STUDY ONTHE PROPERTIES OF HIGH VOLUME FLYASH CONCRETE CONTAINING RECYCLED COARSE AGGREGATE

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***Abstract*—A huge amount of solid concrete waste is generated annually from construction and demolition activities. This has led to the promotion of reusing of recycled concrete aggregate (RCA) or recycled aggregate (RA) as a major measure to reduce waste and to mitigate the harmful effects of construction activities on the environment. In this paper, strength characteristics of high volume fly ash (FA) based concrete with recycled aggregate of 350 kg /m^3 for 0.45 and 0.50 water cement ratios were studied. Natural aggregate (NA) was replaced with recycled aggregate (RA) in different percentages of 30, 40and 50 % (by weight). Similarly, the amount of cement was also replaced with fly ash in different percentages such as 40, 50 and 60 % (by weight). The properties of concrete evaluated are compressive strength and split tensile strength. All properties are measured at 3,7,28 and 56 days. The mix combination with 50% FA and 40% RCA gives higher and 3 % excess compressive strength then conventional concrete for 0.45 water cement ratio at 28 days. The mix combination with 50 % FA and 30 % RCA gives 19 % excess split tensile strength when compared with conventional concrete for 0.50 water cement ratio at 28 days. Hence, these mix combinations can be adopted for an economical concrete containing required characteristic strength.**

***Index Terms*—concrete, fly ash, recycle aggregate, compressive strength, split tensile strength**

I. INTRODUCTION

Globally, the concrete industry consumes large quantities of natural resources, which are becoming insufficient to meet increasing demands. At the same time, many old buildings have reached the end of their service life and are being demolished, resulting in wasted concrete; some concrete waste is used as backfill material, and much being sent to landfills. Recycling concrete by using it as new aggregate in concrete could reduce concrete waste and conserve natural sources of aggregate. Fly ash as some unique properties and is largely useful to a wide range of characteristics. Flay ash is replaced with cement in 40, 50 and 60% for recycle aggregate of 30, 40 and 50%. Fly ash is very fine and it is penetrated in to the microstructure of pours aggregate, which makes it compact and leads to the strength affecting factors. Fly ash increases long-term strength.

II. MATERIALS

Portland cement

OPC of 53 grades was used for making a concrete, used a fresh and free from lumps and it satisfies the requirements of IS: 12269-1987 specifications. The specific gravity of cement is 3.15

Coarse Aggregate

Natural Aggregate

Crushed limestone with a maximum size of 20 mm was used as coarse aggregate and the specific gravity is 2.97. Fineness modulus is 6.15.

Recycled Coarse Aggregate

RA used in this investigation was obtained from concrete test cylinders and not from demolition waste. The concrete cylinders and cubes were made from river sand and crushed limestone which were same types of aggregate used in Natural aggregate, had compressive strengths between 20Mpa to 45Mpa.The specific gravity is 2.30

Fine Aggregate

Local river sand with a fineness modulus of 2.47 and zone II is used. The sand was clean and dry. The specific gravity is of 2.60.

Fly Ash

Fly ash used for the present study is collected from Vijayawada thermal power plant. It satisfies the specifications of Grade 1 of IS 3812(Part 1):2013. The specific gravity is of 2.2.All the properties of materials are listed in Table 1

Water

Fresh portable water that is free from acid and organic substances was used in making and curing of the concretes.

Table 1 Properties of the Materials

Materials	Specific gravity	Fineness modulus	Grade/type	Source
cement	3.15	None	OPC 53 grade	Ambuja
F.A	2.60.	2.47	Zone III	Krishna river
N C.A	2.97	6.15	20 mm	Locally available
R.C.A	2.3	5.15	20 mm	Cylinders
Fly ash	2.2	None	Grade 1 of IS 3812(Part 1):2013	Vijayawada thermal power plant

III.MIX PROPORTIONS

The concrete mix design was performed according to IS10262:2009 method. The mix designed was carried out without considering any replacement of mineral admixture fly ash. After several trials, a cement content of 350kg/m^3 and water/cement ratio of 0.45 and 0.5were used. It was found to give desired workability, strength and durability properties. The final mix proportion arrived at was 1:2.17:3.73 and 1:2.12:3.64 (Cement: Fine aggregate: Coarse aggregate) with 0.45 and 0.50 as its water cement ratio as shown in Table 2.

Table 2 The mix proportions for 0.45 and 0.5 water cement ratio

Quantities	Mix Design 1	Mix Design 2
Cement	350 kg/m^3	350 kg/m^3
Water	157.5 kg/m^3	175 kg/m^3
Fine Aggregate	762.32 kg/m^3	743.6kg/m^3
Coarse Aggregate	1306.206 kg/m^3	1274.13kg/m^3
Water Cement Ratio	0.45	0.5
Mix Proportions	1:2.17:3.73	1:2.12:3.64

IV.SPECIMEN DETAILS

The size of specimens is 100*100mm in cubical shape for testing compressive strength and 150*300 mm round cylindrical shape cylinders for split tensile strength. All the specimens cast for compressive strength was subjected to different periods of curing such as 3, 7, 28, and 56 days. After the desired period of curing, specimens were tested in an automatic compression testing machine with a capacity of 3,000KN.To determine the tensile strength of concrete, they were subjected to an indirect tension test.

V.RESULTS AND DISCUSSION

The results of compressive strength and tensile strength tested in this paper are discussed in the following sections. The combinations chosen are as follows: control concrete (concrete with natural aggregate or with neither recycled aggregate or fly ash); concrete with 0, 30, 40, and 50 % recycled aggregate; and concrete with 40, 50, and 60% fly ash and different combinations of RA and FA. The previous parameters were considered to understand the effect of recycled aggregate and fly ash on strength characteristics. The results are listed in Table 3 and 4.

Effect of RA on Compressive Strength of HVFA Concrete

The results on the variation of compressive strength of concrete with respect to age of concrete for different percentages of RA and a constant percentage of FA as admixture.NA was replaced with 30,40, and 50 % recycled aggregates. From the results, it is understood that control concrete gives a compressive strength of 42.75 and 45.16 N/mm^2 respectively at the ages of 28 and 56 days for 0.45 w/c ratio. Similarly 37.83, 39.67 N/mm^2 respectively at the ages of 28 and 56 days for 0.50 water cement ratio. Results indicate that an increase in the percentage of recycled aggregate reduces compressive strength irrespective of the age of concrete. A similar trend was observed in fly ash concrete also.

At the age of 28 days, percentage reduction in compressive strength was observed to be 4.56, 9.78 and 12 % for 30, 40 and 50 % replacement of NA with RA without any FA addition for 0.45 water cement ratio. Similarly, for 0.50 water cement ratio 13.71, 18.45 and 24.34 %. For 30 % RA, the reduction percentage is 37.64 % for 40 % FA with 0.45 w/c ratios. Hence, it is understood that replacement of cement and NA with FA and RA, respectively will show reduction in strength. For 40 % RA, with 50 % FA gives 3 % excess compressive strength. Further addition of FA results in further reduction in compressive strength. Replacing 50 %, recycled aggregate with 60 % FA gives poorer results compared with the control concrete. Similarly, the compressive strength for 56 days' age is increased slightly.

Effect of FA Content on Compressive Strength of RAC

Due partial replacement of cement with fly ash, the behavior of RA changes rapidly. It is due to the filling of the microstructure of the porous recycled coarse aggregate. Without any RA addition the compressive strength values for 40 % FA, 50 % FA, 60 % FA gives 38,39 and 37.3 N/mm^2 for 0.45 w/c ratio respectively. Similarly, for 0.50 w/c ratio 37.5, 32.3 and 37 N/mm^2.with 40 % FA, the reduction is 37% for 30 % RA; 14 % for 40 % RA; 31 % for 50 % RA for 0.45 w/c ratio at the age of 28 days. With 50 % FA, for 30 % RA gives 2 % excess compressive strength than the conventional concrete for 0.50 w/c ratio. With 60 % FA gives up to 40 %reduction in strength for 0.45 and 0.50 w/c ratio.

Effect of RA on Tensile Strength of HVFA Concrete

The analysis of results shows different variations at the replacement of RA. Without any addition of FA, 30 % RA gives a higher reduction of 20 % at the age of 28 days for 0.45 w/c ratio. Without any addition of FA, 50 % RA gives higher reduction of 11 % tensile strength and 40 % RA gives moderate reduction at the age of 28 days for 0.50 w/c ratio. For 30% RA with the addition of FA, the tensile strength reduction is 33 % for 40 % FA at the age of 28 days for 0.45 w/c ratio. For 40 % RA, the tensile strength is 10.5% excess for 50 % FA for 0.45 w/c ratio at the age of 28 days. For 50 % RA, the tensile strength reduction is about 34.5 % for 60 % FA for 0.45 w/c ratio. For 30% RA, with 50 % FA gives 19 % excess tensile strength than the conventional concrete at the age of 28 days for 0.50 w/c ratio. For 40 % RA, the tensile strength is increased to 3.7 and 7.8 % for 40 % and 50 % FA respectively.

Effect of FA Content on Tensile Strength of RAC

From the analysis of results, percentage of reduction is less for fly ash addition when compared with replacement of aggregate. With 50 % FA, 30 and 40 % RA gives 19 and 7.1 % excess tensile strength when compared with conventional concrete at the age of 28 days for 0.50 w/c ratio. With 50 % Fly ash and 40 %, RA gives 10 % excess tensile strength when compared with conventional concrete at the age of 28 days for 0.45 w/c ratio.In addition, 60 % FA with all percentages of RA have an impact on the tensile strength of concrete; the reduction is up to 34 %.With 40 % FA and 40 % RA gives 3.7 % excess tensile strength when compared with conventional concrete at the age of 28 days for 0.50 w/c ratio.

VI.COMPRESSIVE STRENGTH RESULTS AND GRAPHS

From Figure 1 to 9 shows the compressive strength values for 350 kg/m^3 cement content and 0.45 and 0.5 water cement ratios for different percentages of RA and FA. The cube compressive strength is measured at 3, 7, 28 and 56 days. The compressive strength is greater for 0.45 water cement ratio at 28 days is 42.75 N/mm^2 and 56 days is 45.16 N/mm^2.The mix is a conventional mix concrete.

VII.SPLIT TENSILE STRENGTH RESULTS AND GRAPHS

From Figure 10 to 18 showsthe Split Tensilestrength values for 350 kg/m^3 cement content and 0.45 and 0.5 water cement ratios for different percentages of RA and FA. The Split Tensilestrength is measured at 3, 7, 28 and 56 days. The Split tensile strength is greater for 0.45 water cement ratio at 28 days is 4 N/mm^{2}and 56 days is 4.5 N/mm^2.The mix is a conventional mix concrete.

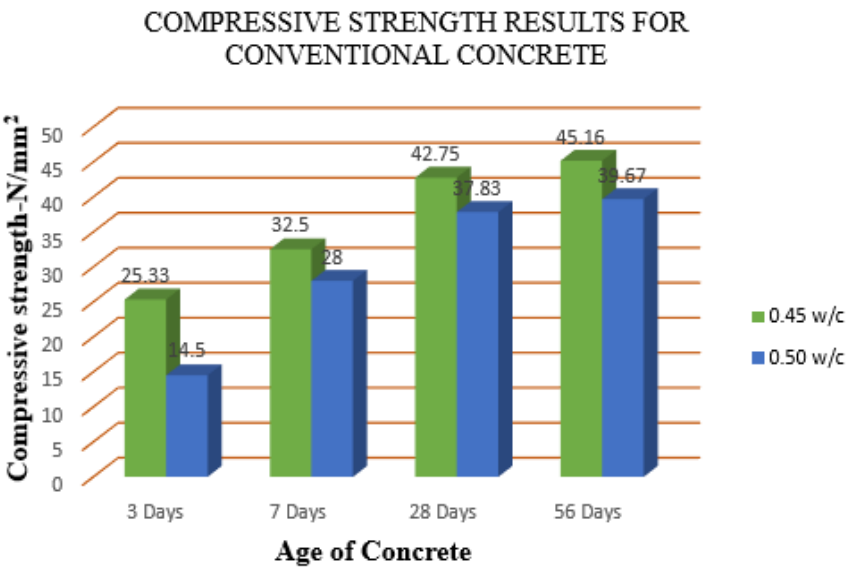

Fig.1 Compressive strength results for conventional concrete

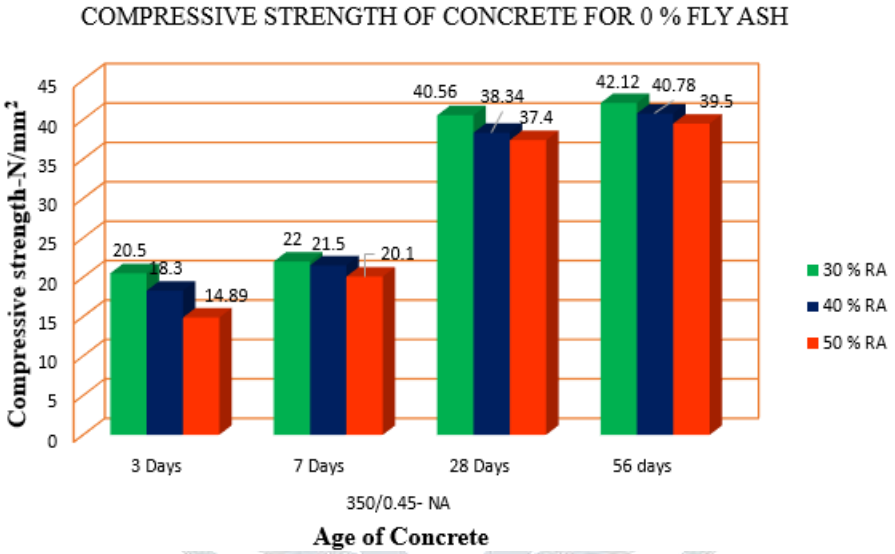

Fig.2 Compressive strength of concrete for 0 %Fly ash different percentages of RA

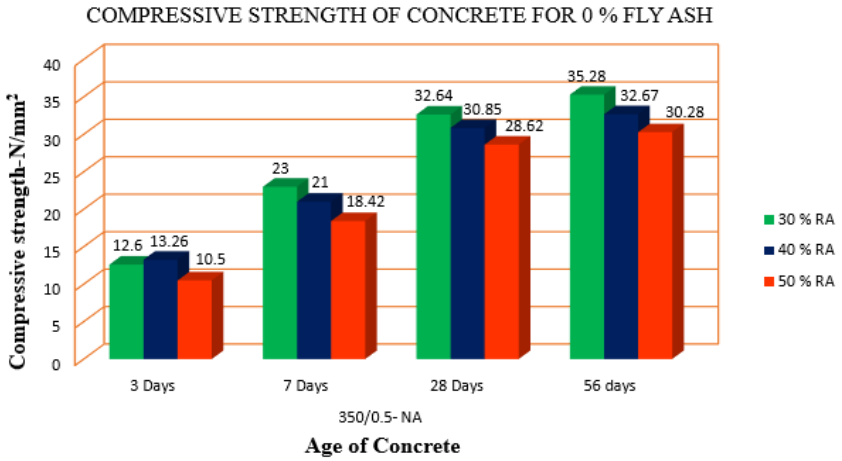

Fig.3 Compressive strength of concrete for 0 % Fly ash for different percentages of RA

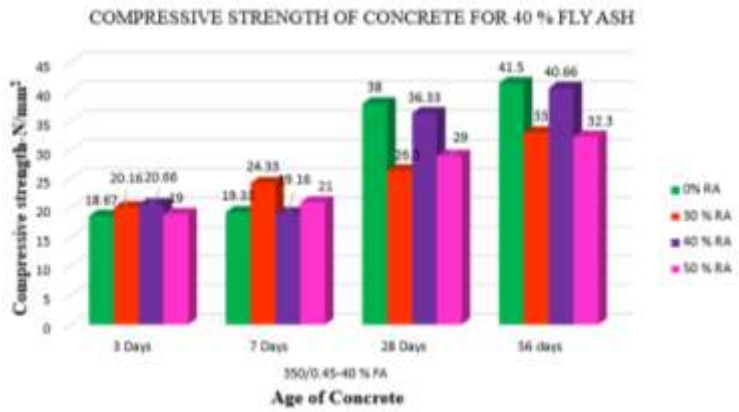

Fig.4 Compressive strength of concrete for 40 % Fly ash for different percentages of RA

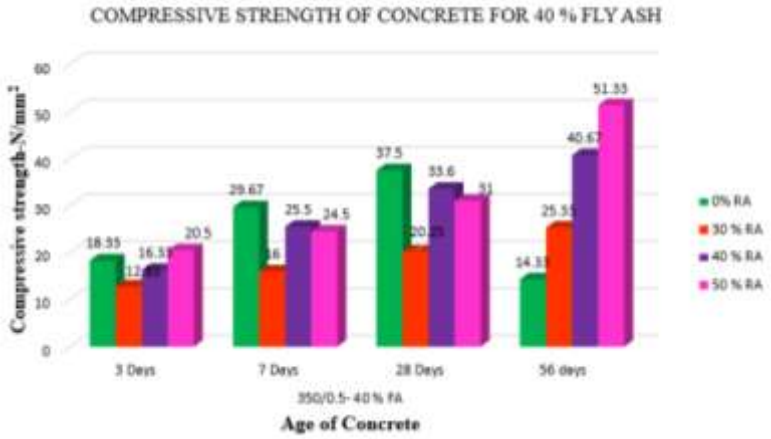

Fig.5 Compressive strength of concrete for 40 % Fly ash for different percentages of RA

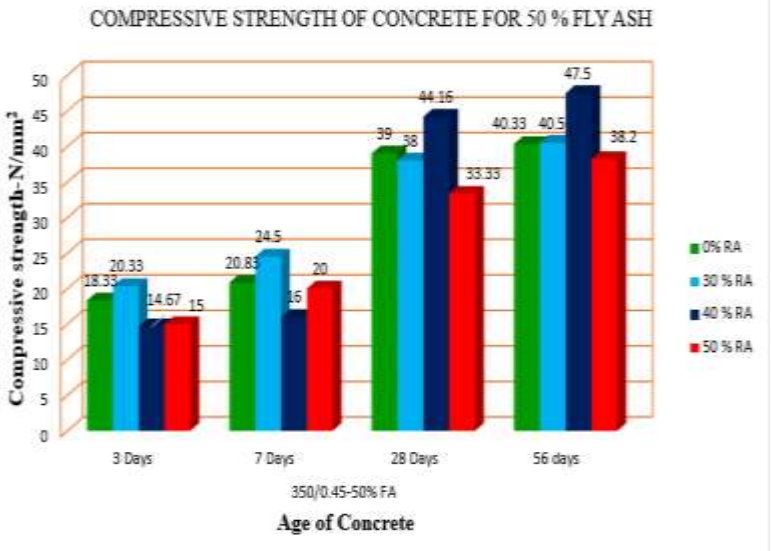

Fig. 6 Compressive strengths of concrete for 50 % Fly ash for different percentages of RA

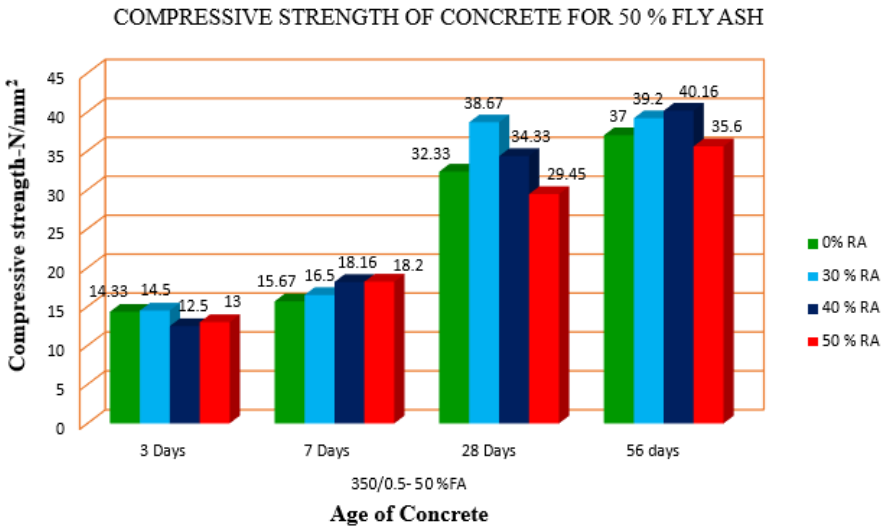

Fig.7 the compressive strength of concrete for 50 % Fly ash for different percentages of RA

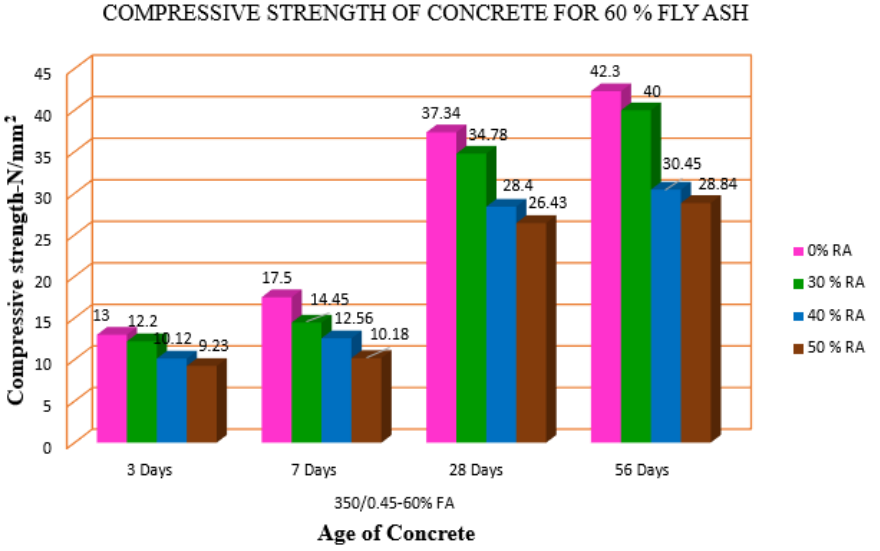

Fig. 8 The compressive strength of concrete for 60 % Fly ash for different percentages of RA

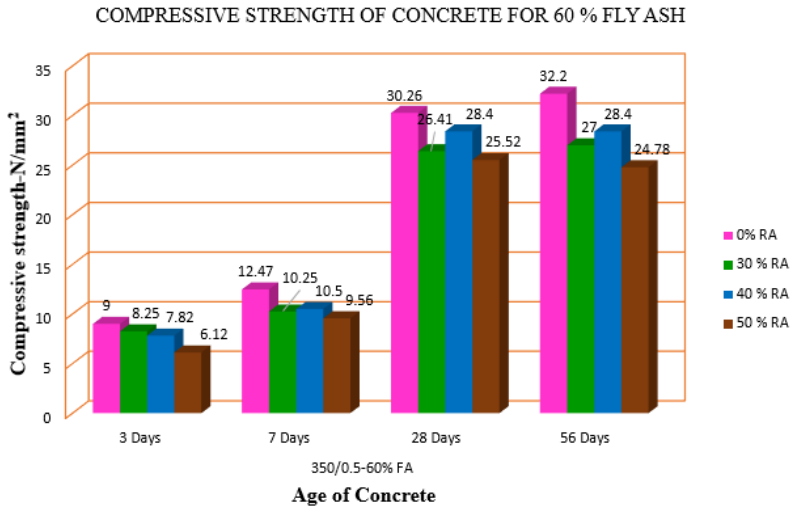

Fig.9 The compressive strength of concrete for 60 % Fly ash for different percentages of RA

Table 3. The compressive and split tensile strength of concrete for different mixes for 350 Kg/m^3 cement content and 0.45 water cement ratio

W/c ratio -0.45	Compressive Strength N/mm^2				Tensile Strength N/mm^2			
Mix combination	*3 Days*	*7 Days*	*28 Days*	*56 Days*	*3 Days*	*7 Days*	*28 Days*	*56 Days*
NA	25.33	32.5	42.75	45.16	2.5	2.9	4	4.5
NA+30%RA	20.5	22	40.56	42.12	1.5	2	3.2	4
NA+40%RA	18.3	21.5	38.34	40.78	1.82	2.12	3.82	4.12
NA+50%RA	14.89	20.1	37.4	39.5	1.4	2.2	3.56	3.78
40%FA+0%RA	18.67	19.33	38	41.5	1.2	1.5	3.5	4.12
40%FA+30%RA	20.16	24.33	26.5	33	2.12	2.42	2.65	2.9
40%FA+40%RA	20.66	19.16	36.33	40.66	2.14	1.82	3.15	4.16
40%FA+50%RA	19.2	21.5	29.26	32.3	1.2	2.2	2.8	3.1
50%FA+0%RA	18.33	20.83	39	40.33	1.82	2	3.56	4.24
50%FA+30%RA	20.33	24.5	38	40.5	2.02	2.12	3.56	3.94
50%FA+40%RA	14.67	16	44.16	47.5	1.54	1.52	4.42	4.24
50%FA+50%RA	15	20	33.33	38.2	1.4	2.34	3.32	3.83
60%FA+0%RA	13	17.5	37.34	42.3	1.2	1.73	3.43	4.2
60%FA+30%RA	12.2	14.45	34.78	40	1.12	1.34	3.423	4
60%FA+40%RA	10.12	12.56	28.4	30.45	1.12	1.24	2.65	3.45
60%FA+50%RA	9.23	10.18	26.43	28.84	2.2	1.2	2.62	2.82

Table4 The compressive and split tensile strength of concrete for different mixes for 350 Kg/m^3 cement content and 0.50 water cement ratio

W/c- 0.50	Compressive strength N/mm^2				Tensile strength N/mm^2			
Mix combination	*3 Days*	*7 Days*	*28 Days*	*56 Days*	*3 Days*	*7 Days*	*28 Days*	*56 Days*
NA	14.5	28	37.83	39.67	1.5	2	3.2	4
NA+30%RA	12.6	23	32.64	35.28	1.2	2.1	2.87	3.24
NA+40%RA	13.26	21	30.85	32.67	1.32	2.1	3.17	3.2
NA+50%RA	10.5	18.42	28.62	30.28	1.02	1.85	2.82	2.91
40%FA+0%RA	18.33	29.67	37.5	41.33	1.5	2.5	3.62	4.15
40%FA+30%RA	12.83	16	20.25	25.33	1.5	1.21	2.56	2.82
40%FA+40%RA	16.33	25.5	33.6	40.67	1.2	2.56	3.32	4.13
40%FA+50%RA	20.5	24.5	31	51.33	1.8	2.2	3	5.12
50%FA+0%RA	14.33	15.67	32.33	37	1.2	1.5	3.1	3.5
50%FA+30%RA	14.5	16.5	38.67	39.2	1.5	1.6	3.82	3.9
50%FA+40%RA	12.5	18.167	34.33	40.16	1.26	1.62	3.43	3.96
50%FA+50%RA	13	18.2	29.45	35.6	1.3	1.85	2.2	3.5
60%FA+0%RA	6.83	10.16	37	42.5	1.2	1.8	2.56	3.56
60%FA+30%RA	8.25	10.25	26.41	27	0.825	1.02	2.5	2.4
60%FA+40%RA	7.82	10.5	28.4	28.4	0.72	1.25	2.5	2.83
60%FA+50%RA	6.12	9.56	25.52	24.78	0.62	0.94	2.1	2.5

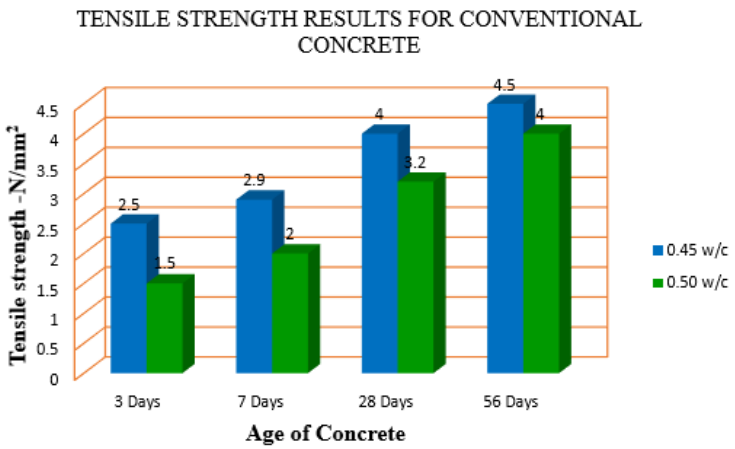

Fig.10 Split Tensile strength results for conventional concrete

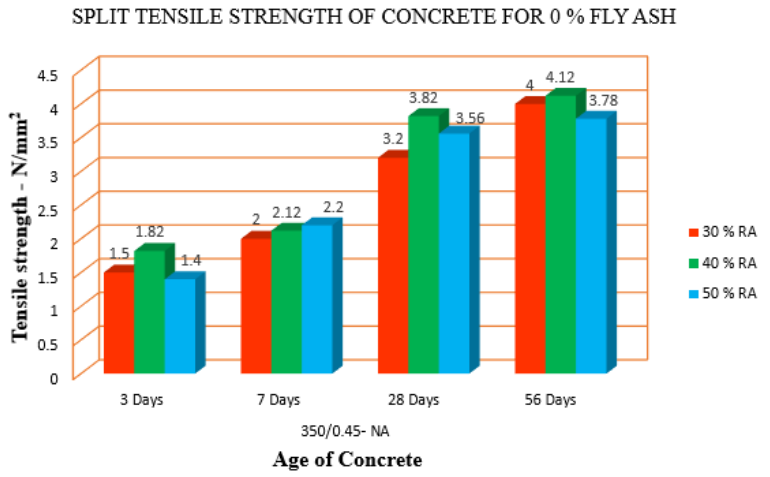

Fig.11 Split Tensile strength of concrete for 0 % Fly ash for different percentages of RA

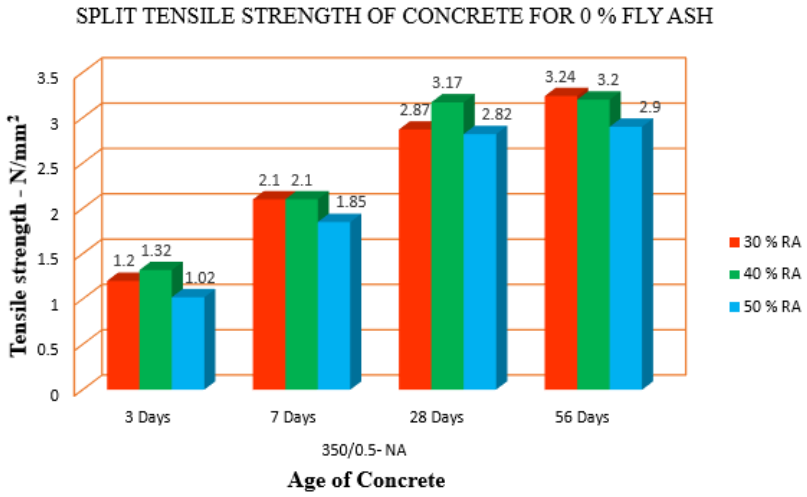

Fig.12 Split Tensile strength of concrete for 0 % Fly ash for different percentages of RA

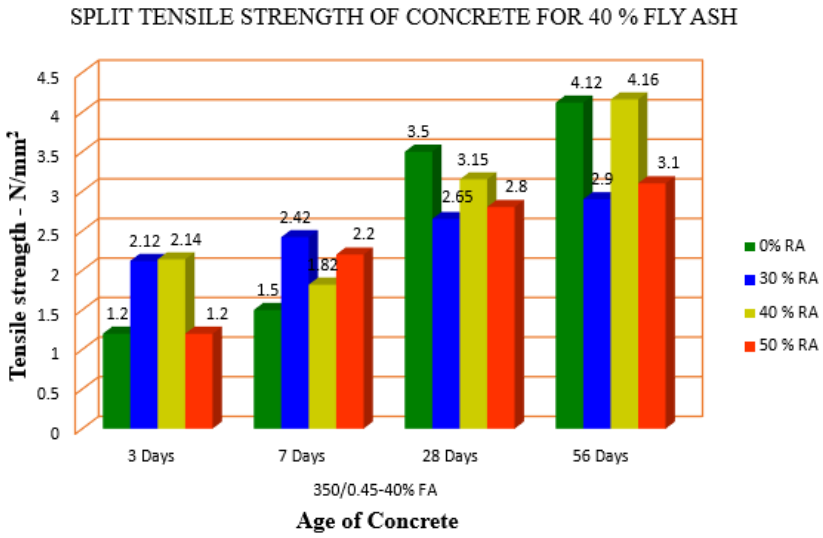

Fig.13 Split Tensile strength of concrete for 40 % Fly ash for different percentages of RA

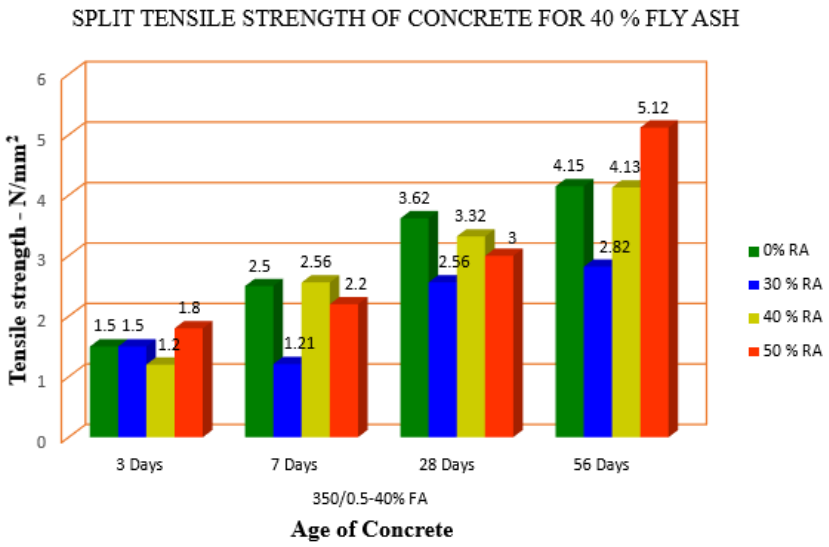

Fig .14 Split Tensile strength of concrete for 40 % Fly ash for different percentages of RA

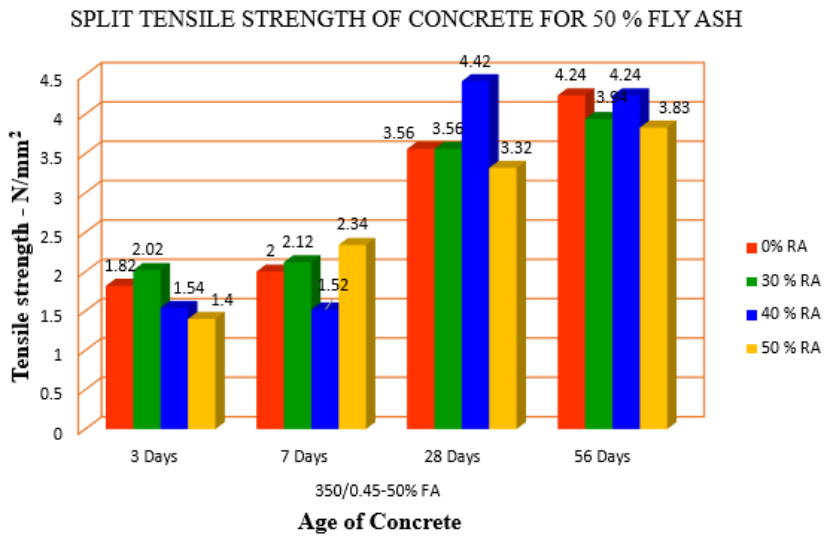

Fig.15 Split Tensile strength of concrete for 50 % Fly ash for different percentages of RA

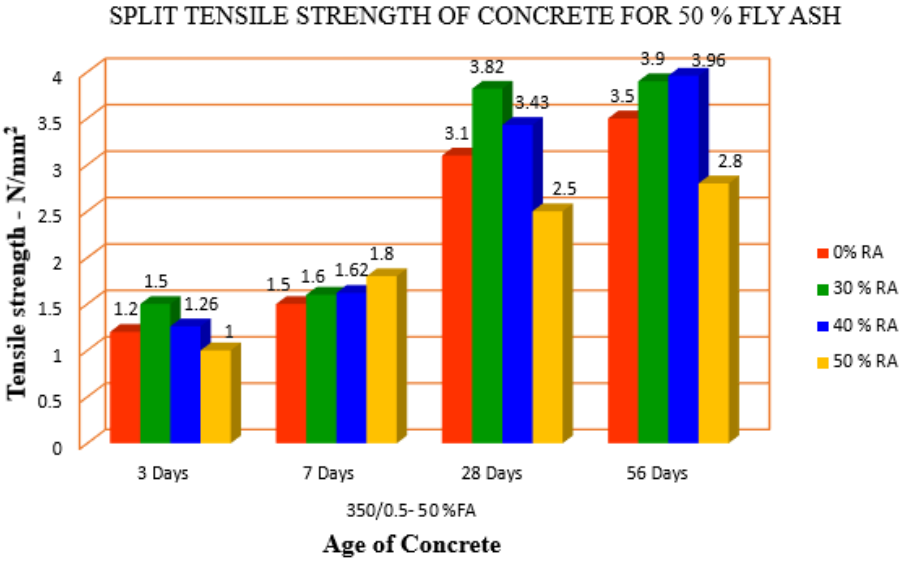

Fig.16 Split Tensile strength of concrete for 50 % Fly ash for different percentages of RA

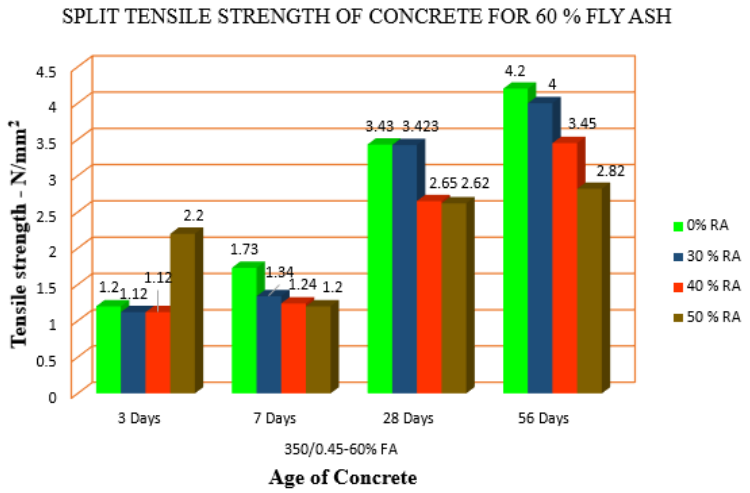

Fig.17 Split Tensile strength of concrete for 60 % Fly ash for different percentages of RA

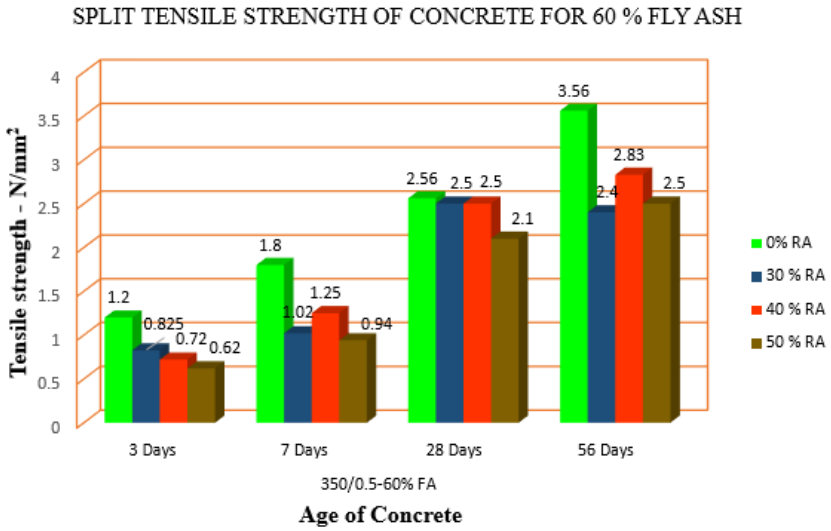

Fig.18 Split Tensile strength of concrete for 60 % Fly ash for different percentages of RA

VIII.CONCLUSIONS

1.The mix combination with 50% FA and 40% RCA gives higher and 3% excess compressive strength then conventional concrete for 0.45 water cement ratio at 28 days. The mix combination with 50% FA and 30% RCA gives higher compressive strength than conventional concrete for 0.50 water cement ratio at 28 days.

2. The mix combination with 60% FA and 0% RCA gives nearly equal strength of conventional concrete for 0.50 water cement ratio.40 percentage reduction is the highest reduction in compressive strength for 60% FA with 50 % RA for 0.50 water cement ratio.

3. So we can partially replace cement by 50% Fly Ash and natural aggregate up to 30% of Recycled Coarse Aggregate replacement. In addition, 60% of cement replacement by fly ash can be adopted without any replacement of aggregates.

4. The mix combination with 50% FA and 30% RCA gives 19% excess split tensile strength when compared with conventional concrete for 0.50 water cement ratio at 28 days. The mix combination with 40%FA and 0% RCA gives 13.12% higher tensile strength than conventional concrete for 0.50 water cement ratio. The mix combination with 50% FA and 40% RCA gives 10% excess strength when compared with conventional concrete for 0.50 water cement ratio at 28 days.

5. The higher percentage of reduction is for 60% FA and 50% RCA for both 0.45 and 0.50 water cement ratios at 28 days. Like in case of compressive strength, we can partially replace cement by 50% Fly Ash and natural aggregate up to 30% of recycled coarse aggregate replacement.

6. Hence, 60% of cement replacement by fly ash can be adopted without any replacement of aggregates.

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