Properties of Blended Puzzolonic Concretes with Fly Ash & Recycled Aggregates

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Abstract
In pursuit of reducing the environmental impact in terms of energy consumption, pollution, industrial waste disposal and global warming, the construction industry is relentlessly striving for alternate concrete making materials. Blended concretes can substitute in order to address these issues. This paper reports the results of a laboratory based experimental study aimed at characterizing the strength properties of blended puzzolonic concretes with recycled aggregates and flyash. Blended concretes of M35 and M45 grades were produced by partially replacing the cement by 25 Percent Fly ash and the natural coarse aggregates were replaced by Recycled Coarse Aggregates(RCA) in different fractions of 0,25,50,75 and 100 percentages. Compressive strength and Split Tensile strength of concrete were evaluated at 7days and 28days of normal water curing. The test results revealed that the compressive strength and the split tensile strength having a close resemblance to conventional concrete with natural coarse aggregate at an optimum replacement level of 25 percent of Fly ash and 75 percent RCA.

Keywords- *Blended concrete, Compressive strength, Split tensile strength, Fly ash, Recycled aggregate.*

I. INTRODUCTION

Sustainability issues are of prime concerns these days as we make use large amount of natural resources for the production of construction materials such as concrete. Depletion of natural resources is one such sustainability issue which needs to be addressed in an efficient manner. Recent trend in construction industry is to make use of the alternative source of construction materials which can substitute the use of virgin materials in order to reduce environmental impact in terms of energy consumption, pollution, industrial waste disposal and global warming and also reducing the carbon footprint. Production of construction and demolition waste has significantly increased globally, over the last few decades, leading to environmental problems due to its uncontrolled disposal. The use of recycled materials has been increasing for the purpose of sustainable development and protecting the environment.

Recycling of demolished concrete has been emerging as a sustainable solution to address the reuse of concrete construction wastes, as well as to prevent the depletion of natural coarse aggregate reserves from growing construction demand. However, some key factors that would affect the properties of blended concretes with fly ash as partial replacement of cement and recycled aggregates as replacement of natural coarse aggregates have not been thoroughly investigated. Key factors such as the proportion of flyash & proportion recycled aggregates, and the design compressive strength of concrete. In particular, little research was done on the combined effects of recycled aggregates and fly ash, popularly used as a partial substitution of cement. Addressing these concerns, this present study investigates the effects of such factors on the mechanical properties of blended concretes with fly ash as partial replacement of cement and recycled aggregates as replacement of natural coarse aggregates.

Five Different Concrete mixes per each of M35 and M45 grade were tested for properties of fresh concrete, compressive strength, & split tensile strength. In general, it is observed that the higher ratio of recycled aggregates resulted in the better flowability of concrete. Also, the use of fly ash improved the flowability of blended concrete. The test results revealed that the compressive strength and the split tensile strength having a close resemblance to conventional concrete with natural coarse aggregate at an optimum replacement level of 25 percent of Fly ash and 75 percent RCA.

II. EXPERIMENTAL DETAILS

Concrete mixes of M35 and M45 grades were produced using different replacement ratios of Natural Coarse Aggregates(NCA) to recycled coarse aggregate(RCA) (100:0%, 75:25%, 50:50%,25:75%,0:100%) respectively. Fly Ash content is partially replaced by 25% by weight of cement in all the mixes.

Cubes of standard size 150mmx150mmx150mm and Cylinders of diameter 150mm and height 300mm were casted to evaluate their compressive strength and split tensile strength respectively. After the desired curing regimes of 7days and 28days the hardened concrete tests were performed on cubes and cylindrical specimens to evaluate the compressive and splitting tensile strength.

III. MATERIALS

Ordinary Portland Cement (OPC) of grade 53 conforming to IS 8112, and Class F low calcium fly ash suitable for use in concrete as an admixture according to IS 3812 (Part 2) were used. Crushed granite natural coarse aggregate (NCA) of 20 mm size and 10 mm size was used. The recycled aggregates used in this study were generated by crushing of concrete cubes, cylinders, prisms which were cast and tested in the concrete laboratory at KITS Warangal and also those cast at various construction sites near Warangal Urban District of Telangana Region.

The cubes were first manually broken into pieces of size less than 100 mm and then were crushed using a mini jaw crusher. The crushed material retained between IS sieves 20 mm and 4.75 mm was used. The particle size distribution of both NCA and RCA were within the margins as specified in IS 383:1970. The physical and mechanical properties of coarse aggregates (NCA&RCA) are given in Table 1&2. The recommended specifications of NCA&RCA, as per some of the International Standards, are also presented in Table 1&2 for comparison. It is seen from Table 2 that the RCA used in the present study is satisfying the acceptance criteria prescribed in JIS A 5021 for Class H and can be used for concrete structures and segments requiring a nominal strength of 45 MPa or less. According to JIS 5021, the RAC prepared with this aggregate can be subjected to any exposure condition without any limitations. Locally available river sand conforming to Zone II of IS 383:1970 was used as fine aggregate.

TABLE 1: SPECIFICATIONS & PROPERTIES OF NATURAL COARSE AGGREGATE .

Test Property	Natural Coarse Aggregate (NCA)	
	Test Result	Acceptance criteria
Specific Gravity	2.79	2.30 2.90 (ACI E1-07)
Bulk Density Kg/m^3	1360	1280 -1920 (ACI E1-07)
Water Absorption (%)	1.9	<2.0 , IS-2386 Part-5
Agg. Crushing Value (%)	20.67	< 30 (IS 383)
Agg. Impact Value (%)	23.3	< 30 (IS 383), <30 (MORTH, 2001)
Agg. Abrasion Value(%)	24.0	< 30 (IS 383), < 40 (MORTH,2001)

TABLE 2: SPECIFICATIONS & PROPERTIES OF RECYCLED AGGREGATE .

Test Property	RCA			
	Test Result	Acceptance criteria		
		ClassH	ClassM	ClassL
Specific Gravity	2.76	2.5 or more (JIS A5021)	2.3 or more (JIS A 5022)	-- (JIS A 5023)
Bulk Density Kg/m^3	1350	1200 (HB 155 : 2002)	--	--
Water Absorption (%)	4.08	3.0 or less (JIS A 5021)	5.0 or less (JISA 5022)	7.0 or less (JIS A 5023)
Agg. Crushing Value (%)	24.37	--	--	--
Agg. Impact Value (%)	45	--	--	--
Agg. Abrasion Value (%)	28	40 or less (KS F 2573)	--	--

CONCRETE MIXES

Concrete mixes of M35 and M45 grade were produced i.e. a) Concrete with 100 % Natural aggregate with 25% fly ash (100NCA), b)75 % Natural aggregate and 25% RCA with 25% fly ash (75NCA+25RCA), c) 50 % Natural aggregate and 50% RCA with 25% fly ash (50NCA+50RCA),, d) 25 % Natural aggregate and 75% RCA with 25% fly ash (25NCA+75RCA), e) 100 % Recycled aggregate with 25% fly ash (100RCA), All the concrete mixes were designed as per IS 10262 to achieve a characteristic compressive strength of 35 MPa and 45MPa. The superplasticizer dosage was kept as 6ml per kg of cementitious material in M45 grade. The details of mix proportions of the concrete mixes are given in Table 3A & 3B

TABLE 3A: MIX PROPORTIONS FOR M35 GRADE

Mix Designation	Cement Kg/m^3	FlyAsh Kg/m^3	Fine Aggregate Kg/m^3	Coarse.Aggregate Kg/m^3				Water Kg/m^3
				NCA		RCA		
				20mm	10mm	20mm	10mm	
100NCA	292.5	97.5	680.0	700.8	467.2	0	0	171.6
75NCA+25RCA	292.5	97.5	680.0	525.6	350.4	175.2	116.8	171.6
50NCA+50RCA	292.5	97.5	680.0	350.4	233.6	350.4	233.6	171.6
25NCA+75RCA	292.5	97.5	680.0	175.2	116.8	525.6	350.4	171.6
100RCA	292.5	97.5	680.0	0	0	700.8	467.2	171.6

TABLE 3B: MIX PROPORTIONS FOR M45 GRADE

Mix Designation	Cement Kg/m^3	FlyAsh Kg/m^3	Fine Aggregate Kg/m^3	Coarse.Aggregate Kg/m^3				Water Kg/m^3
				NCA		RCA		
				20mm	10mm	20mm	10mm	
100NCA	310.50	103.50	690	696	464	0	0	164
75NCA+25RCA	310.50	103.50	690	522	348	174	116	164
50NCA+50RCA	310.50	103.50	690	348	232	348	232	164
25NCA+75RCA	310.50	103.50	690	174	116	522	348	164
100RCA	310.50	103.50	690	0	0	696	464	164

IV. CASTING AND CURING OF SPECIMENS

The concrete mixes were prepared in a drum mixer. Triple mixing method, developed by Kong et al (2010), was adopted for the production of concrete. In conventional method dry mixing of aggregates and cement is carried out first and then the water is added, whereas in triple mixing water is added in two parts allowing less water near Interfacial Transition Zone, making the same more compact contributing to better mechanical and durability properties. The steps involved are as follows: coarse (RCA and NCA) and fine aggregates were initially mixed for 15 sec. A part of water was then added to the aggregate mixture and mixed for 15 sec, and to this wet aggregate the fly ash was added and further mixed for 15 sec to facilitate coating of the surface of aggregate with fly ash. Cement was then added to the surface coated aggregate and the remaining water was added and the mixing was continued for further 1minute. The lubricated moulds were filled with concrete in layers and compacted. The cast specimens were tested after 7days and 28days of normal water curing.

V. RESULTS AND DISCUSSIONS

The average compressive strengths of standard cube specimens are determined using partial replacement of NCA by RCA and a constant replacement of 25% of flyash by cement at the age of 7 and 28days are reported in Table 4&5. It is observed that the compressive strength of RAC is slightly lower than the conventional concrete made from similar mix proportions. The variation in strength of RAC when compared with NAC is in order of 4-12% for M-35 and 3-10% for M-45 concrete respectively. The reduction in strength depends on factors such as grade of source concrete, replacement ratio, water to cementitious material ratio, processing of recycled aggregate etc. It is observed that mix corresponding to 25NCA+75RCA having a close resemblance with the control mix of 100NCA.

The Split tensile strengths of standard cylindrical specimens are determined using partial replacement of NCA by RCA and a constant replacement of 25% of flyash by cement at the age of 7 and 28days are reported in Table 4&5 It is observed that the split tensile strength of RAC is slightly lower than the conventional concrete made from similar mix proportions. The variation in strength of RAC when compared with NAC is in order of 2-19% for M-35 and 3-14% for M-45 concrete respectively. The reduction in strength depends on factors such as grade of source concrete, replacement ratio, water to cementitious material ratio, processing of recycled aggregate etc. It is observed that mix corresponding to 25NCA+75RCA having a close resemblance with the control mix of 100NCA

TABLE:4 VARIATION OF COMPRESSIVE STRENGTH & SPLIT TENSILE STRENGTH WITH % REPLACEMENT OF RCA IN M35 GRADE

Mix Designation	Compressive strength, MPa		Split tensile strength, MPa	
	7 days	28 days	7 days	28 days
100NCA	29.38	45.20	2.91	3.53
75NCA+25RCA	25.87	39.80	2.35	2.84
50NCA+50RCA	27.80	41.64	2.77	3.32
25NCA+75RCA	29.25	43.25	3.05	3.46
100RCA	26.90	40.75	3.01	3.25

TABLE:5 VARIATION OF COMPRESSIVE STRENGTH & SPLIT TENSILE STRENGTH WITH % REPLACEMENT OF RCA IN M45 GRADE

Mix Designation	Compressive strength, MPa		Split tensile strength, MPa	
	7 days	28 days	7 days	28 days
100NCA	35.77	54.2	2.63	3.9
75NCA+25RCA	31.74	48.9	2.22	3.35
50NCA+50RCA	32.76	50.38	2.38	3.56
25NCA+75RCA	35.4	52.6	2.56	3.8
100RCA	33.9	48.8	2.4	3.71

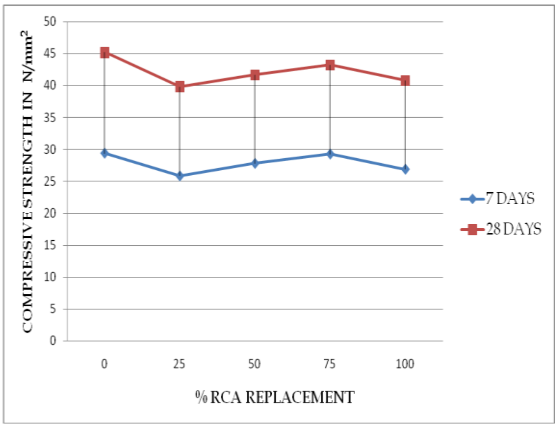

Fig.1. Variation of Compressive strength Vs % RCA replacement in M35 grade

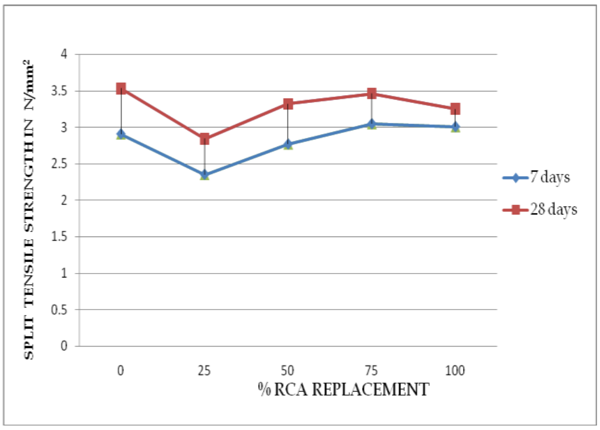

Fig.2. Variation of Split strength Vs % RCA replacement in M35 grade

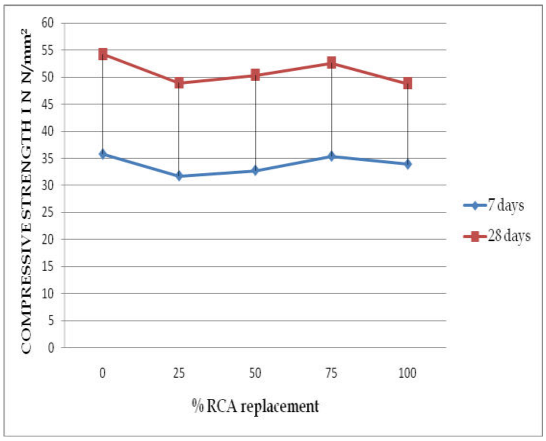

Fig.3. Variation of Compressive strength V % RCA replacement in M45 grade

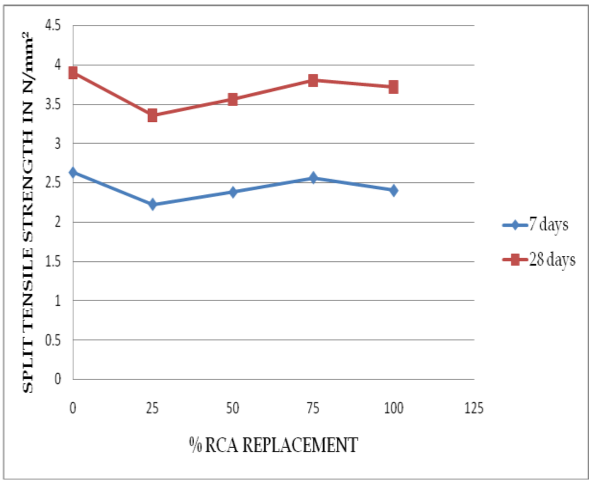

Fig.4. Variation of Split strength Vs % RCA replacement in M45 grade

VI. CONCLUSIONS

1. This present study reveals that mechanical properties of blended concrete appears to be slightly inferior for concrete made with recycled aggregates as compared to conventional concrete.
2. Experimental studies on compressive strength revealed that blended concretes will have a close resemblance with their conventional counterparts when NCA is replaced by 75 percent of RCA.
3. The studies on determination of split tensile strength of blended concretes resulted a close resemblance with conventional concrete when 75 percent of RCA is replacing NCA.
4. Further in order to prevent the excessive mining and to protect the depleting natural aggregate reserves, recycled coarse aggregates can be used as an alternate sustainable concrete making material.

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