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Effect of Recycled Aggregate and Fly Ash in Concrete

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Abstract:*Waste arising from construction and demolition constitutes one of the largest waste streams within the developed and developing nations. The rapid growth in construction and depleting natural resources demands the recycling and reusing technology to be adopted in construction field. The use of recycled coarse aggregate (RCA) and fly ash (FA) is one of theapproaches towards this need.Use of RCA and FA in concrete can be useful for environmental protection and economical terms. In this experimental study the natural coarse aggregate (NCA) is replaced with RCA at different percentage and the mechanical strength of concrete is tested. In addition the FA is introduced as replacement of Cement.The objective of present study is to determine the sustainability of RCA as an alternate material to NCA and to compare the workability, density and compressive strength result using FA. The mix designing is done for water cement ratio 0.5. Cubes are casted by replacing virgin aggregate and cement with 10%, 20%, 30%, 40% RCA and FA and compressive strength is checked. Obtained results are then used to establish an empirical relationship between the strength of concrete by using percentage of RCA and percentage of FA. Results shows that RCA and FA up to 30% can be used for making concrete.*

Keywords:*compressive strength,concrete, fly ash (FA),natural coarse aggregate (NCA), recycled coarse aggregate (RCA).*

I. Introduction

Concrete is the premier civil engineering construction material. It is used in all types of civil engineering works like infrastructure, low and high-rise buildings, defence structure, and environment protection structure. Concrete manufacturing involve consumption of ingredients like cement, aggregates, water.The word “sustainable” is becoming very common worldwide. Sustainable building systems can have a direct implication on the betterment of livelihood conditions of communities. The course towards this involves mainly minimizing the environmental impact of concrete production by substituting virgin mineral materials by recycled ones as well as reducing the global CO_2 emissions. Recycling is the act of the processing the used material for creating new product. The approach adopted here includes a large substitution of NCA by RCA obtained from crushed concrete debris, as well as the use of FA as a partial substitute of Portland cement for FA concrete production.

The high demand for concrete in the construction using normal weight aggregates such as gravel and granite drastically reduces the natural stone deposits and this has damaged the environment thereby causing ecological imbalance. Also, extracting virgin aggregates is causing huge damage to the environment and considerable energy is required for both extraction as well as crushing processes. Therefore, there is a need to explore and to find out suitable replacement material to substitute the natural stone.

In the Construction industry, in urban areas, the demolition of old structure is on the rise either because they are obsolete, unsafe need repair and rehabilitation or else to make a way for newer, larger, taller structures. As a result, large amount of demolished concrete is generated as waste.Most of the demolished is disposed off by dumping it as landfill for reclaiming land. But the cost of transportation and the shortage of dumping grounds make disposal a major problem. Recycling such demolished concrete into aggregate is a relatively simple process which involves breaking, removing, and crushing existing concrete into a material with a specified size and quality. Due to their bonded mortar, RCA have a lower specific gravity and a higher water absorption capacity compared to NCA.

The cement is the most costly and energy intensive component of concrete. The unit cost of concrete can be reduced as much as possible by partial replacement of cement with FA. The disposal of FA is one of the significant issues for environmentalists, as dumping of FA as waste material causes severe environmental problems.FA is the finely divided mineral residue resulting from the combustion of ground or powdered coal in electric power generating thermal plant. FA is a beneficial mineral admixture for concrete. It influences many properties of concrete in both fresh and hardened state.Hence, the use of fly ash as partial replacement of cement imparts environmental benefits, reduces landfill demands, reduces concrete costs and improves concrete properties.

II. Methodology

Plain cement concrete (PCC) & reinforce cement concrete (RCC) is collected from sites. This collected material is crushed by breaker to separate the aggregates & reduce their sizes in smaller fraction. On these separated aggregates various testes are conducted in laboratory as per Indian Standard code & their results are compared. In the present study the sustainability of RCA as an alternate material to NCA and compare the workability, density and compressive strength result using FA concrete.


Fig 1. Construction Debris Fig 2. Fly Ash

2.1 Ingredients

2.1.1Cement : Ordinary Portland cement of Grade 53 Conforming to IS 8112 -1989.

2.1.2 Fine aggregate (FA): The sand used as fine aggregates was locally procured. It was first sieved through 4.75 mm IS sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. The physical properties are reported in Table1.

Table 1: Physical properties of Fine Aggregate (FA)

S.No	Properties	
1	Specificgravity	2.74
2	Bulkdensity(Kg/m^3)	1808
3	Size (mm)	Below4.75
4	Finenessmodulus	2.68

2.1.3 Natural Coarse Aggregate (NCA):

Gravels used as NCA were locally procured having average particle size of 20 mm. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The physical properties are reported in Table 2.

Table 2: Physical properties of NCA are as follows

S. No	Properties	
1	Shape	Angular
2	Specificgravity	2.75
3	Bulkdensity(Kg/m^3)	1685
4	Size (mm)	20mm
5	Crushingvalue(%)	18.5
6	Impact Value(%)	17.68

2.1.4 Fly ash (FA):

FA is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. FA is generally captured by precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash.The chemical compositions of fly ash is reported in Table 3.

Table 3: Chemical composition of Fly ash

Chemical Composition	Fly ash (% weight)	Specified requirementweight (%) IS –3812 part-I
SiO_2	60.0	35.0 minimum
$Al2O_3$	20.0	
CaO	8.0	
MgO	1.0	5.0 maximum
TiO_2	0.5	
Loss ofignition	8.0	12.0 maximum
Na_2O/K_2O	1.0	

2.1.5 Recycled coarse aggregate (RCA):

RCAs used were obtained from construction debris and crushed to 20 mm average particle size. These RCA were used to replace NCA partially. Physical properties of RCA are reported in Table 5.

Table 4: Physical properties of RCA are as follows:

Sr.No	Properties	RCA
1	Shape	Angular
2	Specific Gravity	2.58
3	Bulk density (Kg/m3)	1469.7
4	Size (mm)	20mm
5	Crushing value (%)	36.2
6	Impact Value (%)	35.3

III. Experimental Testing Program

In this study thestandard tests onRCA and FA in fresh and harden state were conducted. The test conducted includes slump test, density test, compressive strength test.

3.1 Slump Test: Theconcrete slump test is an empirical test that measures the workability of fresh concrete. This test is performed to check the consistency of freshly made concrete. Consistency is a term which describes the state of fresh concrete. It refers to the ease with which the concrete flows.

3.2 Density of Concrete

The density of concrete is a measure of its unit weight. The unit weight of concrete (density) varies depending on the amount and density of the aggregate, the amount of entrained air (and entrapped air), and the water and cement content.

3.3Compressive Strength Test

Compressive strength of concrete can be defined as the measured maximum resistance of a concrete to axial loading. The strength of the concrete specimens with different percentage of RCA and FA replacement can be indicating through the compression test. The specimens used in the compression test were 150mmx150mmx150mm and placed for curing at two different ages (7 days, 28days). Three specimens were casted for each ages and average value is taken. The test was conducted on compression testing machine having capacity 2000 KN. The maximum load applied to the specimen until failure was recorded. In this test the strength obtained in KN/m^2.

Fig 3.compressive test

3.4 Mix Proportion: Table 5 shows the mix proportions used to produce the test samples.

Table 5: Mix proportions (1m^3 concrete)

Designation	Mix		Cement	Fly ash	Fine aggregate	Coarse aggregate (Kg/m^3)	
	FA %	RCA %	(Kg/m^3)	(Kg/m^3)	(Kg/m^3)	NCA	RCA
M1	0	0	371.33	0	761.43	1142.15	0
M2	10	0	367.38	40.49	723.41	1131.29	0
M3	20	0	326.4	81.47	716.99	1122.99	0
M4	30	0	261.22	122.46	711.56	1113.5	0
M5	0	10	371.33	0	761.43	1027.59	114.06
M6	0	20	371.33	0	761.43	914.51	228.13
M7	0	30	371.33	0	761.43	799.46	342.69
M8	0	40	371.33	0	761.43	684.9	456.76
M9	10	10	367.38	40.49	723.41	1018.21	113.08
M10	10	20	367.38	40.49	723.41	904.67	226.16
M11	10	30	367.38	40.49	723.41	791.59	339.25
M12	10	40	367.38	40.49	723.41	678.50	452.33
M13	20	10	328.39	81.48	717.026	1010.35	112.09
M14	20	20	328.39	81.48	717.026	897.72	225.17
M15	20	30	328.39	81.48	717.026	785.63	336.77
M16	20	40	328.39	81.48	717.026	673.54	448.86
M17	30	10	285.91	122.46	711.56	1001.92	111.11
M18	30	20	285.91	122.46	711.56	890.81	222.70
M19	30	30	285.91	122.46	711.56	779.21	333.8
M20	30	40	285.91	122.46	711.56	668.11	445.4

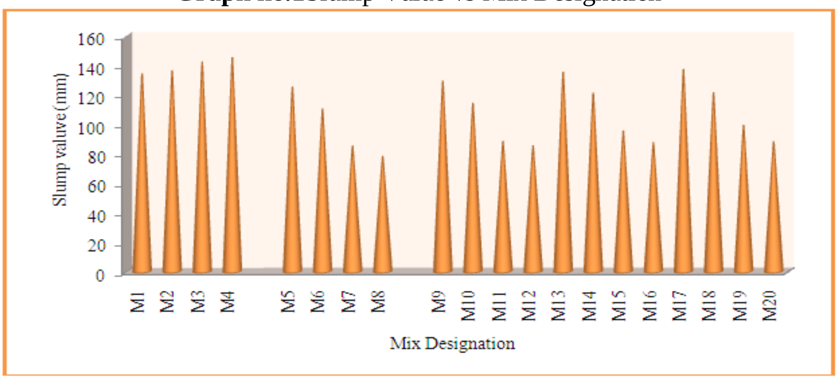
IV. Results And Discussion

The results obtained from these tests are discussed below:

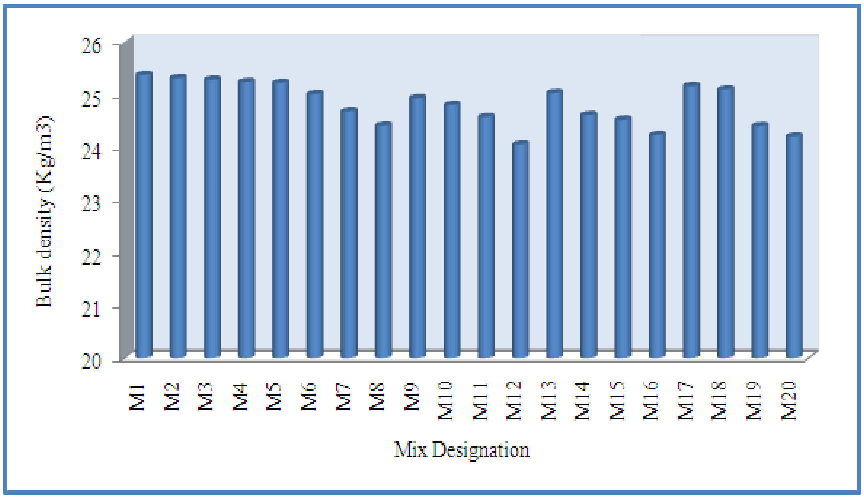
Table 6: Results

Designation	Mix		Slump Value (mm)	Density (KN/m^3)	Compressive strength (MPa)	
	FA %	RCA %		Bulk	7 days	28 days
M1	0	0	134	25.38	22	28.2
M2	10	0	136	25.32	22.7	30.92
M3	20	0	142	25.29	23.4	31.88
M4	30	0	145	25.25	23.1	31.48
M5	0	10	125	25.23	20.43	26.4
M6	0	20	110	25.02	21.26	27.3
M7	0	30	85	24.69	17.2	24.9
M8	0	40	78	24.42	15.83	22.1
M9	10	10	129	24.94	22.1	30.1
M10	10	20	114	24.81	21.3	28.8
M11	10	30	88	24.58	19.8	26.7
M12	10	40	85	24.06	19.1	22.6
M13	20	10	135	25.04	21.38	29.61
M14	20	20	121	24.62	22.2	28.88
M15	20	30	95	24.53	18.33	27.21
M16	20	40	87	24.24	15.51	23.10
M17	30	10	137	25.17	21.61	29.34
M18	30	20	121	25.11	22.43	30.21
M19	30	30	99	24.41	20.48	27.85
M20	30	40	88	24.21	18.37	24.61

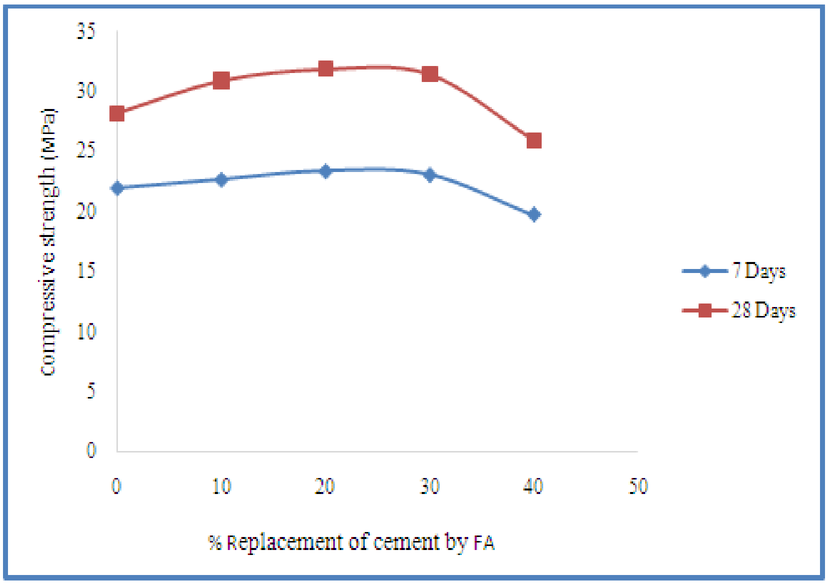
Graph no.1 Slump Value vs Mix Designation



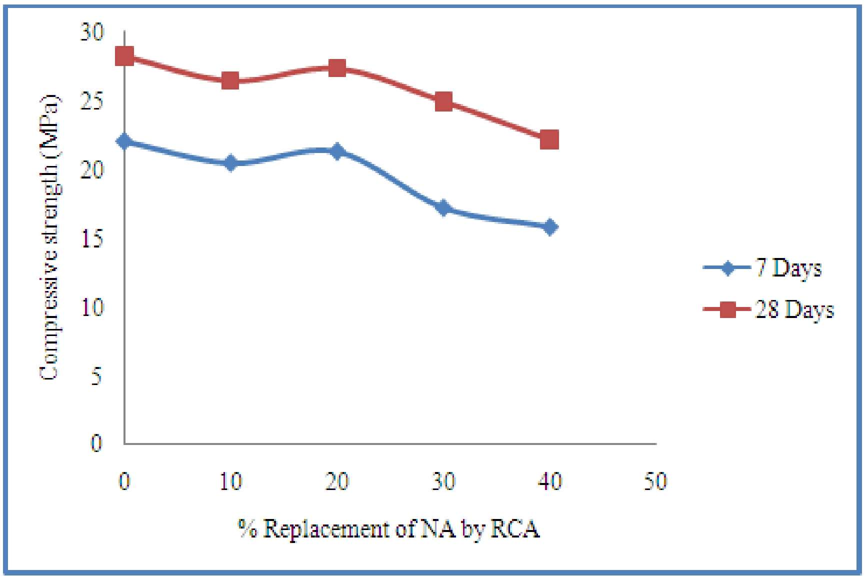
Graph no. 2 Bulk Density vs Mix designation



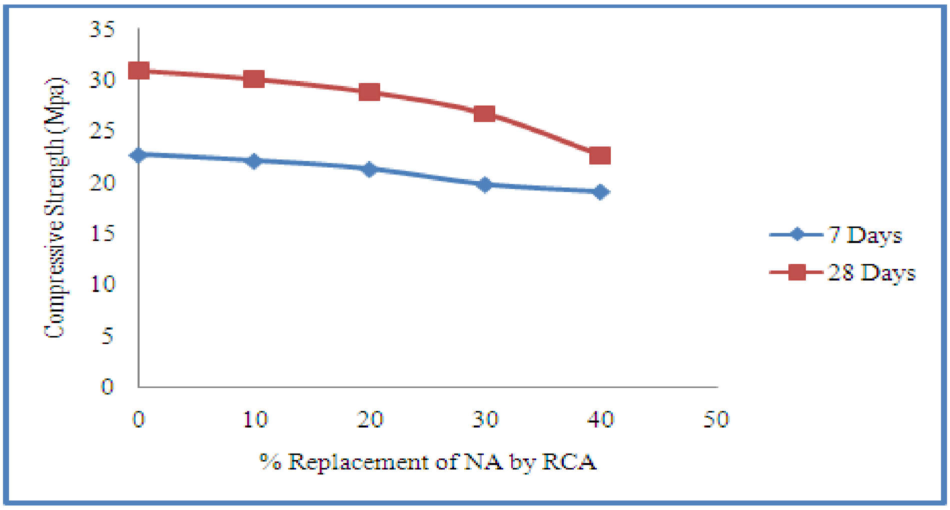
Graph.3 Compressive strength vs % Replacement of Cement by FA



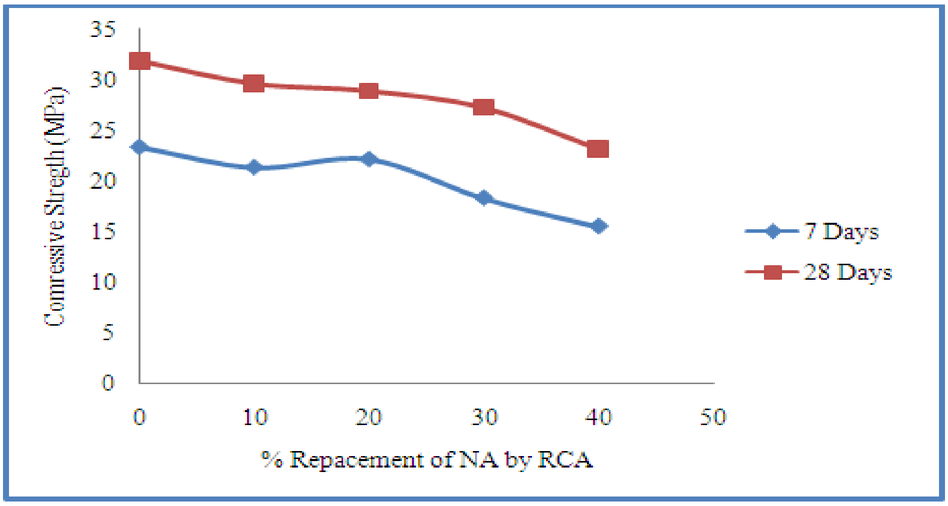
Graph.4 Compressive strength vs % Replacement of NA by RCA For 0 % FA



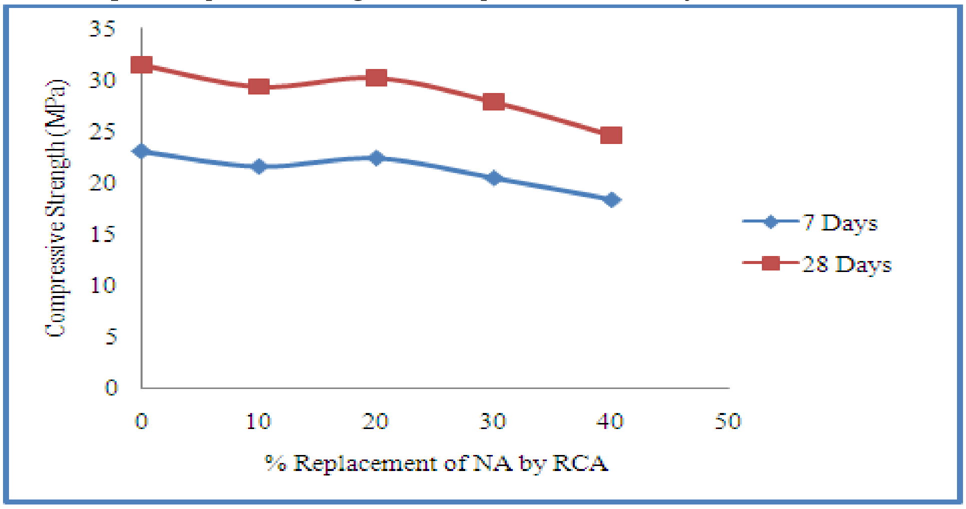
Graph 5 Compressive strength vs % Replacement of NA by RCA For 10% FA



Graph.6 Compressive strength vs % Replacement of NA by RCA For 20% FA



Graph7 Compressive strength vs % Replacement of NA by RCA For 20% FA



As expected the workability of the fresh recycled aggregate (RA) concrete is reduced with the increase ofRCA content. The reduction in workability is caused by the high water absorption of RCA and the high content of fines in the RCA. On the other hand, the introduction of FAimproves the workability of fresh concrete and this can be attributed to the lubricating effect of the fly ash due to its spherical shape. Also since a by weight replacement of fly ash was used and FA is less dense than cement there are more paste volume in the mixes which improves the workability.

The unit mass of concrete (density) varies depending on the amount and density of the aggregate, water and cement contents.It is observed that bulk densities of RA concrete are less than that of natural aggregate (NA) concrete. The density values also depend on the content of RCA. This is due to presence of low density old mortar attached on RCA.It is also observed that air content of concrete mix is unaffected by the replacement of cement by FA. As FA is has lower specific gravity as compared to cement, at higher level of cement replacement, there is a slight reduction in the density of concrete.

Upto 30% replacement of cement with FA significantly increased the strength of concrete. Concrete attained its optimum strength at fly ash replacement of 20%. It may be because, FA is an efficient natural pozzolan,Pozzolanic reaction begins immediately after hydration of cement and continues for a long time thereby increasing strength. Concrete derives its strength from the pozzolanic reaction between silica in fly ash and the calcium hydroxide liberated during the hydration of OPC.The strength of concrete decrease with increase in the percentage of RCA, this may be due to the loose mortar around the RCA which do not allow the proper bonding between the cement paste and aggregate. The amount of reduction in strength depends on parameters such as replacement ratio, w/c ratio, processing of RCA etc. But it has been observed that the concrete produced from 20% replacement of NCA by RCA, shows maximum compressive strength as compared to other replacements of NCA by RCA. This may be due to the fact that 20% RCA added may absorb the additional quantity of water from concrete mass making w/c ratio less without affecting workability. This decrease inw/c ratio may be the reason for increase in compressive strength when 20% NCA are replaced by RCA.Concrete with 30% fly ash and 20% RCA gives higher compressive strength than ordinary concrete. This may due to bonding between the old mortar and fly ash.

V. Conclusion

After detailed study of the results and analysis the following conclusions were made

1. The general properties of RCA including Aggregate impact value, Aggregate crushing value and specific gravity show hardly any noticeable difference from NA, and thus it is proven that RA size affected the workability and strength of concrete and can be seen especially in water absorption.Recycled aggregate concrete may be an alternative to the conventional concrete.
2. Workability for fresh concrete was increased with increase of incorporation of fly ash.
3. Workability for fresh concrete was decreased with increase of incorporation of RCA.
4. Density of concrete is not much affected by the increase in replacement of cement with FA.
5. Density of concrete is decreased with the increase in replacement of NCA with RCA.
6. Density of RCA concrete is less than of concrete with NCA. This is an advantage in the design of structures where the light weight concrete is performed.
7. The specimens up to 30% replacement of FA get the strength more than ordinary strength.
8. The optimum strength of concrete was achieved at 20% replacement of cement by FA.
9. Up to 30% of NCA replaced by RCA gave strength closer to the strength of plain concrete cubes and strength retention is in the range of 88.29-93.61**%** as compared to conventional concrete.
10. Optimum compressive strength is obtained at percentage replacement of FA (30%) and RCA (20%).
11. The FA and RCA are used as 30% or below 30% replacement of cement and natural aggregate get the strength more than targeted strength.
12. Use of fly ash in concrete can save the coal & thermal industry disposal costs and produce a ‘greener’ concrete for construction.

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