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Effect of the Recycled Coarse Aggregate on the Properties of Fly – Ash Base Concrete

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ABSTRACT
The usage of recycled aggregate has been encouraged by the exhaustion of landfill area redevelopment programmes in several parts of the country. However, owing of the lower compressive strength and greater unpredictability in mechanical performance of recycled aggregates, their use has been limited to low-grade applications such as roadwork sub-base and pavements, whereas adoption for higher-grade concrete is uncommon.By separating the mixing process into two, a novel concrete mixing method was promoted to improve the quality of recycled aggregate concrete (RAC) by replacing coarse aggregate with recycled coarse aggregate on a fly ash base concrete. The current paper describes the variation of compressive strength, flexural strength, and split tensile strength using experimental analysis with a modified mixing method and some changes to the fly-ash base concrete by proportioning ingredients with the percentage of recycle coarse aggregates (RCA) and fly-ash. Improvements in strength to recycled aggregate concrete (RAC) were accomplished with fly – ash base concrete, based on experimental work and results.This is due to the porous nature of recycled aggregate (RA) and the premixing process, which plugs some of the gaps and cracks in the aggregate, resulting in a denser aggregate and concrete. The strengthofthe Recycled Aggregate (RA) concrete is higher than the nominal concrete due to an improved interfacial zone.

Keywords: Nominal Concrete, Fly-ash, Recycled aggregate (RA) , Fly – Ash base concrete , Mix design M – 30 .

I. INTRODUCTION

Infrastructural development is based on construction. Concrete is the primary building material, and it is the second most extensively used object in the world after water. The fundamental components of concrete are natural resources such as stone, aggregate, sand, and water, implying that this industry degrades these environmental aspects. Aggregate quarrying and transportation also contribute to environmental imbalances and emissions. Not only has this been a huge problem in several places due to a lack of landfill sites, but the disposal of the rubble of demolished concrete buildings has also become a serious issue.

These environmental issues are driving the development of an urgent and deliberate approach to our natural resources, for which aggregate recycling appears to be a viable option. The paper presents a 'Effect of the Recycled Coarse Aggregate on the Properties of Fly – Ash Base Concrete. The concept of using recycled aggregate in concrete stems from the fact that no fresh research on recycled aggregate has been conducted anywhere in the globe. However, in India, it was not practical to employ recycled aggregates in high-strength concrete production.

II. LITERATURE REVIEW

Tam V.W.Y et al. (2005)[6] introduced the approach of modified concrete mixing. Increased water absorption, higher porosity, and a weaker interfacial transition zone were found by the researchers (ITZ). Due to the poor quality of RAC, the application of RAC for higher grade applications was hampered by the mixture of recycled aggregates (RA) and fresh cement mortar. The two-stage mixing strategy is proposed in this study to strengthen the weak connection of RAC, which is positioned at the ITZ of the RA. The two-stage mixing procedure allows the RA in the cement slurry to gel together, resulting in a superior ITZ by closing in the RA fractures and pores. Laboratory investigations have bolstered the compressive strength. This is the second of two – stage mixing approaches.

According to The C and Teo D.C.C., Yong P. Recycled aggregate concrete (RAC) can attain high compressive strength, split tensile strength, and flexural strength[9]. RAC has a higher compressive strength of 28 days and a stronger split tensile strength of 28 days than natural concrete, but a lower flexural strength of 28 days than natural concrete.

Patil S.P et al (2013)[4] determined in their recycled coarse aggregates study that the compressive strength of concrete containing 50 percent RCA is comparable to that of ordinary concrete. This tensile splitting test demonstrates that when concrete is replaced by 25–50%, it retains its tensile strength. Concrete has a great initial strength, but it gradually lowers as it progresses through the phases. The water absorption of RCA is more than that of regular aggregates. As a result, the usage of RCA in concrete mixtures has been discovered to have strength similar to that of natural aggregate, and it may be employed efficiently as a component of new concrete with maximum value.

The normal consistency improves with the grade of cement and fly ash concentration, according to Marthong C and Agrawal T.P (2012)[3]. Setting time and soundness decrease as cement grade increases. The use of fly ash improves concrete workability, and workability improves when the cement grade is reduced. In fly ash concrete, bleeding is considerably reduced. The compressive strength of concrete increases as the amount of cement increases. As the amount of fly ash in conventional Portland cement increases, the strength of the concrete decreases (OPC). The rate of concrete strength development with ageing is roughly comparable in all three OPC classes.Concrete that has been aged for 90 days and contains 20% fly ash is similar to conventional concrete. Fly ash concrete is more durable than OPC concrete in all OPC grades, and fly ash increases by up to 40% with cement grade substitution. Fly ash concrete shrinks similarly to pure cement concrete in all grades of OPC.

Vyas C.M. and Pitroda J.K. (2013)[3] studied the combination of RCA and fly ash and concluded that recycled coarse aggregate has a wide range of applications in the construction area. The major goal of using recycled coarse aggregate is to reduce the usage of natural resources. Another procedure that can be improved is the use of fly ash in the recycled coarse aggregate mixing. The addition of fly ash to recycled coarse aggregate concrete improves the toughness of the material. The addition of fly ash to recycled coarse aggregate concrete could improve its strength.

According to Bendapudi S.C.K and Saha P (2011)[1], a key goal is to reduce the consumption of Portland cement, which can be easily accomplished by partially substituting it with other cement ingredients. The best known of these products is fly ash, a coal combustion waste that is an excellent cement material. As a result, the efficient use of fly ash in concrete production attracts the attention of relevant technologists and government organizations. Fly ash is already included as a supplementary ingredient for cement in the newest Indian standard on concrete mix proportion (IS: 10262 – 2009). The use of fly ash instead of cement improves the resistance of concrete against sulphate attack expansion. The smaller the fracture tensile strength to compressive strength ratio, the higher the concrete compressive strength.Finally, this literature review revealed that the characteristics of concrete are improved when Portland cement and aggregate are replaced with fly ash.

III. MATERIALS USED

Cement:-Ordinary Portland Cement of Grade 53, meeting IS: 8112 – 1989 standards. Cement was discovered to have a specific gravity of 2.84. The cement density is computed in accordance with IS: 3535 – 1986 requirements. The standard consistency of cement is calculated using the IS: 4031(Part–4)1996 standards. The fineness of the cement is calculated in accordance with IS:4031(Part–1)1996 standards. Le – Chatelier procedures are used to test the soundness of cement according to IS: 4031(Part – 3)1996.These are physical properties of cement.

Characteristics	**Results**
Specific gravity of cement	2.84

Density of cement	3.16 gm/ml
Soundness of cement (Expansion of cement)	1.93 mm
Fineness of cement	4.33%
Standard consistency of cement	40%
Initial setting time of cement	40 min
Final setting time of cement	365 min
Compressive strength of 53 grade cement cube (28day)	56.9 N/mm2
Compressive test of a cube using 15% fly – ash instead of cement	49.9 N/mm2

Fine aggregate:-Gujarat is where most of the sand is obtained. Sand, grading zone III of IS:383 – 1970, was utilised as the principal component, with a specific gravity of 2.55 and a water absorption ratio of 1.01 percent. The bulk density of fine aggregate is computed in line with IS: 2386–1963(Part–4) requirements. The fine aggregate grading is calculated in compliance with IS: 2386–1963(Part–1) requirements.These are the physical properties of fine aggregate. Shows below table .

Characteristics	**Results**
Specific gravity of fine aggregate	2.55
Apparent specific gravity of fine aggregate	2.61
Water absorption ratio of fine aggregate	1.01%
Bulk density of loose fine aggregate	1.66 kg/lt
Bulk density of compacted fine aggregate	1.76 kg/lit
% of voids in fine aggregate	0.0035%

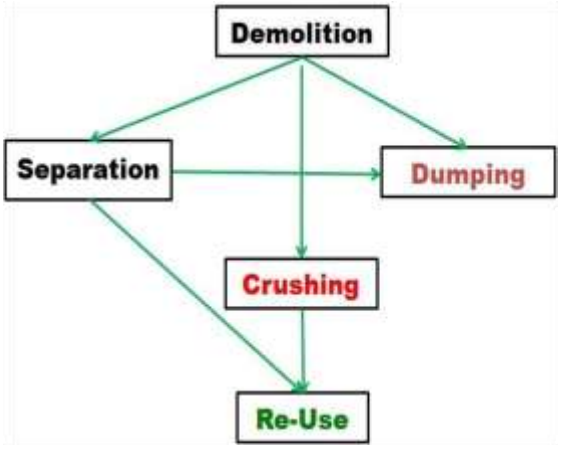
Fineness modulus of fine aggregate	3.77
Zone of fine aggregate	Zone – III
Silt content in fine aggregate	5.49%

Coarse aggregate:-Mechanically crushed stone from a Gujarat quarry with a maximum size of 20mm and conforming to IS: 383–1970 was utilised. The specific gravity was discovered to be 2.82, and the water absorption ratio was found to be 0.56 percent. The bulk density of coarse aggregate is computed in accordance with IS: 2386–1963(Part–4) requirements. The coarse aggregate grading is calculated in compliance with IS: 2386–1963(Part–1) requirements. As per IS: 2386 (Part – 4) 1963, estimate the aggregate crushing value of coarse aggregate. To calculate the aggregate impact value of coarse aggregate in accordance with IS: 2386 (Part – 4) 1963 and IS:383–1970.These are the physical properties of coarse aggregate.

Characteristics	**Results**
Specific gravity of coarse aggregate	2.82
Apparent specific gravity of coarse aggregate	2.86
Water absorption ratio of coarse aggregate	0.56%
Bulk density of loose coarse aggregate	1.51 kg/lit
Bulk density of compacted coarse aggregate	1.64 kg/lit
% of voids in coarse aggregate	0.0046%
Crushing value of coarse aggregate	14%
Impact value of coarse aggregate	13%

Flakiness index of coarse aggregate	5.97%
Elongation index of coarse aggregate	20.93%

Recycled coarse aggregate:-Recycled aggregate is aggregate that has been obtained from the processing of construction and demolition waste. The recycling procedure is depicted in the diagram below.



Characteristics	**Results**
Specific gravity of recycled coarse aggregate	2.60
Apparent specific gravity of recycled coarse aggregate	2.69
Water absorption ratio of recycled coarse aggregate	1.3%
Bulk density of loose recycled coarse aggregate	1.47 kg/lit
Bulk density of compacted recycled coarse aggregate	1.63 kg/lit

These are the physical properties ofRecycled coarse aggregate.

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1. Fly ash:-Fly ash is employed as a partial replacement for cement in all of the trials, accounting for 15% of the total cement content. According to IS:3812 – 1999, Class – F fly ash from Gujarat with a specific gravity of 2.31 is used.

The density of the fly ash is estimated in accordance with IS: 3535 – 1986 requirements. The fineness of the fly ash is determined using the IS: 4031(Part–1)1996 criteria.This are the physical properties of fly ash . shows below the table .

Characteristics	**Results**
Specific gravity of fly ash	2.31
Density of fly ash	2.77 gm/ml
Fineness of fly ash	3%
Standard consistency of fly ash	45%
Initial setting time of fly ash	44 min
Final setting time of fly ash	391 min
Soundness of fly – ash	1.75 mm

IV. METHODOLOGY

4.1 Concrete mix design

The mixing ratio of ordinary grade M–30 concrete is calculated according to IS: 10262 – 2009. In addition, for every 100 percent cement, 15% fly ash is added.

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% of voids in recycled coarse aggregate	0.0043%
Crushing value of recycled coarse aggregate	15.3%
Impact value of recycled coarse aggregate	16%
Flakiness index of recycled coarse aggregate	7.059%
Elongation index of recycled coarse aggregate	22.14%

❖ Mathematically calculation of mix design M30

i. Mix design (M30):- the conclusion follows the result of the calculation of the mixed design M30 for nominal concrete (proportion of mix design is 1:1.52:3.13 after calculation). The properties of material are shown in the table below:

Name of materials	**Properties of materials**
Cement	383.2 kg/m3
Water	191.6 kg/m3
Fine aggregate	583.16 kg/m3
Coarse aggregate	1197.6 kg/m3

ii. Mix design M30:To use 15% fly – ash in cement:

Name of materials	**Properties of materials**
Cement	325.72 kg/m3

Fly ash	57.48 kg/m3
Water	191.6 kg/m3
Fine aggregate	583.16 kg/m3
Coarse aggregate	1197.6 kg/m3

iii. Mix design M30: Coarse aggregates are to be replaced by 25% recycled coarse aggregates:

Name of materials	**Properties of materials**
Cement	325.72 kg/m3
Fly ash	57.48 kg/m3
Water	191.6 kg/m3
Fine aggregate	583.16 kg/m3
Coarse aggregate	898.2 kg/m3
Recycled Coarse aggregate (RCA)	299.4 kg/m3

iv. Mix design M30: Coarse aggregates are to bereplaced by 50% recycled coarse aggregates :

Name of materials	Properties of materials
Cement	325.72 kg/m3
Fly ash	57.48 kg/m3
Water	191.6 kg/m3
Fine aggregate	583.16 kg/m3
Coarse aggregate	598.8 kg/m3
Recycled Coarse aggregate (RCA)	598.8 kg/m3

Mix design M30: Coarse aggregates are to be replaced by 75% recycled coarse aggregates:

Name of materials	Properties of materials
Cement	325.72 kg/m3
Fly ash	57.48 kg/m3
Water	191.6 kg/m3
Fine aggregate	583.16 kg/m3
Coarse aggregate	299.4 kg/m3
Recycled Coarse aggregate (RCA)	898.2 kg/m3

v. Mix design M30: Coarse aggregates are to be replaced by 100% recycled coarse aggregate :

Name of materials	Properties of materials
Cement	325.72 kg/m3
Fly ash	57.48 kg/m3
Water	191.6 kg/m3
Fine aggregate	583.16 kg/m3
Recycled Coarse aggregate (RCA)	1197.6kg/m3

V. RESULTS

1. Results of the compressive strength test of the concrete cubes :-

Type of specimen Mix design M30	7day results In N/mm2	14day results In N/mm2	28day results In N/mm2
Nominal concrete	27.96	36.35	40.13
RCA (25%)	28.53	38.71	42.22
RCA (50%)	29.16	36.97	41
RCA (75%)	29.51	36.75	40.4
RCA (100%)	26.71	35.37	37.73

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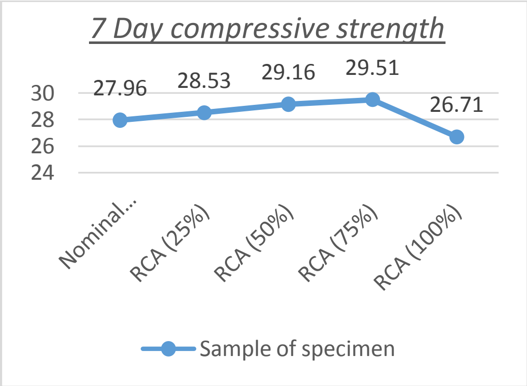

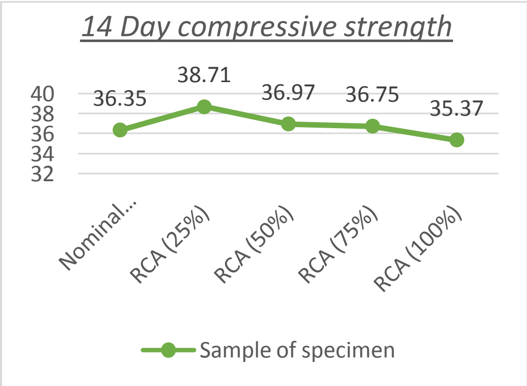

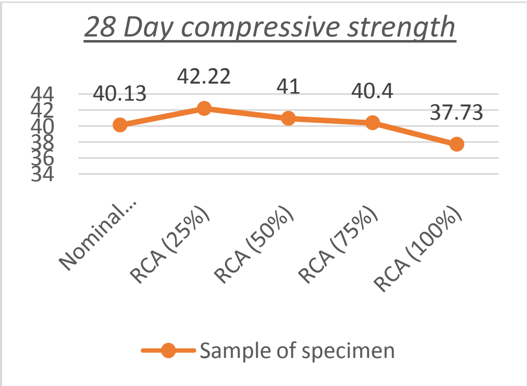

2. Results of the flexural strength test of the concrete beams:-

Type of specimen Mix design M30	**7day results In N/mm2**	**14day results In N/mm2**	**28day results In N/mm2**

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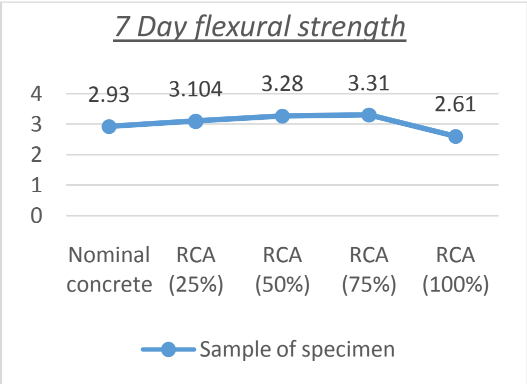
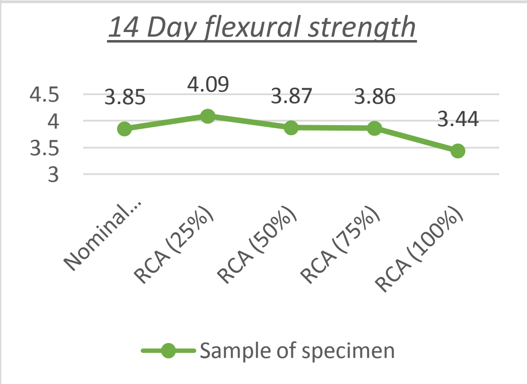
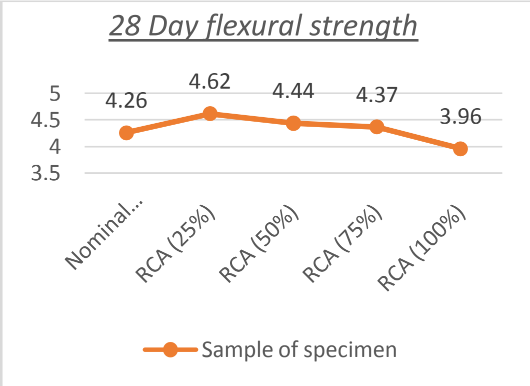
Nominal concrete	2.93	3.85	4.26
RCA (25%)	3.104	4.09	4.62
RCA (50%)	3.28	3.87	4.44
RCA (75%)	3.31	3.86	4.37
RCA (100%)	2.61	3.44	3.96

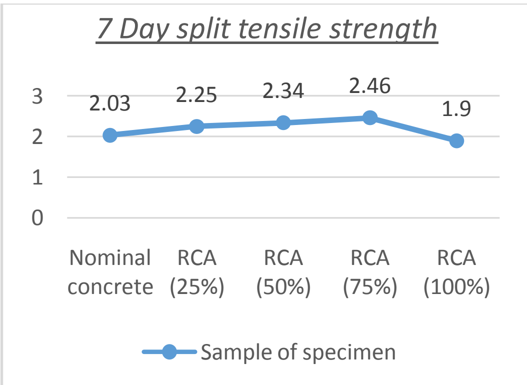


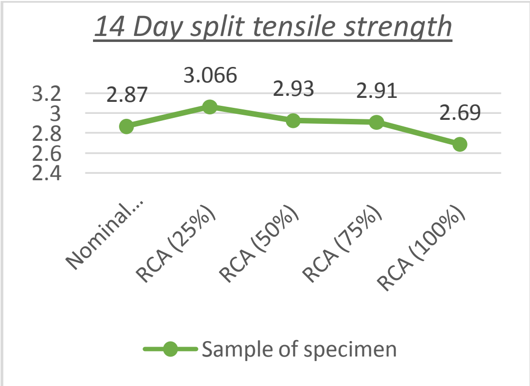


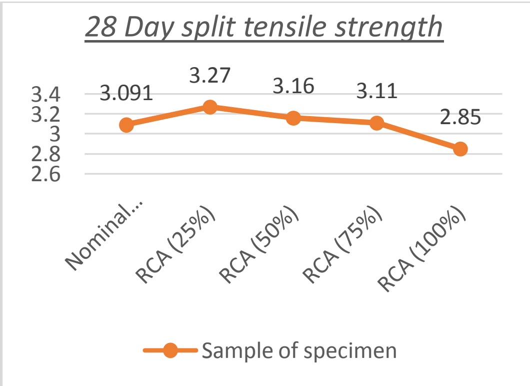


3. Results of the split tensile strength test of the concrete cylindrical specimen :-

Type of specimen Mix design M30	**7day results In N/mm2**	**14day results In N/mm2**	**28day results In N/mm2**
Nominal concrete	2.03	2.87	3.091
RCA (25%)	2.25	3.066	3.27
RCA (50%)	2.34	2.93	3.16
RCA (75%)	2.46	2.91	3.11
RCA (100%)	1.90	2.69	2.85

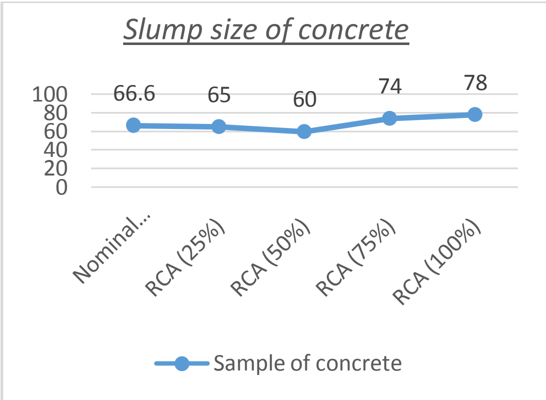






4. Results of the slump test of the concrete :-

Type of concrete Mix design M30	**Results of slump size in mm**
Nominal concrete	66.6
RCA (25%)	65
RCA (50%)	60
RCA (75%)	74
RCA (100%)	78



VI. DISCUSSION

Discussion on the results of compressive strength:-In comparison to Nominal concrete , specimen mix M – 30

(RCA – 25%) shows an increase of 2.04% in 7 day compressive strength, 6.49% in 14 day compressive strength, and 5.21% in 28 day compressive strength. However, specimen mix M – 30 (RCA – 50%) shows an increase of 4.30% in 7 day compressive strength, 1.71% in 14 day compressive strength, and 2.16% in 28 day compressive strength.With respect to nominal concrete, specimen mix M – 30 (RCA – 75%) shows an increase of 5.54% in 7 day compressive strength, 1.10% in 14 day compressive strength, and 1.07% in 28 day compressive strength, whereas specimen mix M – 30 (RCA – 100%) shows a decrease of 4.47% in 7 day compressive strength, 2.70% in 14 day compressive strength, and 5.99% in 28 day compressive strength.

In terms of 28-day compressive strength, specimen M – 30 (25%) displays the highest increase in compressive strength, i.e. 5.21%, as compared to Nominal concrete.

Discussion on the results of flexural strength :- In comparison to nominal concrete , specimen mix M – 30 (RCA – 25%) shows an increase of 5.94% in 7 day flexural strength, 6.23% in 14 day flexural strength, and 8.45% in 28 day flexural strength. However, specimen mix M – 30 (RCA – 50%) shows an increase of 11.95% in 7 day flexural strength, 1.01% in 14 day flexural strength, and 4.23% in 28 day flexural strength. In comparison to Nominal concrete, specimen mix M – 30 (RCA – 75%) shows an increase of 12.96% in 7 day flexural strength, 0.26% in 14 day flexural strength, and 2.59% in 28 day flexural strength, whereas specimen mix M – 30 (RCA – 100%) shows a decrease of 10.92% in 7 day flexural strength, 10.65% in 14 day flexural strength, and 7.04% in 28 day flexural strength.

In terms of 28-day flexural strength, specimen M – 30 (25%) displays the highest increase in flexural strength, i.e. 8.45%, when compared to Nominal concrete.

Discussion on the results of split tensile strength :-With respect to Nominal concrete, specimen mix M – 30 (RCA – 25%) shows an increase of 10.84% in 7 day split tensile strength, 6.83% in 14 day split tensile strength, and 5.79% in 28 day split tensile strength, but specimen mix M – 30 (RCA – 50%) shows an increase of 15.27% in 7 day split tensile strength, 2.09% in 14 day split tensile strength, and 2.232% in 28 day split tensile strength.The specimen mix M – 30 (RCA – 75%) shows an increase of 21.19% in 7 day split tensile strength , 1.39% in 14 day split tensile strength and 1.01% in 28 day split tensile strength , whereas , specimen mix M – 30 (RCA – 100%)shows decrease of 6.40% in 7 day split tensile strength , 6.27% in 14 day split tensile strength and 7.79% in 28 day split tensile strength with respect to Nominal concrete .

From 28 day spit tensile strength point of view , specimen M – 30 (25%) shows optimum increase in split tensile strength i.e. 5.79% with respect to nominal concrete (RCA – 0%) .

Discussion on the results of slump test of concrete :-Slump of mix design M – 30 is 66.6mm which does not contain RCA particles (Nominal concrete) . While the slump of mix design M – 30 of 25% RCA content is 65mm, which is less than the slump of a mix design without RCA content (nominal concrete).

The slump of mix design M – 30 of 50% RCA content is 60mm, which is less than the slump of a mix design without RCA content (Nominal concrete).

The slump of mix design M – 30 of 75% RCA content is 74mm and the slump of mix design M – 30 of 100% RCA content is 78mm, which are greater than the slump of a mix design without RCA content (Nominal concrete).

VII. CONCLUSION

Samples were evaluated after casting and yielded the above results, which were represented by compressive strength graphs, flexural strength graphs, and split tensile strength graphs. The results of this study show that concrete made with a replacement of 25%, 50%, and 75% RCA and the addition of 15% fly ash has higher compressive strength, flexural strength, and split tensile strength for both 7 and 28 day strength than the nominal concrete specimen. However, concrete made with 100% RCA has lower compressive strength, flexural strength, and split tensile strength than the nominal concrete specimen.

When compared to the nominal concrete slump size, the slump sizes of 25% RCA and 50% RCA are less. However, as compared to the nominal concrete slump size, the slump sizes of 75 percent RCA and 100 percent RCA are larger.

Concrete with a 25 percent RCA replacement and a 15 percent fly ash addition has the highest 28-day strength. When compared to nominal concrete, the slump size of 25% RCA is bettered. This concrete will be both cost-effective and sturdy, and it can be utilised in place of nominal concrete in any building project.

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9. IS Codes

A. IS: 3812 – 1999 Specification for Fly Ash to use as pozzolana and admixture.
B. IS: 10262 – 2009 Concrete mix proportioning guidelines (FirstRevision).
C. IS: 12269 – 1987 53 grade ordinary Portland cement specifications.
D. IS: 383 – 1970 Specification for coarse and fine aggregate from natural sources of concrete.
E. IS: 3535 – 1986 Methods of sampling hydraulic cements (FirstRevision).
F. IS: 2386 – 1963 (Part – 1) Methods of test for aggregates for concrete (Particle size and shape).
G. IS: 2386 – 1963 (Part – 2) Methods of test for aggregates for concrete (Estimation of deleterious materials and organic impurities).
H. IS : 2386 – 1963 (Part – 3) Methods of test for aggregates for concrete (Specific gravity , density , voids , absorption and bulking) .
I. IS: 2386 – 1963 (Part – 4) Methods of test for aggregates for concrete (Mechanical properties).
J. IS: 4031 (Part – 1)1996 method of physical tests for hydraulic cement (Part – 1 determination of fineness by dry sieving) (Second revision).
K. IS : 4031 (Part – 4)1988 Methods of physical tests for hydraulic cement (Part – 4 : determination of consistency of standard cement paste)(first revision).
L. IS : 4031 (Part – 5)1988 Methods of physical tests for hydraulic cement (Part –

5 : determination of initial and final setting times) (first revision) .

M. IS : 4031 (Part – 3)1988 Methods of physical tests for hydraulic cement (Part – 3 : determination of soundness) (first revision) .
N. IS : 456 – 2000 Plain and Reinforced Concrete – Code of Practice (Fourth revision) .
O. IS: 516 – 1959 (Reaffirmed 2004) Methods of Tests for Strength of Concrete.
P. IS: 1199 – 1959 (Reaffirmed 2004) Methods of Sampling And Analysis of Concrete.
Q. IS: 5816 – 1999 (Reaffirmed 2004) Splitting Tensile Strength of Concrete Method of Tests.