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A STUDY ON BEHAVIOUR OF RECYCLED COARSE AGGREGATE IN TERNARY BLENDED CONCRETE WITH SILICA FUME & FLY ASH

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Abstract*— Utilization of industrial wastes and construction wastes in concrete production resolves the major problems in waste disposal and thereby reducing the environmental impacts. There are number of industrial and construction wastes like steel slag, copper slag, fly ash, imperial smelting furnace slag, blast furnace slag, foundry sand, coal bottom ash, Ferro chrome slag, silica fume, palm oil clinker, broken bricks and crushed concrete etc. Out of these materials recycled aggregate, fly ash and silica fume were used in this study. In this project the strength characteristics of two groups having 50 % and 100 % recycled aggregates as a replacement of coarse aggregates were studied for ternary blend concrete mix. In both mix group's fine aggregate was also partially replaced with Foundry sand. The ternary blend was developed by partial replacement of cement with two mineral admixtures Fly ash and silica fume. The cement has been replaced by fly ash consequently in the range of 0%, 10%, 20% and 30% by weight of cement and 2.5% of silica fume in common for M-30 mix. Concrete mixtures were produced, tested and compared in terms of compressive and split tensile strength with the conventional concrete for standard ages.

1. INTRODUCTION

1.1 Construction waste in India:

Now-a-days India has taken a major application on developing the infrastructures such as express highways, power projects, metro projects, irrigation structures and industrial structures etc., to meet the needs of globalization. As the industrialization increases the amount of waste material produced is also increasing, which is became an ecological issue and must be managed. To protect the environment efforts are being made for using industrial waste in concrete for conserving natural resources and reduce cost of constructional materials. The consumption of waste in concrete makes it inexpensive. The reuse of wastes in concrete and supposed to be as the best ecological option for taking care of issue of waste disposal. By partial replacement of cement with industrial waste reduces cement content and cost of construction. There are different industrial wastes, in this study fly ash and silica fume were used as a partial replacement for cement.

1.2 Ternary Blended concrete:

Ternary concrete mixtures include three different cementitious materials. The combinations of Portland cement with supplementary cementitious Materials like slag cement, fly ash, metakaolin, rice husk ash, glass powder or silica fume are considered as ternary mixture. An attempt has made to study the strength properties of ternary blended concrete using mineral admixtures like Fly ash and Silica fume. The influence of foundry sand and recycled aggregate on the ternary blend was also studied in this project. The cement has been replaced by fly ash accordingly in the range of 0%, 20% and 30% by weight of cement and 2.5% of silica fume in common for M-30 and M-40 mix. Concrete mixtures were produced, tested and compared in terms of compressive, split tensile strength and flexural strength with the conventional concrete for standard ages.

1.3 Benefits of recycled coarse aggregate in ternary blended concrete:

The usage of recycled aggregate as replacement to coarse aggregate in concrete has the benefits in the aspects of cost and reduction of pollution from construction industry. The cost of concrete manufacturing will reduce considerably over conventional concrete by including recycled aggregate along with silica fume and fly ash since it is readily available at very low cost and there-by reducing the pollution or effective usage of construction and industrial waste.

2. LITERATURE REVIEW

2.1 Deepa A Sinha(2012):

The essential focus of his investigation was to explore the properties of ternary blended bond melding silica seethe, metakaolin and GGBS. The properties investigated fuse usefulness, compressive quality and flexural quality. In this endeavor, he had displaced cement by ternary blend of fly fiery debris, metakaolin, silica rage, GGBS up to 30% to choose the convenience, compressive quality and flexural quality by using beneficial cementitious materials. He found that displacing of bond with Fly-slag gives higher quality than customary concrete at 90days. Supplanting of cement with 15% fly-powder and 15% metakaolin gives the best results as stand out from various mixes for compressive nature of 28 days.

2.2 A.K. Mullick (2007):

In his paper he delineates the traits of cementitious structures required to meet the different necessities of solidarity and sturdiness of bond and highlights the upsides of part substitution of OPC by fly red hot garbage, granulated slag and scaled down scale silica - either freely or in blend in ternary blends. Solid blend with the modern squanders like fly powder, slag and silica smolder are all the more durable in stubborn condition.

2.3 Basar and Aksoy (2012):

He had stated that waste foundry sand can be viably used in making unprecedented ready-mix concrete as partial supplanting of fine aggregate with no unfavorable mechanical, micro-structural and ecological effect, but substitution should not exceed 20%.

3. MATERIALS USED

3.1 Cement:

In this project Ordinary Portland Cement of 53 Grade Ultra Tech Company, available in the local market was used. Care has been taken to see that the cement was taken from single batching in air tight bags to prevent it from being effected by moisture conditions. Thus cement procured was Tested for physical requirements in accordance with IS: 169-1989.

Tests on Cement

i) Specific gravity
ii) Initial and final setting time
iii) Fineness of cement

Table 3.1: Properties of cement

S.No	Properties	Remarks
1.	Specific Gravity	3.15
2.	Initial setting time	40 min
3.	Final setting time	550 min

3.2 Fine aggregate and Coarse aggregate:

Locally available river sand in the market was used in the investigation. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity in accordance with IS: 2386-1963.

For coarse aggregate crushed aggregates of less than 12.5mm size produced from local crushing plants were used. The aggregate exclusively passing through 12.5mm sieve size and retained on 10mm sieve is selected. The aggregates were tested for their physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386-1963.

Tests on aggregates

i) specific gravity
ii) Water absorption
iii) Bulk density

Table 3.2: Properties of aggregate

S.No.	Property	Fine aggreate	Coarse aggregate
1.	Specific gravity	2.65	2.74
2.	Water absorption	0.6%	1.5%
3.	Bulk density(kN/m^3)	14.97	15.18

3.3 Water:

Water plays a vital role in achieving the strength of concrete. Water participates in chemical reaction with cement and cement paste is formed and binds with coarse aggregate and fine aggregates. If water content exceeds permissible limits it may cause bleeding. If less water is used, the required workability is not achieved. Potable water fit for drinking is required to be used in the concrete and it should have pH value ranges between 6 to 9.

3.4 Recycled Coarse Aggregates:

The waste from the demolition of concrete structures are collected, aggregates are separated as recycled aggregates. The proposed recycled aggregates are used in the concrete mix for this project. The recycled aggregates are conformed by means of grading. As per requirement 20 mm angular recycled coarse aggregates are selected for partial substitution.

Figure 3.1: Recycled Coarse Aggregate

3.5 Foundry sand:

Foundry sand obtained from aluminium casting industry used as a replacement for fine aggregate in substitution rate of 20%, using M30 mix.

Figure 3.2: Foundry Sand

3.6 Fly ash

Fly ash particles are usually spherical and size range from 0.5 µm to 300 µm. In this project, Class F fly ash was used having a lower content of Cao and exhibit Pozzolonic properties.
The physical properties of fly ash were given in the table.

Table 3.3: Physical Properties of Fly ash

Property	Value
Specific gravity	2.21
Mean grain size (µm)	20
Colour	Grey to black

Figure 3.3: Fly Ash

3.7 Silica fume:

It is waste by product in the manufacturing of basic silica, like wise referred as micro silica or dense silica. It is a pozzolanic material having size under 1µm and circular shape ultrafine material. The particle surface is around 20,000m^2/kg. It is of light to dull dark shading colour and most part acts as filler material in fine aggregates, in this way to improve the various properties of concrete.

Figure 3.4: Silica Fume

4. METHODOLOGY

4.1 Experimental procedure

Different types mixes were prepared by M30 grade ternary blended concrete mix of different fly ash levels 0%, 10%, 20%, 30% replacement of cement and silica fume of 2.5% were prepared. Two mix groups with 50% RA and 100% RA were cast in this study. Sand was partially replaced with foundry sand in both mix groups. The mix proportion of different materials is given in the table. Here A1, A2, A3, A4 indicates ternary blended concrete group of

50% recycled aggregate and B1, B2, B3, B4 indicates ternary blended concrete group of 100% recycled aggregate. The two groups were compared with conventional concrete (CC).

4.2 Concrete mix for M30 Grade:

In the present study, the mix design for M30 grade concrete was done as per code (IS 10262-2009). The stipulations for design and data for the mix proportions are discussed below.

Table 4.1: Details of aggregate replacement for mix codes

Mix	Coarse aggregate (%)	Recycled aggregate (%)	Cement (%)	Silica fume (%)	Fly ash (%)	Fine aggregate (%)	Foundry sand (%)
CC	100	0	100	0	0	100	0
A1	50	50	100	0	0	100	0
A2	50	50	87.5	2.5	10	80	20
A3	50	50	77.5	2.5	20	80	20
A4	50	50	67.5	2.5	30	80	20
B1	0	100	100	0	0	100	0
B2	0	100	87.5	2.5	10	80	20
B3	0	100	77.5	2.5	20	80	20
B4	0	100	67.5	2.5	30	80	20

Table 4.2: Mix Proportion for different percentages

Mix	Coarse aggregate (%)	Recycled aggregate (%)	Cement (%)	Silica fume (%)	Fly ash (%)	Fine aggregate (%)	Foundry sand (%)
CC	100	0	100	0	0	100	0
A1	50	50	100	0	0	100	0
A2	50	50	87.5	2.5	10	80	20
A3	50	50	77.5	2.5	20	80	20
A4	50	50	67.5	2.5	30	80	20
B1	0	100	100	0	0	100	0
B2	0	100	87.5	2.5	10	80	20
B3	0	100	77.5	2.5	20	80	20
B4	0	100	67.5	2.5	30	80	20

5. TESTS ON CONCRETE

5.1 Workability:

The property of fresh concrete which is indicated by the amount of useful internal work required to fully compact the concrete without bleeding or segregation in the finished product. Workability is one of the physical parameters of concrete which affects the strength and durability as Well as the cost of labor and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e without bleeding or Segregation.

5.2 Determination of workability by slump-cone test:

It is the most usually utilized technique for estimating consistency of concrete which can be utilized either in research facility or at site of work. It's anything but a reasonable strategy for wet or extremely dry concrete. It doesn't gauge all variables adding to functionality, nor is it constantly illustrative of the placability of the concrete. Be that as it may, it is utilized advantageously as a control test.

Figure 5.1: Slump Cone Test

Table 5.1: Slump test results

Mix	Recycled aggregate (%)	Silica fume (%)	Fly ash (%)	Foundry sand (%)	Slump value (mm)
CC	0	0	0	0	60
A1	50	0	0	0	55
A2	50	2.5	10	20	80
A3	50	2.5	20	20	95
A4	50	2.5	30	20	100
B1	100	0	0	0	55
B2	100	2.5	10	20	80
B3	100	2.5	20	20	95
B4	100	2.5	30	20	100

5.3 Determination of workability by Compacting Factor Test:

Figure 5.2: Compaction Factor test

To measure the workability of concrete we can perform the compaction factor test also, due to the compaction factor test is the most effective test to measure the concrete workability. This test is planned fundamentally for use in the laboratory yet it very well may be likewise utilized in the field. After the slump cone test this test is the best test performed to the measure the concrete workability, and it is the test which gives the values extremely exact, it is the sensitive test when contrasted with the slump cone test and much helpful for concretes where the concrete workability is low and when we utilize the compaction by vibration.

Table 5.2: Compaction factor test results

Mix	Recycled aggregate (%)	Silica fume (%)	Fly ash (%)	Foundry sand (%)	Compaction factor
CC	0	0	0	0	0.93
A1	50	0	0	0	0.88
A2	50	2.5	10	20	0.92
A3	50	2.5	20	20	0.94
A4	50	2.5	30	20	0.93
B1	100	0	0	0	0.89
B2	100	2.5	10	20	0.92
B3	100	2.5	20	20	0.93
B4	100	2.5	30	20	0.92

5.4 Testing of cube specimens

The cube specimens cured as explained above are tested as per standard procedure after removal from curing tank and allowed to dry under shade. The cube specimens are tested for

- Compressive strength test
- Split tensile strength
- Flexural strength

6. RESULTS AND DISCUSSIONS

6.1 General

The compressive strength, split tensile strength and flexural strength tests are performed for different mix proportions A1, A2, A3, A4 in group 1 with 50% recycled coarse aggregate and B1, B2, B3, B4 in group II with 100% recycled coarse aggregate. The test results are compared with conventional concrete (CC) and the results are given in this chapter. Here CC, A1, A2, A3, A4, B1, B2, B3, B4 represents the following proportions.

Table 6.1: Mix proportions of different materials

Mix	Recycled aggregate (%)	Silica fume (%)	Fly ash (%)	Foundry sand (%)
CC	0	0	0	0
A1	50	0	0	0
A2	50	2.5	10	20
A3	50	2.5	20	20
A4	50	2.5	30	20
B1	100	0	0	0
B2	100	2.5	10	20
B3	100	2.5	20	20
B4	100	2.5	30	20

6.2 Compressive strength results:

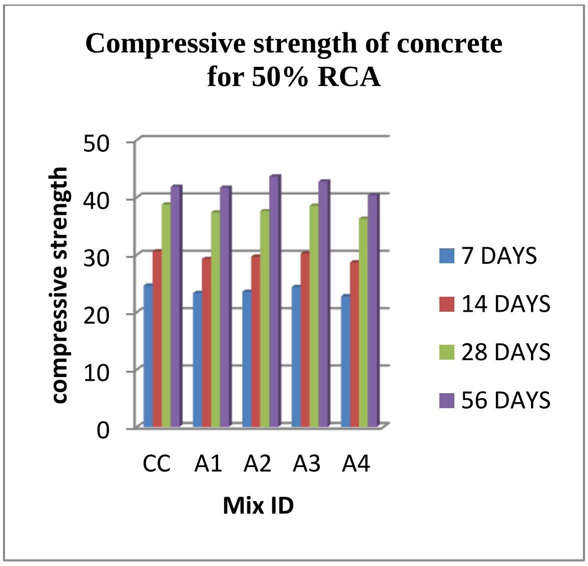
In this study, it was found that the compressive strength of concrete incorporating fly ash, silica fume, foundry sand and recycled aggregate depended on the percentage of these materials used. The compressive strength of concrete for 7days, 14 days, 28 days and 56 days of cured concrete specimen are shown in table below. Concrete specimen of size 150x150x150 mm was used for compression test. Two specimens with each proportion were subjected to compression strength test.

Figure 6.1: Compression testing

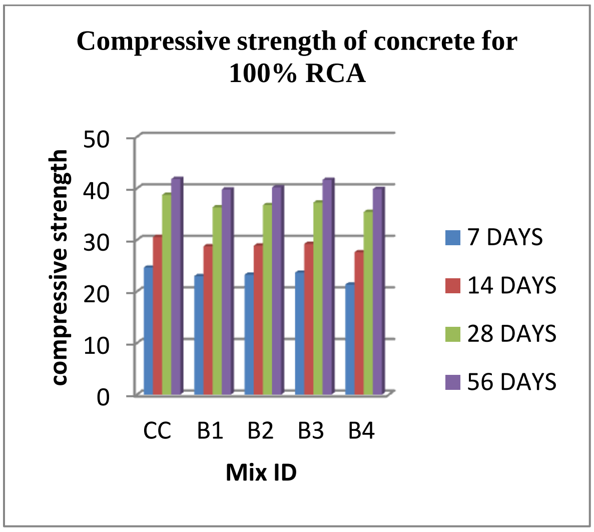
Table 6.2: Compressive strength test results

Mix- ID	Compressive Strength			
	7 DAYS	14 DAYS	28 DAYS	56 DAYS
CC	24.63	30.58	38.75	41.82
A1	23.33	29.26	37.35	41.69
A2	23.54	29.67	37.59	43.63
A3	24.37	30.21	38.54	42.74
A4	22.75	28.65	36.26	40.36
B1	22.97	28.75	36.33	39.79
B2	22.36	28.89	36.76	40.2
B3	23.65	29.22	37.25	41.65
B4	21.34	27.61	35.43	39.87

Graph6.1: compressive strength graph for 50% recycled coarse aggregate



Graph 6.2: Compressive strength graph for 100% recycled coarse aggregate



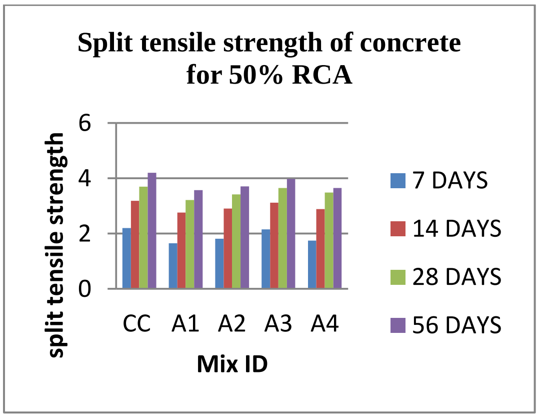
6.3 Split tensile strength results:

Split tensile test was conducted as per IS 516:1959. A cylindrical concrete specimen of diameter 150 mm and height 300 mm is used. The tensile strength of concrete specimen cured at 7, 14, 28 and 56 days are shown in table. Tensile strength is varying with mix proportion.

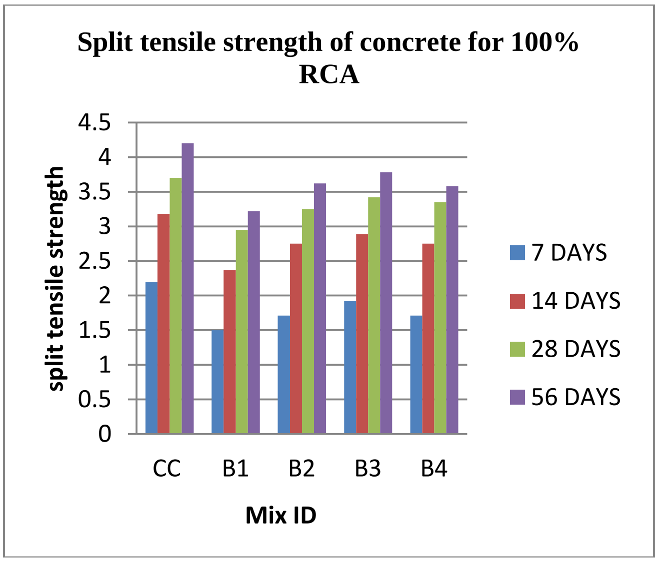
Table 6.3: Split tensile strength test results

Mix id	Flexural strength			
	7 DAYS	14 DAYS	28 DAYS	56 DAYS
CC	2.8	3.2	3.9	4.2
A1	2.2	2.75	3.26	3.5
A2	2.52	2.83	3.4	3.71
A3	2.67	3.13	3.76	4.1
A4	2.4	2.7	3.62	3.82
B1	1.98	2.58	3.12	3.32
B2	2.3	2.63	3.26	3.51
B3	2.48	2.89	3.58	3.91
B4	2.36	2.68	3.43	3.62

Graph 6.3: Split tensile strength graph for 50% recycled coarse aggregate



Graph 6.4: Split tensile strength graph for 100% recycled coarse aggregate



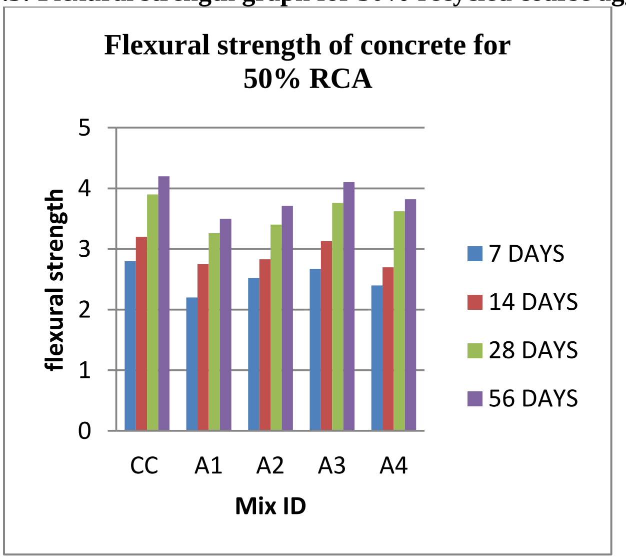
6.4 Flexural strength results:

Flexural strength test is carried out on concrete beam specimen of size 50x10x10 mm. Flexural strength test is conducted as per IS 516:1959. Three specimen of each percentage of mix proportions is subjected for flexural test. The flexural strength at 7, 14, 28 and 56 days of cured specimen is shown in table.

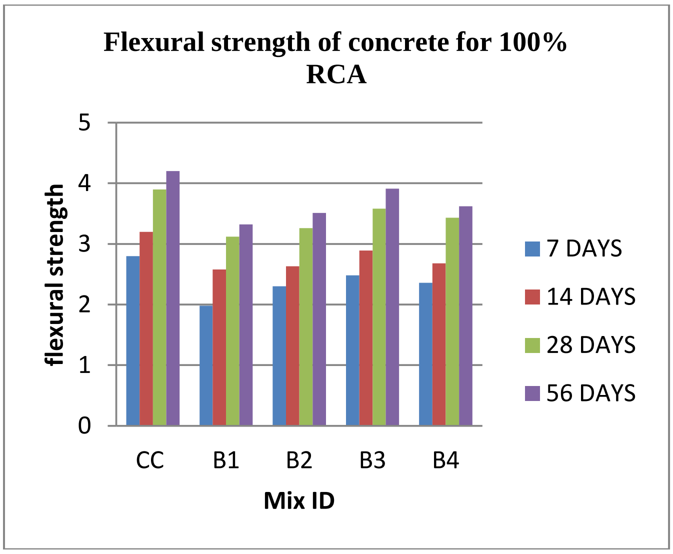
Table 6.4: Flexural strength test results

Mix id	Flexural strength			
	7 DAYS	14 DAYS	28 DAYS	56 DAYS
CC	2.8	3.2	3.9	4.2
A1	2.2	2.75	3.26	3.5
A2	2.52	2.83	3.4	3.71
A3	2.67	3.13	3.76	4.1
A4	2.4	2.7	3.62	3.82
B1	1.98	2.58	3.12	3.32
B2	2.3	2.63	3.26	3.51
B3	2.48	2.89	3.58	3.91
B4	2.36	2.68	3.43	3.62

Graph 6.5: Flexural strength graph for 50% recycled coarse aggregate



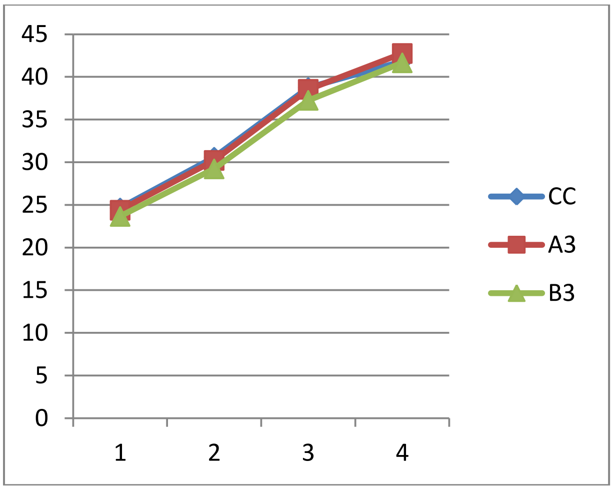
Graph 6.6: Flexural strength graph for 100% recycled coarse aggregate



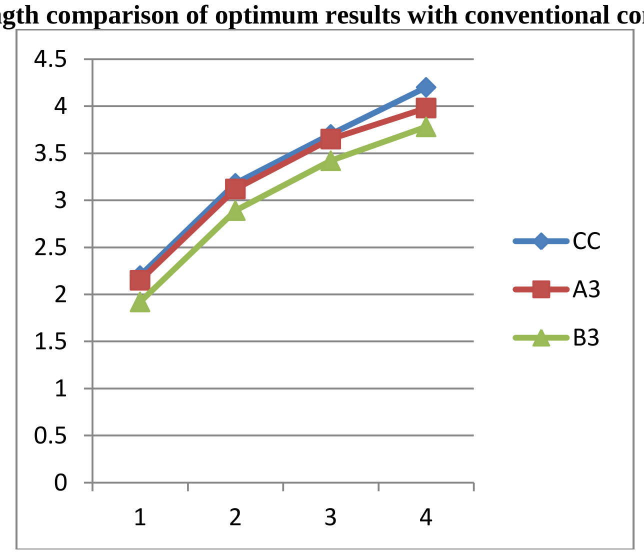
6.5 Strength comparison of optimum results for 28 days

The optimum test results for compressive strength, split tensile strength and flexural strength has been compared with conventional concrete for 28 days and the corresponding has been shown below.

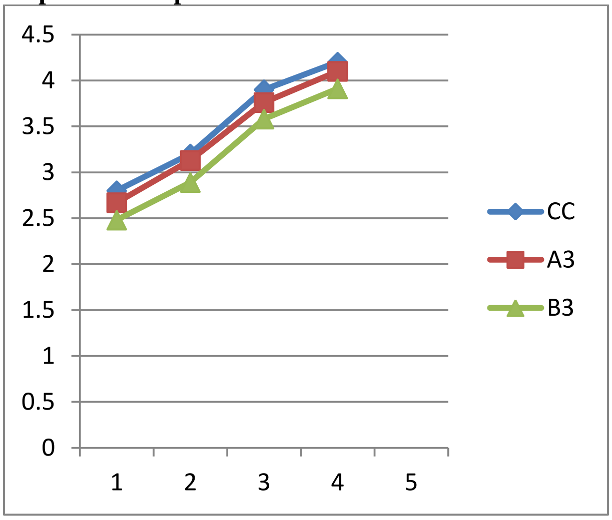
Graph 6.7: Compressive strength comparison of optimum results with conventional concrete for 28 days



Graph 6.8: Split tensile strength comparison of optimum results with conventional concrete for 28 days



Graph 6.9: Flexural strength comparison of optimum results with conventional concrete for 28 days



7. SUMMARY AND CONCLUSIONS

7.1 General:

The basic objective of the study is to prepare a concrete much more stable and durable than the conventional by replacing aggregates both coarse and fine. Mix designs for all the replacements of materials has done and a total of 90 specimens (42 cubes, 42 cylinders, 6 beams) are prepared and tested in the aspect of strength calculation and also comparisons has done.

7.2 Conclusions:

In this experimental study ternary blended recycled aggregate concrete strength characteristics were studied and the following conclusions were arrived:

1. The strength of the concrete irrespective of percentage of recycled aggregate and admixtures in concrete increased when age increases.
2. The 50% and 100% replacement of natural coarse aggregate with recycled aggregate showed an average 4% and 7% reduction in strength respectively.
3. The replacements of cement with fly ash and silica fume, fine aggregate with foundry sand affect the strength of the concrete in earlier age and regain the strength in later age.
4. The 20% replacement with fly ash didn't affect the concrete strength in 50% recycled aggregate concrete and 2% strength variation was found in 100% recycled aggregate concrete.
5. For 30% replacement with fly ash shows significant strength reduction in 50% and 100% recycled aggregate concrete.
6. The other strength parameters like tensile strength and flexural strength also show the comparable variation as showed in compressive strength.
7. The elastic modulus of concrete was significantly affected when replacement percentage of aggregate and cement increases.
8. Based on the above results and discussion the concrete with 50% recycled aggregate, 20% fly ash, 2.5% silica fume and 20% foundry sand is acceptable in terms of utilizing waste material which leads to control the environmental problem and it can be tried in the field by compromising 7% strength.

FUTURE SCOPE OF WORK

There is a vast scope of research in the recycled aggregate usage in concrete, the possible research investigations that can be done are mentioned below:

- It can become a new practice in construction field of replacing conventional concrete with ternary blended concrete and recycled coarse aggregate.
- More of research can be done to increase the strength of concrete by adding super plasticizer.
- Research on ternary blended concrete in hot and cold weather condition can be done.
- Many other properties of ternary blended concrete can be study such as chemical and physical properties.

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