COMPRESSIVE AND SPLIT TENSILE STRENGTHS OF POLYETHYLENE TEREPHTHALATE (PET) FIBRE REINFORCED RECYCLE AGGREGATE CONCRETE

N.Venkata Ramana[1], R.Harathi[2], Vaishali G Ghorpade[3]

[1]*Associate Professor, Civil Engineering Department,* UBDT *College of Engineering, Davangere, Karnataka (State), (India)*

[2]*Assistant Executive Engineers, PABR sub division no:3, , HLC Division, I and CAD Department Anantapuram, Andhra Pradesh (State), (India)*

[3]*Professor, Departmnent of Civil Engineering, JNTUA Collegeof Engineering Anantapur, Andhra Pradesh (State), (India)*

ABSTRACT

This paper presents the compressive and split tensile strength of PET fibre reinforced recycles aggregate concrete. The Natural Aggregate (NC) was replaced by recycle aggregate (RA) in the proportion of 25, 50, 75 and 100%. PET fibres are added to the Recycle Aggregate Concrete (RAC) by 1 and 2% volume. 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 Model (RM) wasdeveloped to predict the split tensile strength by knowing the compressive strength of concerned mix of concreteand the same is presented in this article.

Key Words:-RAC, PET Fibres, Compressive Strength, Cube, Split Tensile Strength, Cylinder, Regression Model

I. INTRODUCTION

For design grade of concrete the aggregate (coarse and fine) occupies about three fourth (3/4) of the volume of specimen and play a significant role in concrete properties such as fresh and harden concrete properties, dimensional stability and durability. Conventional concrete consists of sand as fine aggregate and gravel(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 recycle aggregate (RA). Many research works has been carried out on Recycle aggregate concrete (RAC). Now days the plastic is also is a waste and this waste is using for many works as recycle products. Among the different type of plastics groups, 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. BabooRai 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. JianzhuangXialet.al[8] has given a overview of study on recycle aggregate concrete. In this paper different properties of RACand its 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 with combination of RA. So the authors had planned to evaluate compressive strength (CS) and split tensile strength (STS) of PET fibre recycle aggregate concrete and also to establish the relation between the two strengths. To find CS and STS of PET fibre reinforced recycle aggregate concrete, 45 cubes and 45 cylinders were cast and tested in the laboratory.

II. MATERIALS USED

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) 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).

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.

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

5) Recycle aggregate concrete: The Recycled coarse aggregate obtained by crushing demolished concrete mass 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.

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

7) PET Fibres: The waste PET fibres were obtained by cutting of unused drinking water bottles. The fibres were cut from steel wire cutter and it is labor oriented. The PET fibres were sieved and found that 10mm size are more in fiber content and the thickness was observed as 1mm. (Figure.1)

Figure.1 PET fibres

III. CASTING AND CURING

Concrete was prepared by a design mix proportion of 1:1.90:3.09 with a W/C ratio of 0.45 which correspond to M20 grade of concrete. The entire mix was homogeneously mixed with calculated quantity of required materials. The standardcubes and cylinders were (cube size is 150 x 150 x 150mm and cylinder size is 15mm dia, 300mm height) cast and tested after 28 days of curing as per IS specifications. A total 15 mixes (45cubes&45 cylinders) were consider in the investigation and for each mix three cubes and three cylinders are tested. The average value of ultimate load and stress of three cube and cylinder specimens are presented in Table.1.In the table.1, RAC indicates recycle aggregate concrete , F1 and F2 indicates PET fibre volume fraction of 1 and 2% by volume of cast specimen and the number 0,25,50,75 and 100 indicates the % of replacement of granite aggregate with recycle aggregate. The RAC-0 considered as reference mix (M20) or Natural aggregate concrete (NAC), in this forth coming sections, the other mixes were compared with reference mix or NAC.

IV. TEST RESULTS AND DISCUSSION

4.1 Compressive Strength

The compressive strength results are presented in Table.1. From this table it is observed that as % of RA content increases the compressive strength decreases. For 25 to 75% replacement of RA in conventional mix the strength decrement is about 2 to 14%. The reason may be the bond between recycle aggregate concrete and new cement mortar forms weak links ,but it is vice versa for NA. The Compressive strength of RAC with fibres is in the range of 30 to 19 MPa. As the % fibre increase the compressive strength decreses. The design compressive strength of concrete is 20MPa, for PET fibre RAC this value touches at 2% of PET fibre and 75% RA. This indicated that, RAC with 1% fibre volume and upto 100% replacement of RA is effectively utilized, but the RAC with 2% fibre upto 75% replacement of RA is pemited for the designer/engineer incharge at site. The decrese 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 improvement and another reason may be particle size and shape between natural and platic fibre. Frigione[10] was reported this type of trend for natural aggregate concrete with plastic waste.VenkataRamana et.al.,[11] developed some regression models to predict the compressive strengths for 0,1 and 2% of PET fibres for recycle aggregate concrete.

4.2 Split Tensile Strength

The split tensile strength results are presented in Table.1. From the results it observed that as the % of RA content increases the tensile strength is decresed. The % of decrease is about 1 to 9% for 25 to 100% replacement of RA. Mukaiet.al[12] and Ravindrarajah[13] reported the similar observations. They reported that for recycle aggregate concrete the split tensile strength is about10 to 20% of conventional concrete.

The split tensile strength of RAC with PET fibres is decreasing as % of PET fibre volume increases. The percentage of decrement for 1% fibre is 5to 17% and for 2% fibre 23 to 32% for RAC concrete when compared with conventional concrete. The decrement in strength may be due to interfacial transition zone, the smooth surface of PET fibres causes weaker bond between the plastic and additive material(cement paste).Kou et.al [14] reported the same trend results for concrete.

From through inspection of tested specimen the author noticed that the concrete cylinders with PET fibres did not split into two fractions after determination of tensile strength.The probable reason may be the PET fibres may act as bridge between the two split pieces.

Table.1: Compressive and Split Tensile Strengths

Sl.No.	Nomenclature	Average Ultimate compressive Load(KN)	Average Ultimate Compressive Strength (N/mm2)	% of Decrease or increase of compressive strength	Average Ultimate Split tensile Load(KN)	Average split tensile Strength (N/mm2)	% of Decrease or increase of split tensile strength
1	RAC-0	750	33.33	-	240	3.39	-
2	RAC-25	723	32.13	-2.89	236	3.34	-1.47
3	RAC-50	696	30.93	-7.2	230	3.25	-4.12
4	RAC-75	673	29.19	-12.42	224	3.17	-6.48
5	RAC-100	645	28.6	-13.98	219	3.09	-8.85
6	RACF1-0	680	30.22	-9.33	226	3.19	-5.89
7	RACF1-25	647	28.75	-13.74	219	3.09	-8.85
8	RACF1-50	619	27.51	-17.46	215	3.04	-10.32
9	RACF1-75	596	26.54	-20.55	209	2.95	-12.97
10	RACF1-100	577	25.64	-23.07	200	2.83	-16.51
11	RACF2-0	506	22.48	-32.55	185	2.61	-23.00
12	RACF2-25	485	21.55	-35.34	180	2.55	-24.77
13	RACF2-50	467	20.75	-37.74	174	2.46	-27.43
14	RACF2-75	452	20.08	-39.97	170	2.40	-29.20
15	RACF2-100	436	19.37	-41.88	164	2.32	-31.56

4.3 Relation between Split Tensile Strength and Compressive Strength

The split tensile strength is often used to obtain the tensile strength of concrete, rather than by a direct tensile strength test, because the former is easier to perform. In practical applications, the tensile strength of concrete is often estimated from the compressive strength. The split tensile strength of the RAC with relation of compressive strength was obtained by the previous investigators ofXioet.al[15] as f_t=0.75(f_{ck})0.5. This relation was deduced for RAC without considering the PET fibre. In the ACI 318-M-11 code and Chinees code (GB 50010-2002). The relationship between split and compressive strength normal concrete expressed as

$f_{sp}=0.49\sqrt{f_{ck}}$-------------------------- As per ACI code

(Note: cylinder compressive strength=0.76 compressive strength)

$f_{sp}=0.19(f_{ck})$ 0.75-------------------------- As per GB code

By using the above equations the results are presented in Table 2. From this table it is observed that the results under estimates for RAC concrete with and without fibres.To improve the above equations a regression analysis was performed to the obtained test results and the following regression equation is deduced with correlation coefficient R2 is 0.996 and Standard Deviation (SD) is 0.022.

$f_{sp}=0.78\sqrt{f_{ck}}-1.12$

Comparison between the test results and that predicted by proposed equation is presented in Table.3 and Figure.1The ration between EXP/RM is about 1.0 to 1.02. From this it noticed that the proposed equation has good agreement with the experimental results.

Table.2: Comparison of Experimental Split Tensile Strength with Different Codes

Sl.No	Nomenclature	EXP Split tensile strength	As per Xiao et.al	ACI	GB	EXP/Xiao	EXP/ACI	EXP/GB
1	RAC-0	3.39	2.34	2.83	2.64	1.45	1.20	1.29
2	RAC-25	3.34	2.29	2.78	2.56	1.46	1.20	1.30
3	RAC-50	3.25	2.23	2.73	2.59	1.46	1.19	1.30
4	RAC-75	3.17	2.15	2.65	2.39	1.47	1.20	1.33
5	RAC-100	3.09	2.13	2.62	2.35	1.45	1.18	1.31
6	RACF1-0	3.19	2.20	2.69	2.45	1.45	1.18	1.30
7	RACF1-25	3.09	2.13	2.63	2.36	1.45	1.18	1.31
8	RACF1-50	3.04	2.07	2.57	2.28	1.47	1.18	1.33
9	RACF1-75	2.95	2.02	2.52	2.22	1.46	1.17	1.33
10	RACF1-100	2.83	1.98	2.48	2.16	1.43	1.14	1.31
11	RACF2-0	2.61	1.82	2.32	1.96	1.44	1.12	1.33
12	RACF2-25	2.55	1.77	2.27	1.90	1.44	1.12	1.34
13	RACF2-50	2.46	1.72	2.23	1.85	1.43	1.10	1.33
14	RACF2-75	2.40	1.69	2.20	1.80	1.42	1.09	1.33
15	RACF2-100	2.32	1.65	2.16	1.75	1.41	1.08	1.32

Table 3: Regression Model Performance for Split Tensile Strength

Sl.No	Nomenclature	Experimental Split tensile strength	Regression Model	Exp Split tensile strength / Regression Model
1	RAC-0	3.39	3.38	1.00
2	RAC-25	3.34	3.30	1.01
3	RAC-50	3.25	3.21	1.01
4	RAC-75	3.17	3.09	1.02
5	RAC-100	3.09	3.05	1.01
6	RACF1-0	3.19	3.16	1.01
7	RACF1-25	3.09	3.06	1.01
8	RACF1-50	3.04	2.97	1.02
9	RACF1-75	2.95	2.89	1.02
10	RACF1-100	2.83	2.82	1.00
11	RACF2-0	2.61	2.57	1.01
12	RACF2-25	2.55	2.50	1.02
13	RACF2-50	2.46	2.43	1.01
14	RACF2-75	2.40	2.37	1.01
15	RACF2-100	2.32	2.30	1.01

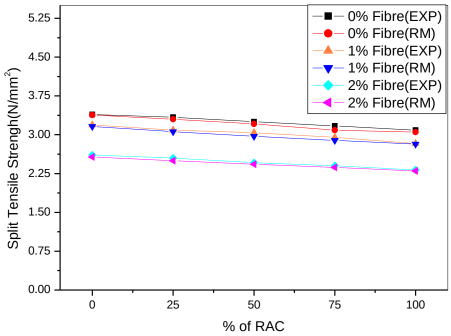

Fig.2: Performance of Regression Model

V. CONCLUSIONS

The following conclusions are drawn from the present experimental work.

1. The compressive and split tensile strengths are decreases as the RA content increase in the conventional concrete mix.
2. The compressiveand splittensile strengths decreased about 2 to 14% and 1 to 8% with RA content of 25 to 100% respectively
3. As PET fibre volume increases in the RAC the compressive andsplit tensile strengths are decreased.
4. The PET fibre volume with 1% can be used effectively without change in design mix.
5. The Maximum permissible limit for recycle aggregate content with 2% fibre volume is 75%.

6. For RAC with 1% PET fibre volume the compressiveand split tensile strengths decreased about 9to 23% and6 to 17% with RA content of 0 to 100% respectively when compared with conventional concrete.

7. For RAC with 2% PET fibre volume the compressive and splittensile strengths decreased about 32to 42% and 25 to 31% with RA content of 0 to 100% respectively when compared with conventional concrete.

REFERENCES

[1] Marzouk O Y, Dheilly RM Queneudec M, Valorization of post consumer waste plastic in cementitious concrete composites,Waste Manage,27,pp310-318,2007.

[2] Siddique R,Khatib J, Kaur I ,"Use of recycled plastic in concrete, A review waste management" 28,pp1835-1852,2008.

[3] Kou SC,Poon CS ,"Properties of light weight aggregate concrete prepared with PVC granules drived form scraped PVC pipes", Waste manage (Oxf),29(2),pp621-628,2009.

[4] AkcaozogluS,AtisCD,Akcaozoglu K, "An investigation on the use of shreadded waste PET bottles as aggregate in light weight concrete",Waste manage (Oxf),32(2),pp258-290,2010.

[5] Kandasamy R and MurugesanR , "Fibre reinforced concrete using domestic waste plastic as fibres", ARPN journal of Engineering and Applied Sciences,6(3),pp75-82,2011.

[6] BabooRai, TabinRushadS,Bhavesh KR, Duggal SK , "Study of waste plastic mix concrete with plasticizer", ID 4692,72,pp1-5,2012.

[7] BhogayataA,Shah K D, Vyas B A, Arora N K "Performance of concrete by using Non recyclable plastic wastes as concrete constituent", International journal of Engineering Research and Technology(IJERT),1(4),pp1-3,2012.

[8] JianzhuangXiao,WenguiLi,Yuhui Fan, XioHuang,"An over view of study on recycle aggregate concrete in china (1996-2011)",Construction and building materials,31,pp364-383,2012.

[9] Xiao J.Zh., J.B. Li. ChZhang,"On relationship between the mechanical properties of recycle aggregate concrete:An over view",Materials and structures,39,pp655-664,2006.

[10] Frigione M, "Recycling of PET bottle as fine aggregate in concrete", Waste Manage (Oxf),30(6),pp1101-1106,2010.

[11] VenkataRamana.N, R.Harathi, S.NarasimhaBabu, S.VinayBabu, "Regression", International Journal of Engineering Research and Development,Volume 8, Issue 5PP. 11-16(August 2013).

[12] MukaiT,KikuchiM,"Studies on utilization of recycled concrete for structural memebrs (part1 and part2).Summaries of technical papers of annual meeting, ArcchitInstJpn, pp85-88,1978.

[13] RavindrarajahRS,Tam TC (1985),Properties of concrete made with crushed concrete as coarse aggregate,Maga Concrete Res,37(130),pp29-38,1985.

[14] Kou SC, Lee G,PoonCS,LaiWL,"Properties of light weight aggregate concrete prepared with PVC granules derived from scraped PVC pipes" Waste Manage (Oxf) 29(2), pp621-628, 2009.

[15] Xiao JZ , Li JB,ZhangC,"On relationship between the technical properties of recycle aggregate concrete:an overview "Material Struct,39(6): pp655-664,2006