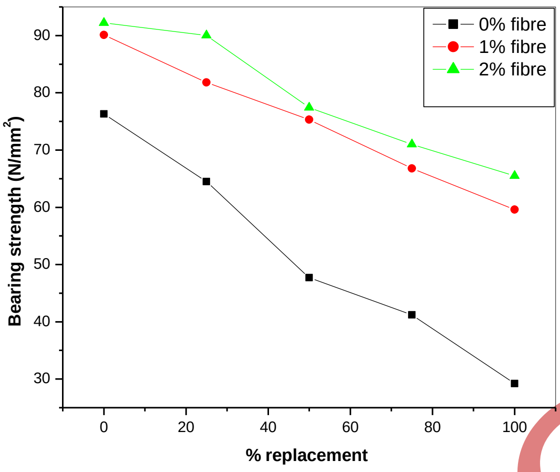

Fig. 5: Bearing Strength vs. % replacement

4.3 Relationship Between Bearing And Compressive Strength

The bearing strength of concrete is most important parameter during the design of axially loaded elements. For normal concrete the IS 456-2000 recommended the following equation.

$f_b=0.45(f_{ck})\sqrt{(A1/A2)}$-------------------------IS 456-2000

In the above expression

f_{ck} = Characteristic compressive strength (N/mm^2)

A1=bearing area

A2=punching area

$\sqrt{(A1/A2)}$ should not be more than 2

The validity of the above equations was demonstrated in Table 4. From this table it is observed that the IS code is estimates the bearing strength more than 10% variation when compared with experimental data. Hence the there is a necessity to develop a regression model (RM) to suit the experimental values for recycle aggregate concrete. In this aspect few regression modals with a correlation coefficient R^2=0.99 for all % of fibres were developed and the same presented below.

f_b= 2.30(f_{ck})-0.15(%of replacement)+1.50---------------- for 0% fibre

f_b= 0.75(f_{ck})-0.20(%of replacement)+60.00---------------- for 1% fibre

f_b= -2.00(f_{ck})-0.50(%of replacement)+150.00----------------for 2% fibre

In the above expressions

f_b = Bearing strength (N/mm^2)

f_{ck} = Characteristic compressive strength (N/mm^2)

The performance of the proposed model is presented in Table 5. From this table it is observed that the ratio between experimental (EXP) and regression modal (RM) values is about 0.98 to 1.00. The ratio inferences the proposed modal is best suited to the experimental values and also may concluded that it is better than IS code formula.

Table 4: Performance of IS456-2000

% Fibre	% Recycle aggregate	IS456-2000	Exp	Exp/IS456-2000
0%	0	70.33	78.15	1.11
	25	64.47	71.64	1.11
	50	58.61	65.13	1.11
	75	51.61	57.38	1.11
	100	40.93	45.48	1.11
1%	0	74.39	82.66	1.11
	25	67.77	75.31	1.11
	50	60.69	67.44	1.11
	75	54.47	60.53	1.11
	100	47.83	53.15	1.11
2%	0	79.79	88.66	1.11
	25	71.28	79.20	1.11
	50	62.35	69.28	1.11
	75	52.93	58.82	1.11
	100	42.97	47.75	1.11

Table 5: Performance of Regression Modal (RM)

Sl.No.	% of fibre	% of replacement	Exp. Bearing strength(N/mm^2)	Bearing strength (N/mm^2) as per RM	Exp/RM
1	0%	0	78.15	78.15	1.00
2		25	71.64	71.64	1.00
3		50	65.13	65.13	1.00
4		75	57.38	57.38	1.00
5		100	45.98	52.28	0.87
6	1%	0	82.66	82.66	1.00
7		25	75.31	75.31	1.00
8		50	67.44	68.13	0.99
9		75	60.53	61.15	0.99
10		100	53.15	54.23	0.98
11	2%	0	88.66	89.56	0.99
12		25	79.20	80.00	0.99
13		50	69.28	69.98	0.99
14		75	58.82	59.42	0.99
15		100	47.75	48.72	0.98

4.4 Failure Mode Analysis

For each mix three cubes were tested for bearing strength with bearing area ratio of five. In all the cubes during experimentation (fig.6), radial cracks were observed and this can be viewed in figure 7. This type of cracks were also observed by S.A.Al-Taan and J.A.Al-Hamdony[15] for steel fiber concrete. The dimensional stability is more for higher percentage concrete cubes when compared with other percentage fibres and also the crack width is decreased as the % of fibre content increases.

Fig. 6: Cubes testing for bearing strength using 67.1mm square plate

Fig. 7: Failure mode of cube

V.CONCLUSIONS

1. As % of Recycle Aggregate (RA) content in the mix increases the compressive strength decreases.
2. The decrease in the compressive strength for RAC is about 3 to 14 % for 25 to 100% of RA content in the design mix when compared to RAC.
3. The compressive strength decrease as % of PET fiber volume increase in RAC.
4. The decrease of compressive strength for 1% and 2% of PET fibre volume is about 9 to 41 % compared to reference mix.
5. The bearing strengths were decreases as the recycle aggregate content increases in the concrete mix.
6. For a particular recycle aggregate content as the PET fibres increase the bearing strengths were increasing.
7. The bearing strengths were incresing as the %of PET fibres increases in the concrete mix.
8. The maximum replacement of recycle aggregate at first crack and ultimate stage is 50 and 25% without affecting the design strength of natural aggregate concrete (with and without addition of PET fibres).

9. For bearing test specimens the crack width is decreasing as the PET fibre content increases.

10. Lateral confinement effect is more for bearing test specimens than the compressive test specimens.

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