STUDY OF STRENGTH CHARACTERISTICS OF CONCRETE USING RECYCLED AGGREGATES

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Abstract*— *The study aimed at investigating the structural use of recycled coarse aggregate by studying the strength characteristics of Recycled Aggregate in concrete and appropriate percentage of fly ash is used for the replacement of conventional cement. The laboratory experimental work has been conducted to determine the strength characteristics of concrete by replacing recycled aggregates and fly ash in different percentages. To calculate mix design of concrete for required design strength we have to determine the physical, chemical properties of cement, coarse, fine, recycled aggregates and fly ash. The total laboratory experiments are conduced according to standard and codal provisions; mainly Indian Standard Specifications are followed.

On the basis of the laboratory studies carried out on M30 grade (the mix design calculated as per the IS: 10262-2009) recycled aggregate concrete. By observing the experimental results, we can conclude that the strength results of recycled aggregate concrete comparing to conventional concrete are increased when fly is added as 10% replacement of conventional cement, and without fly ash it is decreased. Hence for economical view 10% of fly ash is added is preferable and in the perspective of compressive strength, split tensile strength, flexural strength 10% is suggested. At 50% replacement of coarse aggregate with recycled aggregates the results are not even met half of design strength Thus, 10%-40% replacements recycled aggregates recommended for ordinary building and works special concrete production.

Keywords: Recycled aggregate, fly ash, strength properties, cement concrete, partial replacement

I. INTRODUCTION

All over the world, the concrete industry consumes large amounts of natural resources, which are becoming insufficient to meet the increasing demands. At the same time, large number of old buildings other structures have reached the end of their service life and are being demolished, resulting in generation of demolished concrete. Some of this concrete waste is used as backfill material, and much being sent to landfills. Recycling concrete by using it as replacement to new aggregate in concrete could reduce concrete waste and conserve natural sources of aggregate. In the last two decades, a variety of recycling methods for construction and demolition wastes (CDW) have been explored and are in well-developed stage. It is known as recycled aggregate (RA).

Sustainable materials are one of the strategies to be considered by the construction industry to help circumvent waste problem. A couple of ways to achieve the goal of reducing volumetric in-waste is to introduce Recycled Concrete Aggregate (RCA) from the largest sources of such waste such as construction and demolition projects and Fly Ash (FA) from burning coal into the production of concrete. This is the primary impetus for the recycled materials of concrete pavement in the form of RCA and FA and has become an obvious choice for concrete pavement. The advantages of using RCA and FA are of economic and environmental concern. The potential for the use of Recycled Concrete Aggregate (RCA) has been explored previously, but its use with Fly Ash (FA) in concrete pavement has not been thoroughly studied. Subsequently there is a need to assess the performance of RCA with fly ash for use in concrete pavement.

Recycled aggregate properties

- The main property of recycled aggregate is density, which is lesser than the natural aggregate, because of the porous and less dense residual mortar lumps that is adhering to the surfaces.
- The strength of recycled aggregate is lesser than natural aggregate because of the weight of recycled aggregate is lighter than natural aggregate. This is the general effect that will reduce the strength of reinforced concrete.
- The recycled aggregates have less specific gravity and high water absorption as compared to the conventional aggregates. The main reason for this is existence of mortar on the aggregates.
- Bulk density of the Recycled aggregate sample for RFCA and RCA-20mm is less as compared to NFA and NA-20mm.The lesser value of loose bulk density of recycled aggregate is attributed to the adhered mortar on aggregate which increases the size of the aggregate and will have better interlocking which in turn reduces the voids in rodded condition and the higher porosity than that of natural aggregates.
- The crushing value of Recycled aggregate is less due to the adhered mortars on the surface of aggregate makes the RCA weaker towards impact resistance and crushing.

II. FLY ASH

Fly ash (or) pulverized fly ash is a waste material from the combustion of pulverized coal collected by mechanical separators, from the thermal plants. Fly ash is one of the most used by-product materials in the construction field resembling Portland cement.

The composition varies with type of fuel burnt, load on the boiler and type of separation. The fly ash consists of spherical glassy particles ranging from 1 to 150 micron in diameter and also passes through a 45-micron sieve. The constituents of fly ash are mentioned below in the table1.

Table1: Composition of flyash

Sl. no	Chemical Compound	Composition %
1	Silicon dioxide (SiO_2)	30-60%
2	Aluminiumoxide (Al_2O_3)	15-30%
3	Un burnt fuel	< 30%
4	Calcium oxide	1-7%
5	Sulphur tri oxide	Small amounts

Many class C ashes when exposed to water will hydrate and harden in less than 45 minutes. In concrete, class Fly ash is often used at dosages of 15% to 25% by mass of cementitious material and class C fly ash is used at dosages of 15% to 40%. Dosage varies with their activity of the ash and the desired effects on the concrete. Because of their spherical morphology, when using fly ash admixtures as replacement for cement, workability and long-term strengths are achieved in concretes. In such cases, they act like small balls to reduce inter particle friction. Fly ashes are also used in concrete mixes in order to reduce the heat of hydration, permeability, and bleeding.

III. CEMENT

The most common cement currently used in construction is type I/II Portland cement. This cement conforms to the strength requirement of a Type I and the C3A content restriction of a Type II. This type of cement is typically used in construction and is readily available from a variety of sources. The Blaine fineness is used to quantify the surface area of cement. The surface area provides a direct indication of the cement fineness. The typical fineness of cement ranges from 350 to 500m^2/kg for Type I and Type III cements, respectively

Grade of Cement

OPC confirming to Indian standards IS: 8112-1989

Specific gravity of cement

The specific gravity of cement was determined using Pycnometer conical flask for each cement three replicate samples were taken and the average value was taken as the representative value of specific gravity for that particular cement. The determined values of specific gravity of OPC are 3.13 respectively.

Proportioning of Ingredients

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance. The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. In this present investigation one value of water-cement ratio i.e. 0.41 is adopted.

The proportioning of all ingredients is obtained in the following steps:

1. For the slump range of 30-60mm, water content of 192 kg/m^3 was selected. [From Table 38, SP:23] [20]
2. The cement content was then calculated by dividing the water content by the corresponding water-cement ratio.
3. Then wet density of concrete was calculated from Fig. 44 [SP:23], corresponding to the specific gravity of aggregates (saturated and surface dry condition)
4. The total aggregate content was then calculated by subtracting the total mass of water and cement contents from wet density of concrete.
5. The percentage of fine aggregate (sand) was calculated from Fig. 45 [SP: 23] corresponding to grading Zone-III, the required slump and required water-cement ratio.
6. The coarse aggregate content was calculated by subtracting the sand content from the total aggregate content.
7. After getting the proportions of the mix, trail slump tests were carried out. Finally a water content of 210kg/m^3 was selected for all the water-cement ratios to have the similar workability in all the mixes. The mix proportions and quantities of ingredients of all the concrete mixes are presented in table below

Table2: Final quantities of ingredients per m3 of concrete for different water-cement ratios for RCA and (Fly ash + RCA)

Type of Cement	w/c	Water	Cement	Fly ash	Fine Aggregate	Coarse Aggregate
RCA	0.46	192	417	-	538	1170
Fly ash + RCA	0.58	192	330	140	741	1002

Preparation of samples

- The cubes of size 15cm ×15cm × 15cm were prepared to find the compressive strength test from the above concrete mixes.
- The cylinders of size 100 x 200 mm were prepared to find the split tensile strength from the above mixes.
- The beams of size 10cm x 10cm x 50cm were prepared to find the flexure strength from the above concrete mixes.
- After 24hrs of preparation, the cubes, cylinders, beams were taken out from the moulds and kept for moist curing.
- Note: For each test three concrete samples are prepared.

Design Mix for Fresh Concrete M (30)

Table3: Quantities of ingredients per m3 of concrete for water-cement ratio of recycled aggregate

w/c	Cement(kg)	Fine aggregate(kg)	Coarse aggregate(kg)
192	470	753	958
0.41	1	1.60	2.03

Design mix for fly ash M (30)

Table4: Quantities of ingredients per m3 of concrete for water-cement ratio of Fly ash

w/c	Cement(kg)	Fly ash(kg)	Fine aggregate(kg)	Coarse aggregate(kg)
192	330	140	741	1002
0.58	1	0.42	2.24	3.03

OPC and PPC for different water-cement ratios are listed below

The workability factors like slump value and compaction factor values are determined by the slump cone test and flow test of concrete respectively.

Table5: Workability values of coarse aggregate with recycled aggregate

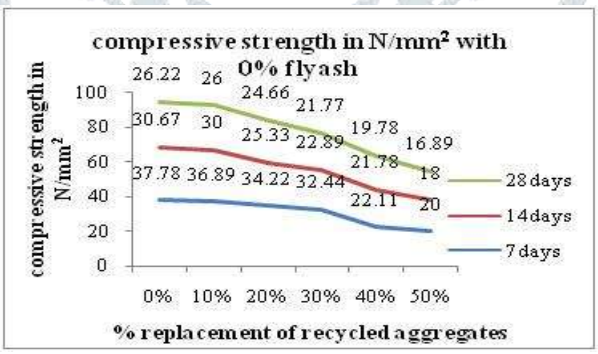
Mix proportion	Slump (mm)	Compaction factor
0%	87	0.92
10%	83	0.93
20%	75	0.87
30%	78	0.86
40%	74	0.86
50%	71	0.81

Table6: Workability values using fly ash and recycled aggregate

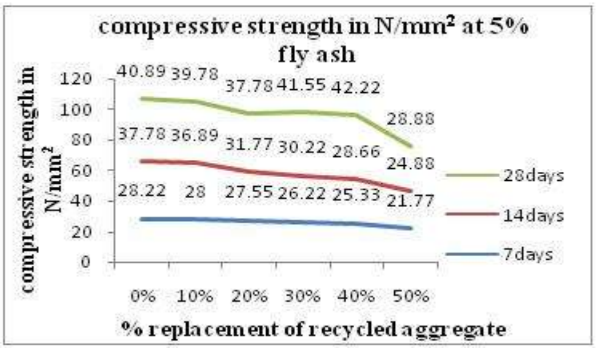
Mix proportion	Slump (mm)	Compaction factor
0%	85	0.92
10%	25	0.85
20%	23	0.83
30%	22	0.86
40%	26	0.82
50%	21	0.81

Compressive Strength Test

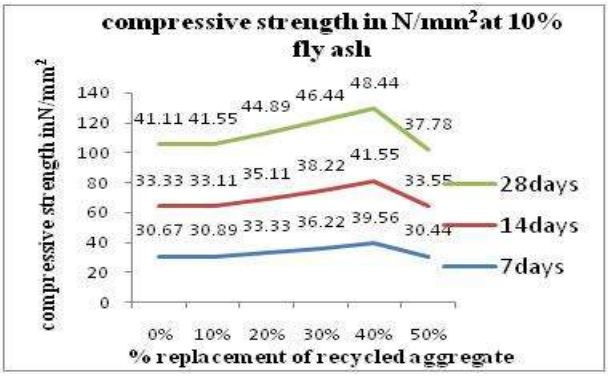
The compressive strength of OPC of different water-cement ratios are determined at ages 7, 14 and 28 days in the compression testing machine. The analysis of results of compressive strength values for different replacements percentages of recycled aggregate and for fly ash at 0%,5%,10%are shown in the graph1,graph2,graph3 respectively



Graph1: Compressive strength vs %replacement of recycled aggregate



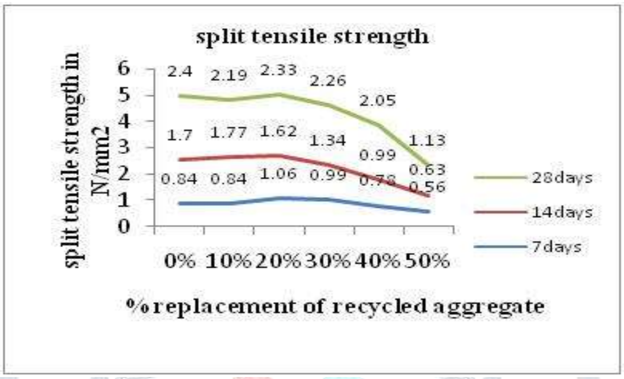
Graph2: Compressive strength vs %replacement of fly ash and recycled aggregate



Graph3: Compressive strength vs %replacement of fly ash and recycled aggregate

Split Tensile Strength

The split tensile strength values for OPC mix with replacements of recycled aggregates at the ages of 7days, 14days, and 28days.The analysis of results of split tensile strength values for different replacements percentages of recycled aggregate and for fly ash at 0%,5%,10% are shown in the graph4,graph5,graph6 respectively.



Graph4: Split tensile strength vs %replacement recycled aggregate

Graph5: Tensile strength vs % replacement of recycled aggregate

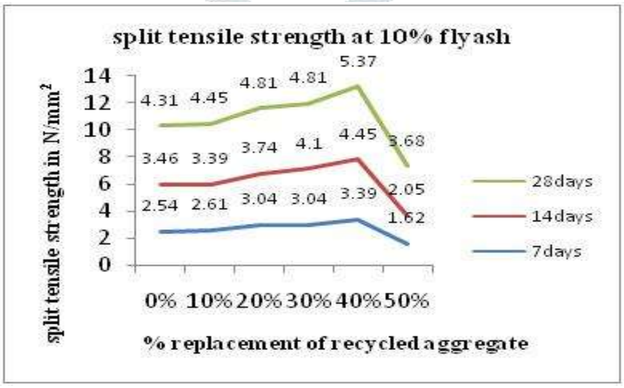
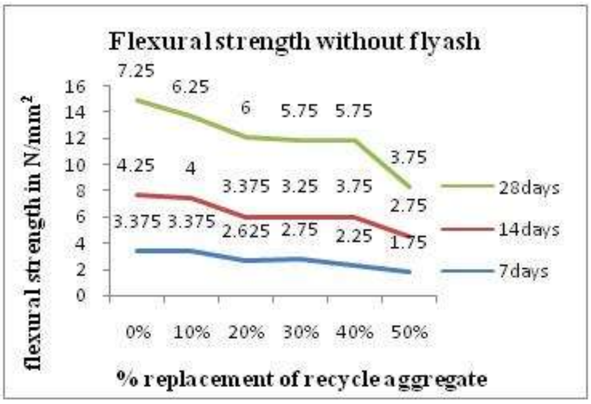


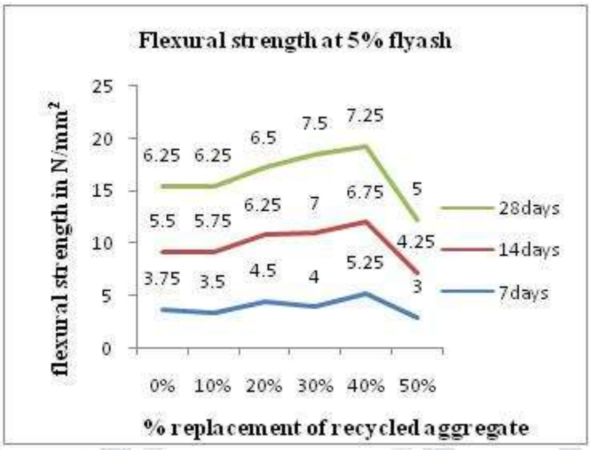
Figure 6: Tensile strength vs % replacement of recycled aggregate

Flexural Strength Test:

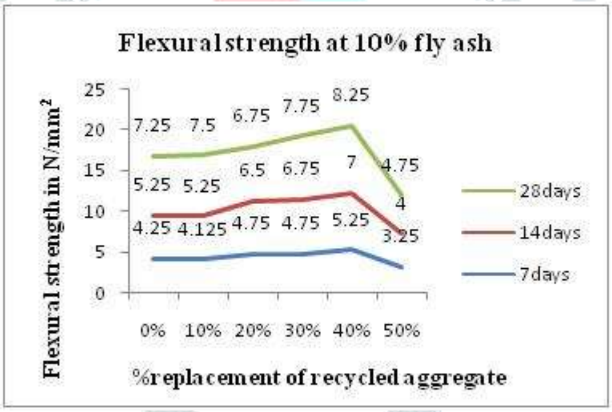
The flexural strength values for OPC mix with replacements of recycled aggregates at the ages of 7days, 14days, and 28days.The analysis of results of flexural strength values for different replacements percentages of recycled aggregate and for fly ash at 0%,5%,10% are shown in the graph7,graph8,graph9 respectively



Graph7: Flexural strength vs % replacement of recycled aggregate



Graph8: Flexural strength vs % replacement of recycled aggregate



Graph9: Flexural strength vs % replacement of fly ash and recycled aggregate

IV. CONCLUSIONS

1 Without adding fly ash to the cement with partial replacements of recycled aggregate the strength decreases.
2 By adding 10% of fly ash to the cement with partial replacements of recycled aggregate the strength slightly increases.
3 The compressive strength split tensile, flexural strength of concrete at different days it reduced at certain replacements.
4 At the level of 50% the test does not attain any strength.
5 The crack width , strengths are measured for concrete and recycled aggregate are measured
6 When compared to normal cement values by adding of fly ash to the cement the strength values increased.
7 We can replace the material up to 10%-20% where it loss some strength when compared to other proportions.
8 The experimental results of concrete beams, are adopt for small house constructions
9 Hence it used for less importance of work, by utilizing the environment waste where the material available in bulk amount.

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