

# Influence of Fly Ash on the Performance of Recycled Aggregate Concrete

N. Sowmith<sup>1</sup>, P.S.S. Anjaneya Babu<sup>2</sup>

<sup>1</sup>PG Student, Department Of Civil Engineering, Gudlavalleru Engineering College, India

<sup>2</sup>Assistant Professor, Department Of Civil Engineering, Gudlavalleru Engineering College, India

**Abstract:** *The infrastructure of a country or state depends on the development of innovative ventures constructed in that state/ country. Due to increase in construction the natural aggregates are depleting day by day. So the recycling technique is adopted in construction field. Recycled coarse aggregate (RCA) is one of the approaches for this need. The strength of concrete decrease with increase in the percentage of recycled coarse aggregate but there are methods to increase the strength of RCA such as surface treatments, two stage mixing and pozzolanic material. In this project the method of using pozzolanic material and two stage mixing method is studied, here fly ash is used as pozzolanic material. The paper investigates about the effect of replacement of fly ash on fresh and hardened properties of recycled aggregate concrete. Most of the research work done on replacement of coarse aggregate with recycled aggregates about 25%, 50%, 75% & 100% and class F. fly ash is used to replace ordinary Portland cement by 10% & 20% to improve the workability and strength of recycled aggregate concrete. The compressive strength and split tensile strength of recycled aggregate concrete is compared with the conventional concrete.*

**Keywords:** Compressive strength, fly ash, ordinary Portland cement, Recycled coarse aggregate, Split tensile strength.

## 1. Introduction

Reduce, Re-use, Recycle are the stepping stones for sustainability which is the most basic concern of the present day and the most significant research to be under taken. Concrete is considered as the basic material for every type of construction and is mostly used. This leads to the emission of carbon dioxide and green house gases into the atmosphere which is adding up with the present day polluted sphere. The use of less cement and natural aggregates used in concrete production lowers the impact of concrete industry on the environment. Aggregates, in terms of volume are the major components of concrete and may have significant effect on both engineering properties and the final cost of concrete mixture. Moreover natural resources are depleted remarkably due to extensive use generated by high demand of new buildings and constructions. Every year, it is estimated that the construction industry in India generates about 10-12 million tonnes of waste annually. In the USA, the construction waste produced is 123 million tons per year. In EU, 850 million tons of construction and demolition waste are generated per year. Therefore, as concrete is still the material the most used in civil and industrial infrastructure and is also the major absorbing of natural mineral resources, recycling rubble concrete gains importance. It preserves natural resources and eliminates the need for disposal by using the demolished concrete as an alternative aggregates for new concrete production.

On the other hand, aggregate in fact, is known to play a substantial role in determining workability, strength, dimensional stability, and durability of the concrete. Due to their bonded mortar, recycled concrete aggregates have a lower specific gravity and a higher water absorption capacity compared to natural aggregates. The compressive strength varies with the compressive strength of the old concrete and the water-cementing materials ratio (w/c) of

the new concrete. While recycling old concrete into aggregate, a relatively simple process which involves breaking, removing, and crushing existing concrete into a material with a specified size and quality. The properties of concrete made with RCA are strongly dependent on the quality of the recycled materials used as well as the primary concrete crushed. Indeed, extracting virgin aggregates is causing huge damage to the environment and considerable energy is required for both extraction as well as crushing processes. Thus, a growing interest in substituting natural aggregates with alternative recycled aggregates derived from different constructions and demolitions wastes.

To increase the strength of recycled aggregate concrete there are methods such as surface treatments, mixing methods and use of pozzolanic materials. In surface treatment, collected RCA is cleaned with different acids to increase the strength of RCA. There are three methods of mixing; they are normal mixing method (NM), double mixing method (DM) and triple mixing method (TM)<sup>[9]</sup>. Pozzolanic materials improve the strength of RCA by filling air voids which were occurred in RCA and also by using pozzolanic material it increases the bond strength between mortar and cement paste. In the present study double stage mixing method and pozzolanic material is used to increase the strength of RCA. Here fly ash (FA) is undertaken as supplementary cementing materials (SCMs) as replacement for cement. Fly ash is classified into two types class C and class F. Here class F fly ash is used. Fly ash is a waste product from the thermal power plants and available free of cost. With this the impact on the environment due to cement can be reduced. Over years several researches with fly ash as a replacement of cement in concrete production had come up with qualitative results like improvement in the workability and long term strength, reduction in permeability, risk minimization due to alkali silica reaction, lowering in heat of hydration in mass concrete, and enhancement in the durability performance

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(resistance to chloride and sulphate attack). Extensive research work has already been performed on the use of fly ash and other supplementary cementitious materials to enhance sustainability and durability of concrete material. In the present investigation 10% & 20% fly ash is used as replacement to cement and to improve the properties of recycled aggregate concrete. The current investigation attempts to strengthen the RCA with using pozzolanic material and by using two stage mixing method with various proportions of 25%, 50%, 75%, and 100% RCA in concrete. Limbachiya et.al and Ouchagour<sup>[7],[8]</sup> has proven that RCA could successfully be used as a substitute for natural aggregate to produce normal and high strength concrete, meeting required design strength and desire probability performance. They made a general conclusion that up to 30% RCA can be used as a replacement for natural aggregate without any negative effects on fresh and hardened concrete properties of Portland cement.

## 2. Experimental work

The main objective of this paper is to compare the hardened properties of concrete with different amount of recycled aggregates such as 25%, 50%, 75% and 100%. The scope of this investigation is limited to target strength of concrete.

The experimental work for this study includes the materials used, the concrete mixes proportion, tests that has been used for determining the fresh concrete performance and tests that has been conducted for assessing the hardened concrete performance. Mix design was designed as per IS-10262-2009 as control mix with natural coarse aggregate. The mix proportion was found and finally with the W/C ratio of 0.42, the control mix was with the 100% natural coarse aggregates and other mixes were also prepared with (75%+25%), (50%+50%), (75%+25%) and (100%+0%) combination of natural coarse aggregates and recycled coarse aggregates respectively.

### 2.1 Materials Used

#### 2.1.1 Cement

Ordinary Portland cement of 53 grade conforming to IS: 12269-1987 was used for this entire study.

**Table 1: Tests on Cement**

S. No	Particulars of tests	Test results	Requirements as per IS codes
1	standard consistency	31%	IS 4031- 1988 (part-4)
2	Specific gravity	3.1	
3	Setting time		
	a) Initial	98 minutes	As per 12269 -2013 30 min. Minimum
	b) Final	300 minutes	As per 12269 -2013 600 min. Maximum

#### 2.1.2 Fine Aggregate

Locally available river sand passing through IS sieve 4.75mm was used as fine aggregate and the following tests were carried out on a sand as per IS 2386- 1986 (part 3).

**Table 2: Tests on Fine Aggregate.**

S. No	Particulars of test	Test results
1	Specific gravity	2.53
2	Water absorption (%)	1.35
3	Bulk density (kg/m <sup>3</sup> )	1680
4	Sieve analysis	Zone II

#### 2.1.3 Coarse Aggregate

For this study, two types of coarse aggregates were used for the preparation of concrete i.e. Natural coarse aggregate (NCA) and Recycled coarse aggregate (RCA). Both NCA and RCA aggregates were screened into two different size fractions (i.e. 70% of 20mm to 16mm sized and 30% of 12mm to 10mm sized) and combined to form NCA & RCA.

##### 2.1.3.1 Natural coarse aggregate

For this study, locally available crushed stone aggregate of size 20mm were used and the following tests were carried out on NCA.

**Table 3: Tests on Coarse Aggregate**

S. No	Particulars of test	Test results
1	Specific gravity	2.76
2	Fineness modulus	3.32
3	Crushing value (%)	19.69
4	Impact value (%)	23.20

##### 2.1.3.2 Recycled Aggregate

Recycled aggregate were prepared by crushing the M40 grade manufactured cubes. The cubes were cured for 28days and broken into smaller pieces by hammer then sieved to collect maximum size of 20mm and minimum size of 10mm. The following tests were carried out on RCA.

**Table 4: Tests on Recycled Coarse Aggregate**

S. No	Particulars of test	Test results
1	Specific gravity	2.61
2	Fineness modulus	3.57
3	Crushing value (%)	17.23
4	Impact value (%)	20.61

#### 2.1.4 Water

In this study portable water conforming to IS: 456-2000 was used for casting and curing.

#### 2.1.5 Fly Ash

In this study class F fly ash was used as pozzalonic material to replace cement.

## 3. Mix Design

Concrete mix proportions were designed as per IS 10262: 2009 code with the target slump of 25-50mm. A super plasticizer of SP430 was used for high degree of workability. The content of super plasticizer was 0.8% of cement used. The resulting concrete is proportioned for M40 grade as per nominal mix design. The natural coarse aggregate is replaced by recycled coarse aggregate in percentages i.e., 0%, 25%, 50%, 100% and these specimens were tested for compression and split tensile strengths. The variations of compressive strength and split tensile strength

with fly ash and without fly ash are discussed in the result section.

### 3.1 Mix Proportions

Here three mixes of concrete were prepared i.e., Mix - 01, Mix - 02 and Mix - 03. Mix - 01 was prepared by using fly

ash as cement replacement by 10% with w/c ratio 0.42, Mix - 02 was prepared by using fly ash as cement replacement by 20% with w/c ratio 0.42 and Mix - 03 was prepared without using fly ash with w/c ratio 0.45. The crushed aggregates are used for the replacement of natural aggregates in different proportions such as 0%, 25%, 50%, 75%, and 100%.

**Table 5:** Mix 01, with 10% fly ash (w/c 0.42)

S. No	% of replacement		Cement (kg/m <sup>3</sup> )	Fly Ash (kg/m <sup>3</sup> )	Sand (kg/m <sup>3</sup> )	Water (kg/m <sup>3</sup> )	NCA (kg/m <sup>3</sup> )	RCA (kg/m <sup>3</sup> )
	NCA (%)	RCA (%)						
01	75	25	373.32	41.48	842.06	177.77	827.54	275.84
02	50	50	373.32	41.48	842.06	177.77	551.69	551.69
03	25	75	373.32	41.48	842.06	177.77	275.84	827.54
04	0	100	373.32	41.48	842.06	177.77	0	1103.39

**Table 6:** Mix 02, with 20% fly ash (w/c 0.42)

S. No	% of replacement		Cement (kg/m <sup>3</sup> )	Fly Ash (kg/m <sup>3</sup> )	Sand (kg/m <sup>3</sup> )	Water (kg/m <sup>3</sup> )	NCA (kg/m <sup>3</sup> )	RCA (kg/m <sup>3</sup> )
	NCA (%)	RCA (%)						
01	75	25	331.84	82.96	842.06	177.77	827.54	275.84
02	50	50	331.84	82.96	842.06	177.77	551.69	551.69
03	25	75	331.84	82.96	842.06	177.77	275.84	827.54
04	0	100	331.84	82.96	842.06	177.77	0	1103.39

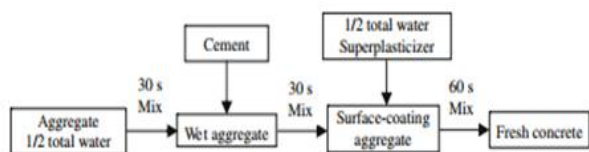
**Table 7:** Mix 03, without fly ash (w/c 0.45)

S. No	% of replacement		Cement (kg/m <sup>3</sup> )	Sand (kg/m <sup>3</sup> )	Water (kg/m <sup>3</sup> )	NCA (kg/m <sup>3</sup> )	RCA (kg/m <sup>3</sup> )
	NCA (%)	RCA (%)					
01	100	0	414.81	842.06	186.66	1103.39	0
02	75	25	414.81	842.06	186.66	827.54	275.84
03	50	50	414.81	842.06	186.66	551.69	551.69
04	25	75	414.81	842.06	186.66	275.84	827.54
05	0	100	414.81	842.06	186.66	0	1103.39

### 3.2 Mixing Procedure

Mixing of ingredients is done in pan mixer of capacity 40 litres. The cementations materials are thoroughly blended and then the aggregate is added and mixed followed by gradual addition of water and mixing. Mixing is done until a mixture of uniform colour and consistency are achieved which is then ready for casting. Mixing of concrete is done by Double mixing method<sup>[15]</sup>.

rod is 16mm diameter, 0.6m long with bullet is used. The mould is placed on a smooth, horizontal, rigid and non-absorbent surface. The mould is then filled in four layers, each approximately 1/4<sup>th</sup> of the height of the mould. Each layer is tamped 25 times by the tamping rod taking care to distribute the strokes evenly over the cross section.



**Figure 1:** Double mixing method coated with cement and admixture

### 4.2 Compressive Strength

The cubes of size 150x150x150mm were casted. After 24 hours, the specimens are removed from the moulds and subjected to curing for 7 days and 28 days in portable water. After curing, the specimens are tested for compressive strength using compression testing machine of 2000 KN capacity (IS: 516 – 1959). The maximum load at failure is taken. The average compressive strength of concrete specimens is calculated by using the following equation.

$$\text{Compressive strength of concrete} = \frac{\text{Ultimate compressive load (N)}}{\text{Area of cross section (mm square)}}$$

## 4. Tests on fresh and hardened concrete

### 4.1 Slump Test

Slump test is the most commonly used method & measuring consistency of concrete which - be employed either in laboratory or at site work. For the present work, slump tests were conducted as per IS: 1199 -1959 for all mixes. It is not suitable method for vary wet or very dry concrete. This method is suitable for medium slump. The apparatus for conducting the slump test essentially consists a metallic Mould in the form of frustum of a cone having the dimensions of top diameter 10cm, bottom diameter 20cm and height 30cm. For tamping the concrete; a steel tamping

### 4.3 Split tensile Strength

The cylinders are of size 150 mm diameter and 300mm length is casted. After 24 hours, the specimens are removed from the moulds and subjected to curing for 7 days and 28 days in portable water. After curing, the specimens are tested for split tensile strength using compression testing machine of 2000 KN capacity (IS: 516 – 1959). The maximum load at failure is taken. The ultimate load is taken

and the average Split tensile Strength is calculated using the equation.

$$\text{split tensile strength} = \frac{2 \times \text{Ultimate compressive load (N)}}{\pi \times \text{length} \times \text{Diameter (mm square)}}$$

## 5. Results and discussions

### 5.1 Slump

Workability of the three mixes Mix 1, Mix 2 and Mix 3 is gradually decreased with increase in percentage of recycled aggregates. The set with 20% fly ash has more workability than without fly ash. Workability with different % of RCA (in slump value) is shown in table 8.

**Table 8:** Workability for Mix with different % of FA and RCA

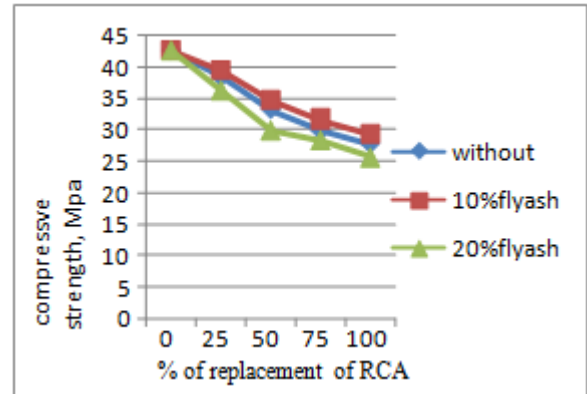
% replacement of RCA	Without Fly Ash		With 10% Fly Ash		With 20% fly ash	
	w/c ratio	slump	w/c ratio	slump	w/c ratio	slump
0	0.45	45	0.45	45	0.45	45
25	0.45	42	0.42	41	0.42	40
50	0.45	38	0.42	37	0.42	37
75	0.45	33	0.42	34	0.42	35
100	0.45	30	0.42	32	0.42	33

### 5.2 Compressive Strength

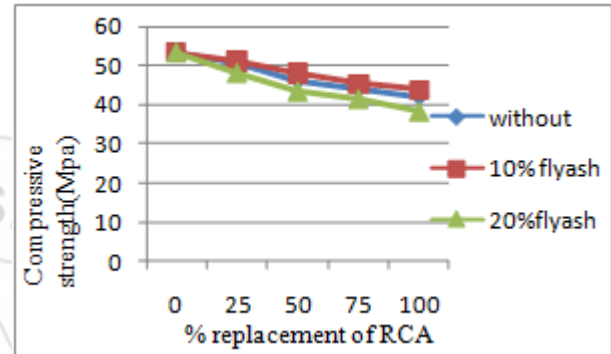
The experimental results obtained after the curing of 7 days and 28 days are shown in the table 9 and figure 2, 3. The compressive strength of the two sets is decreased with the increase in percentage of recycled aggregates. Generally, 30MPa strength value is widely used in construction purposes. At 28 days 100% replacement of RCA with addition of fly ash achieves strength of 38.18Mpa. In long period of time this strength can be equal or exceed to the strength of natural aggregate concrete.

**Table 9:** Compressive strength for 7 and 28 days with and without fly ash

% replacement of RCA	without fly ash		with 10% fly ash		With 20% fly ash	
	Compressive strength (Mpa)		Compressive strength (Mpa)		compressive strength, (Mpa)	
	7 days	28 days	7 days	28 days	7 days	28 days
0	42.74	53.40	42.74	53.40	42.74	53.40
25	38.47	50.75	39.48	51.21	36.31	48.17
50	33.32	46.45	34.71	48.17	29.91	43.41
75	29.85	44.31	31.65	45.42	28.33	41.41
100	27.75	42.16	29.31	43.82	25.58	38.18



**Figure 2:** Compressive strength of concrete for 7 days.



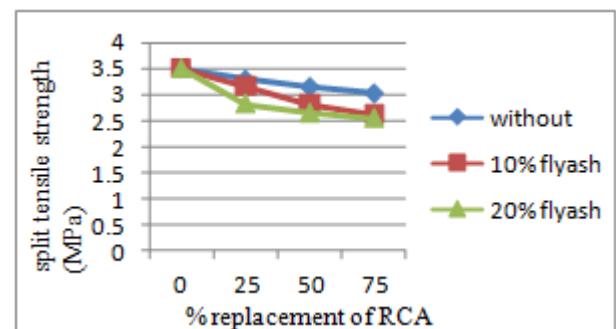
**Figure 3:** Compressive strength of concrete for 28 days.

### 5.3 Split Tensile Strength

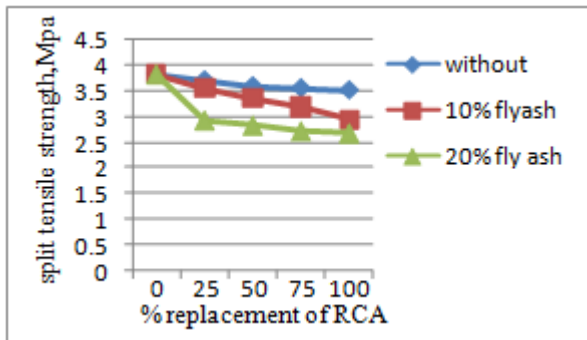
The split tensile strength results obtained after the curing of 7 days and 28 days are shown in the table 10 and figure 5, 6. The split tensile strength of the two sets is also decreased with the increase in percentage of recycled aggregates. The split tensile strength decreases with increase in the percentage of fly ash.

**Table 10:** Split Tensile strength for 7 and 28 days with and without fly ash

% replacement of RCA	without fly ash		With 10% fly ash		With 20% fly ash	
	Split Tensile strength, Mpa		Split Tensile strength, Mpa		Split Tensile strength, Mpa	
	7 days	28days	7 days	28 days	7 days	28 days
0	3.50	3.83	3.50	3.83	3.50	3.83
25	3.29	3.71	3.17	3.55	2.82	2.94
50	3.15	3.59	2.82	3.36	2.64	2.84
75	3.03	3.55	2.62	3.19	2.54	2.73
100	2.97	3.51	2.54	2.94	2.46	2.69



**Figure 4:** Split tensile strength of concrete for 7 days.



**Figure 5:** Split Tensile strength for 28 days.

## 6. Conclusions

From the study following conclusions are made

- 1) The strength of concrete decrease with increase in the percentage of recycle aggregate, this may be because of the loose mortar around the recycle aggregate which do not allow the proper bonding between the cement paste and aggregate.
- 2) Workability of RAC concrete can be improved by replacing cement with fly ash about 10% and 20% by weight of cement.
- 3) The strength (30Mpa) is generally used for a wide range of structural uses. From the present study it is concluded that by decreasing the water to cement ratio to 0.42, the above strength can be achieved through recycled aggregates and fly ash.
- 4) Generally, fly ash based concrete has the ability to develop strength over prolonged periods of time. So at a long period of run the compressive strength of RAC with fly ash achieves similar strength of natural aggregate concrete by adding fly ash.
- 5) In conclusion, if properly designed RAC, especially that containing fly ash, can be an effective alternative to natural concrete for structural purposes.

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