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Study the Effect of Fly Ash, Silica Fume and Recycled Aggregate on the Compressive Strength of Concrete

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Abstract

Concrete behaviour is affected by the packing degree of the concrete components, making it necessary for engineers working to consider, in detail, particle packing concepts and their influence on concrete behaviour for being able to select suitable aggregate materials. It is believed that particle packing efficiency has an enormous effect on the properties of fresh concrete and hardened concrete. Ultimate target of the project will be promoting the development and production of optimized concrete composites based on combination of an optimized aggregate design and optimized binder compositions. Influence of both size and shape of aggregates on particle packing mechanism as well as on properties of concrete will be assessed. Apart from strength, an increase in packing density of the cementitious materials would also improve the overall performance of the concrete.

Keywords: *Packing Method, Compressive Strength, Recycled Aggregate,*

1. Introduction

The fly ash, is similar to other pozzolans, affects the technical properties of the concretes and mortars by its pozzolanic characteristics and filler effect. It is known that the filler effect of the fly ash is more effective than the pozzolanic characteristics when affecting the properties of concrete. The fly ash have pozzolanic activity because they contain surplus amount of silica, alumina and iron oxide; they have a structure with very fine particles and amorphous. Materials with silica and alumina in the structure of fly ashes make additional calcium silicate hydrate (C-S-H) by reacting with calcium hydroxide occurring as a consequence of hydration of the cement. Micro silica is a by-product of Electric Arc furnace used in the production of ferrosilicon and silicon industries. The average grain size of micro silica is less than 0.1 microns. It is a very fine active artificial pozzolanic and cementitious material. The main field of application is as pozzolanic material for high performance concrete. Today, there are critical shortages of natural resources in present scenario. Production of concrete and utilization of concrete has rapidly increased, which results in increased consumption of natural aggregate as the largest concrete component.

A possible solution of these problems is to recycle demolished concrete and produce an alternative aggregate for structural concrete in this way. RCA reduces the impact on landfills; decreases energy consumption and can provide cost savings. However, there is totally the beneficial use of RCA in concrete construction.

Recycled aggregate is comprised of crushed, graded in organic particles processed from the material that have been used in the construction and demolition debris. The aim of this project is to determine the strength characteristic of recycled aggregates, for application in structural concrete. Coarse aggregate is important material in concrete for compressive strength, so there is utilization of demolished concrete in place of natural coarse aggregate.

All countries are focusing on sustainable technology that can be adopted for the use of concrete in a better way. So it is felt that the use of cementitious materials improve packing density of concrete which can be a solution to many problems. The cementitious materials including natural aggregates are mixed in different proportions and the mixed concrete is casted into cubes. These specimens are tested for 3, 7 and 28 days of curing.

2. Experimental Work

2.1 Material Used and properties

In this study 25% and 50% of RA was used in making of cubes to test the compressive strength of concrete. We have also used different percentages of Fly ash and Silica fume to observe the effect of it on the concrete compressive strength. This study helps to design the concrete for structural purpose using RA. The percentages of Fly ash and Silica fume used in this work are 25%, 30%, 35%, and 5%, 10%, and 15 % respectively. It can help in a less consumption of traditional resources of concrete and other building materials.Literature review indicates that the partial replacement of cement by fly ash and micro silica in concrete not only solves the problem of their disposal but also improves the basic properties of concrete like decreases permeability to water, compressive strength with higher strength to weight ratio of material, workability, reduction in self weight etc. Also when the coarse aggregate is partially replaced by recycled concrete aggregate there is little or no effect on the durability and strength properties of concrete. In this way recycled aggregate is safely used in construction industry and the burden on the environment is reduced to greater extent.

The materials used in the present investigation are:

- Cement – OPC 43 grade conforming to IS 8112 – 1989
- Fine aggregate – natural sand – IS383 – 1970
- Coarse aggregate – crushed 20mm maximum size – IS383 – 1970
- Fly ash
- Micro silica
- Recycled concrete aggregate
- Portable water
- Super plasticizer (Chryso)

2.2 Mix proportion and Identification

The study on the effect of Fly Ash, Silica Fume and Recycled Aggregate on the Compressive Strength of Concrete is to pack the concrete with optimum density with less number of pores which will increase its strength and durability. This can be obtained through particle packing method. This helps in reducing the usage of Portland cement by replacing a certain amount of cement by different cementitious materials. These materials will attain strength equal to that of the traditional cement bonding.

The materials used for replacing cement are fly ash and micro silica. These two materials are finer than cement and have a better bonding capacity. Coarse aggregate is replaced by recycled aggregate. The literature reviews state that partial replacement of the cementitious materials increases the durability and strength of concrete. The design mixes were prepared and different specimens were casted and later on tested after that the results is drawn and concluded.

Table 1 Mix Proportion

Water	Cement	Fine Aggregate	Coarse Aggregate
147.75	492.5	652.35	1182.17
0.3	1	1.3245	2.4003

The Fly Ash, Silica Fume and Recycled Aggregate (Variable Parameters w/w) are taken as partial replacement of Cement and Natural Aggregate respectively. The design of experiment shows the relation between variable parameters, values, levels and replica of test cubes in 3, 7 and 28 days as conducted for work is shown in table 2 given below:

Table 2 Design of Experiment

Design of Experiment			
Variable Constituents	Level	Value	Replicate
Duration of Curing , days	3	3, 7, 28	3
Fly Ash (% w/w)	3	25, 30, 35	3
Silica Fume (% w/w)	3	5, 10, 15	3
Recycled Aggregate (% w/w)	2	25, 50	2

A properly designed mixture possesses the desired workability for the fresh concrete and the required durability and strength for the hardened concrete. Typically, a mix is about 10 to 15 percent cement, 60 to 75 percent aggregate and 15 to 20 percent water. Entrained air in many concrete mixes may also take up another 5 to 8 percent. Mix Design Proportioning for Mix 2 to Mix 19 consist of:

(i) 25% of Natural aggregate replacement by Recycled aggregate

(ii) 50% of Natural aggregate replacement by Recycled aggregate

The proportioning of mix design for M2 to M10 (25% of coarse aggregate replacement by Recycled aggregate) and M11 to M19 (50% of coarse aggregate replacement by recycled aggregate)

2.3 Concrete Mix Details

The descriptions of Mix Proportion for Mixes M2 to M19 are shown in the table 2.3, where cementitious materials (Fly Ash and Silica Fume) and Recycled Aggregates are used as a partial replacement of Cement and Natural Aggregate respectively. The Super Plasticizer (CHRYSO) is also used as a water reducer 1% to the total volume of concrete.

2.3.2 Mix design details of M1

The Mix design of M25 grade Concrete using Ordinary Portland Cement + Fine Aggregate + Coarse Aggregate + Super Plasticizer is shown in table below:

Table 2.2 Mix design details of M1

MATERIALS	QUANTITY (kg/m^{3})
Cement	492.5
Fine aggregate	728
Coarse aggregate	1323.98554
Water	147.75
Super plasticizer	3.44

2.3.3 Mix design details of M2

Table 2.3 Mix design details of M2

MATERIALS	QUANTITY (kg/m^{3})
Cement	344.75
Fly ash	123.125
Silica fume	24.625
Fine aggregate	649.020
Coarse aggregate	884.73
Recycled aggregate	294.91
Water	147.75 lit
Super plasticizer	3.44 it

Table 2.4 Description of Mix Proportion

Design Id	Material	Level	Proportion (%)
M2	Fly Ash	1	25
	Silica Fume	1	5
	Recycled Aggregate	1	25
	Super Plasticizer	1	1
M3	Fly Ash	1	25
	Silica Fume	2	10
	Recycled Aggregate	1	25
	Super Plasticizer	1	1
M4	Fly Ash	1	25
	Silica Fume	3	15
	Recycled Aggregate	1	25
	Super Plasticizer	1	1
M5	Fly Ash	2	30
	Silica Fume	1	5
	Recycled Aggregate	1	25
	Super Plasticizer	1	1
M6	Fly Ash	2	30
	Silica Fume	2	10
	Recycled Aggregate	1	25
	Super Plasticizer	1	1
M7	Fly Ash	2	30
	Silica Fume	3	15
	Recycled Aggregate	1	25
	Super Plasticizer	1	1
M8	**Fly Ash**	**3**	**35**
	Silica Fume	**1**	**5**

	Recycled Aggregate	**1**	**25**
	Super Plasticizer	**1**	**1**
M9	Fly Ash	3	35
	Silica Fume	2	10
	Recycled Aggregate	1	25
	Super Plasticizer	1	1
M10	Fly Ash	3	35
	Silica Fume	3	15
	Recycled Aggregate	1	25
	Super Plasticizer	1	1
M11	Fly Ash	1	25
	Silica Fume	1	5
	Recycled Aggregate	2	50
	Super Plasticizer	1	1
M12	Fly Ash	1	25
	Silica Fume	2	10
	Recycled Aggregate	2	50
	Super Plasticizer	1	1
M13	Fly Ash	1	25
	Silica Fume	3	15
	Recycled Aggregate	2	50
	Super Plasticizer	1	1
M14	Fly Ash	2	30
	Silica Fume	1	5
	Recycled Aggregate	2	50
	Super Plasticizer	1	1
M15	Fly Ash	2	30
	Silica Fume	2	10
	Recycled Aggregate	2	50
	Super Plasticizer	1	1
M16	Fly Ash	2	30
	Silica Fume	3	15
	Recycled Aggregate	2	50
	Super Plasticizer	1	1
M17	Fly Ash	3	35
	Silica Fume	1	5
	Recycled Aggregate	2	50
	Super Plasticizer	1	1
M18	Fly Ash	3	35
	Silica Fume	2	10
	Recycled Aggregate	2	50
	Super Plasticizer	1	1
M19	Fly Ash	3	35
	Silica Fume	3	15
	Recycled Aggregate	2	50
	Super Plasticizer	1	1

3 Test Program

The main aim of this experimental work is to study the effect of Fly Ash, Silica Fume and Recycled Aggregate on the Compressive Strength of Concrete.

3.1 Tests on Materials

The various types of tests conducted on cement, fine aggregate and coarse aggregate and the results are tabulated in table 3.1, table 3.2 and table 3.3 respectively.

Table 3.1 below shows the different types of tests carried out on cement.

Table 3.1 Test on Cement

Test	Values
Specific Gravity	3.15
Fineness	97.33%
Consistency	31%
Initial Setting Time	34 min

Table 3.2 & 3.3 below shows the different types of tests carried out on fine aggregate, coarse aggregate.

Table 3.2 Test on Fine aggregates

Test	Values
Specific Gravity	2.68
Free Surface Moisture	2%
Gradation	Zone II

Table 3.3 below shows the different types of tests carried out on coarse aggregate.

Table 3.3 Test on Coarse Aggregates

Test	Values
Specific Gravity	2.74
Aggregate Impact Value	32.73%
Aggregate Crushing Values	18.90%

4 Concrete Tests

4.1 Fresh Concrete test

The tests conducted on fresh concrete are shown below in Table 4.1.

Table 4.1 Test on fresh concrete

Test	Value
Slump	85 mm

4.2 Hardened Concrete test

The tests were conducted on hardened concrete to determine its compressive strength. After casting the specimen, the curing has been done properly to achieve the target strength. The Compressive Strength tests were conducted to know the hardened properties of Cubes for Mix 1 to Mix 19 for 3 days, 7 days and 28 days. The focus of the study was to:

- Confine the concrete in an optimum way such that the concrete is tightly confined with minimum of voids in it.
- To obtain the high strength, durable and less permeable concrete by particle packing method.

Fig1. Compression test on Concrete Cubes

Table 4.2 Overall Compressive Strength Of Concrete Cubes

Design Id	Compressive Strength (N/mm^2)		
	3 days	7 days	28 days
M1	17.73	23.34	30.55
M2	17.47	20.00	33.69
M3	16.00	20.96	32.52
M4	16.79	21.34	28.94
M5	14.97	20.69	35.12
M6	15.56	23.01	33.50
M7	17.93	22.38	27.92
M8	**18.58**	**24.09**	**36.23**
M9	18.82	23.87	32.39
M10	17.13	23.88	30.28
M11	15.23	21.00	31.67

M12	14.34	20.96	29.89
M13	16.98	21.09	26.0
M14	13.08	19.20	32.43
M15	12.98	19.90	32.72
M16	13.00	18.75	23.56
M17	15.00	21.88	33.15
M18	14.20	15.02	29.20
M19	13.99	17.19	24.32

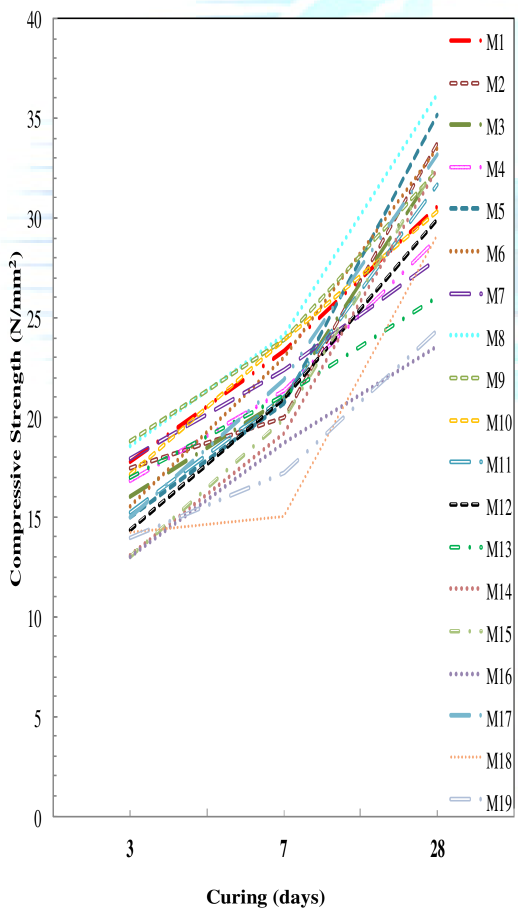


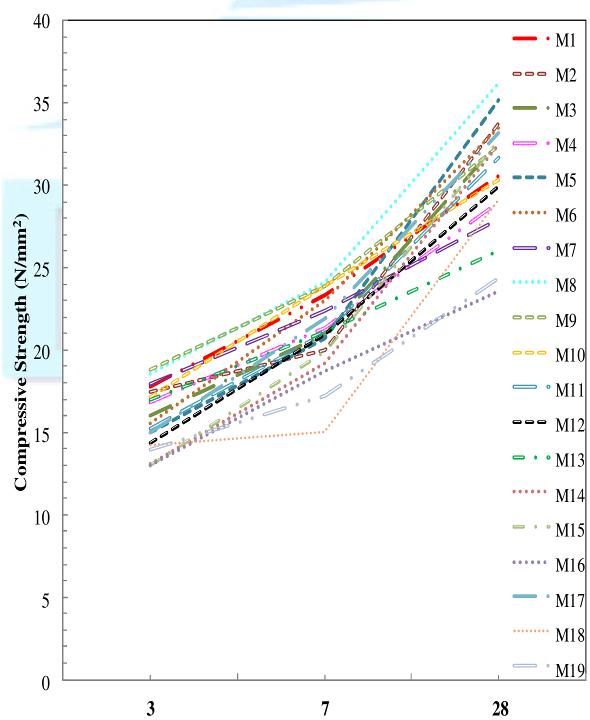
Figure 2 Overall Compressive Strength of Concrete Cubes

It is also seen that when we increase the percentage of fly ash from 25% to 35% with 5% of silica fume, the compressive strength of concrete cube increases. Also the compressive strength of concrete cube decreases when we increase the percentage of silica fume from 5% to 15% when added with fly ash.

From the graph it is clear that the mix 4, 7, 10, 12, 13, 16, 18 and 19 have compressive strength below the normal mix. From table 7.2, it is seen that M8 has got more than 18 percentage of the strength than the normal concrete; this is because the M8 has less amount of silica fume percentage (5%) when added with 35 percentage of fly ash as compared to other mixes.

It is also seen that M16 has got least strength (-22.80%) than other mixes when compared to normal concrete, this is because the amount of weak bound area in recycled aggregate concrete is higher than those in original concrete due to the old mortar attached to coarse aggregate in recycled aggregate particles when used in large amount (50% of replacement of natural aggregate by recycled aggregate). Also according to RILEM Technical Committee (International union of laboratories and experts in construction materials, system and structures) only up to 30 percentage of natural aggregate can be replaced by recycled aggregate for new construction.

Table 4.3 Percentage Increase or Decrease in Compressive Strength of Concrete Cubes



Normal Mix	**Other Mix**	**Increase or Decrease in Strength (%)**
M1 (30.55 N/mm^2)	M2	10.31
	M3	6.47
	M4	-5.24
	M5	14.97
	M6	9.66
	M7	-8.61
	M8	**18.6**
	M9	6.05
	M10	-0.86
	M11	3.67
	M12	-2.16
	M13	-14.89
	M14	6.17
	M15	7.1
	M16	-22.8
	M17	8.51
	M18	-4.4
	M19	-20.37

5 Conclusions

The performance of concrete with different proportions of admixtures and recycled aggregate was studied in depth. The compressive strength test was carried out and following conclusions are drawn:

1. When we increase the percentage of the ground fly ash from 25% to 35%, the strength of concrete is increased.
2. There is a decrease in the strength when the percentage of silica fume increases from 5 to 15% when added with Fly Ash.
3. Study shows that this deficiency could be overcome by using silica fume in small quantity when added with fly ash.
4. By using fly ash and up to 5% silica fume in the recyclable aggregate concrete we can get even more strength then natural aggregate concrete.
5. From table 4.3, it can be seen that M8 shows higher strength (18.6 N/mm^2) as compared to normal mix.
6. According to our study, M8 has best proportion of mix percentage to use.

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