High Density Concrete Using Fly Ash, Micro Silica and Recycled Aggregate – An Experimental Study

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Abstract

Concrete is the most important engineering material and the addition or replacement of some of the materials may change the properties of the concrete. In recent years a lot of research work has been carried out in order to obtain more durable and long term performance of concrete structures in the dynamic environment.
In this experimental study, concrete mixes of different proportions with Fly ash, micro silica and recycled concrete aggregate are prepared and tested after different days of moisture curing and what is the effect of these materials on the strength of concrete is studied We are replacing the cement by Fly ash and Micro silica with 0%, 5%, 10% and 15% and the coarse aggregate with Recycled Concrete Aggregate with 0%, 5%, 10% and 15%. Here the grade of concrete is M 25. The experimental investigation is carried out and finally the strength of each mix is calculated and the results are produced.

Keywords: **fly ash, micro silica, recycled concrete aggregate, partial replacement**

1. Introduction

High density or heavyweight concrete is concrete with a density greater than 2600kg/m^3. Its primary use is in radiation shielding, either in nuclear power plants or in radiation therapy units. It can also be used as ballast in offshore locations such as pipelines.
High density concretes should be specified to BS 8500-1 as a designed or a prescribed concrete in the same way as normal density concrete, with an additional clause specifying the target density. BS 8500-1 states that the density for heavyweight concrete should not be less than 130kg/m^3 less than the specified target density. There is no upper limit on the density.
Heavyweight concretes can be designed in the same way as normal weight concretes, but the additional self weight should be taken into account. They can be transported and placed in the same way as normal weight concretes but the additional density means that smaller volumes can be transported and placed

2. Particle Packing

Concrete behavior 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 behavior 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.

3. Fly ash

Fly ash is an industrial waste material having pozzolanic properties. In construction sector fly ash is used in the production of cement. It is used as a base and sub-base material in high way construction, as a filling material in dams. In retaining walls and for the production of light construction materials. Fly ash is similar to other pozzolans, affects the technical properties of the concrete and mortars by its pozzolanic properties and filler effect. The fly ashes have pozzolanic activity because they contain surplus amount of silica, alumina and iron oxide, they have a very fine particle structure. Furthermore, the fact that fly ash contains the fine particles which increase the compactness of concrete and fills the spaces in the concrete mortar. Using fly ash in the concrete generally increases the workability, decreases the bleeding, decreases the hydration temperature and reduces the permeability of the hardened concrete. The physical and chemical properties of fly ash are shown in table 1 below.

Table 1: Properties of fly ash

Physical properties	
Colour	Whitish grey
Specific gravity	2.288
Avg. particle size	6.92 microns
Chemical properties	
Silica	59%
Alumina	21%
Ferric oxide	3.70%
Calcium oxide	6.90%

Magnesium oxide	1.40%
Potassium oxide	0.90%
Sulphur oxide	1.00%

4. Micro Silica

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 < 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. The physical and chemical properties of micro silica are shown in table 2 below.

Table 2: Properties of micro silica

Physical properties	
Odour	Odourless
Colour	White colour powder
Specific gravity	2.63
pH of 5% solution	6.90
Chemical properties	
Silica	99.886%
Alumina	0.043%
Ferric oxide	0.040%
Calcium oxide	0.001%
Titanium oxide	0.001%
Potassium oxide	0.001%
Sodium oxide	0.003%

5. Recycled Concrete Aggregate

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.

6. Objective of the Study

- The main objective of the study is to pack the concrete in an optimum way such that the concrete is tightly packed without or less number of pores in it.
- To obtain the high strength and durable concrete by particle packing method.

7. Methodology

The study on the characteristic properties of concrete by the partial replacement of cement and aggregate by fly ash, micro silica and recycled aggregate 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 also 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. Materials were collected for the preliminary tests of concrete. Tests will be conducted for cement, fine aggregate and coarse aggregate. The design mixes will be prepared and different specimens will be casted and later on tested after that the results will be drawn and concluded.

Table 3: Mix Proportion

Water	**Cement**	**Fine Aggregate**	**Coarse Aggregate**
188.79	377.58	495	1171
0.5	1	1.31	3.10

From above table the mix ratio is 1:1.31:3.10

8. Experimental Investigations

The main aim of this experimental work is to study the durability related properties of concrete with different proportions of cementitious materials and to compare them.

9. Materials used in the Present Work

The materials used in the present investigation are;

- Cement – OPC 53 grade conforming to IS 12269 – 1987
- Fine aggregate – natural sand – IS383 – 1970
- Coarse aggregate – crushed 20mm maximum size – IS383 – 1970

- Fly ash
- Micro silica
- Recycled concrete aggregate
- Portable water

10. Tests on Materials

The various types of tests were conducted on cement, fine aggregate and coarse aggregate and the results are tabulated in table 4, table 5 and table 6 respectively.

The table 4 below shows the different types of tests carried out on cement.

Table 4: Test on Cement

Test	Values
Specific Gravity	2.90
Fineness	97.33%
Consistency	31%
Initial Setting Time	34 min

The table 5 below shows the different types of tests carried out on fine aggregate.

Table 5: Test on Fine aggregates

Test	Values
Specific Gravity	2.73
Free Surface Moisture	2%
Gradation	Zone II

The table 6 below shows the different types of tests carried out on coarse aggregate.

Table 6: Test on Coarse Aggregates

Test	Values
Specific Gravity	2.78
Aggregate Impact Value	32.73%
Aggregate Crushing Values	18.90%

We have a total of 13 mixes of concrete with different proportion of fly ash, micro silica and recycled concrete aggregate (0%, 5%, 10% and 15%) on which the experimental investigation is carried out.

- Mix 1- OPC + FA + CA
- Mix 2- OPC + FA + CA + 5% Fly ash
- Mix 3- OPC + FA + CA + 5% Fly ash + 5% Micro silica + 5% Recycled concrete aggregate
- Mix 4- OPC + FA + CA + 5% Fly ash + 10% Micro silica + 10% Recycled concrete aggregate
- Mix 5- OPC + FA + CA + 5% Fly ash + 15% Micro silica + 15% Recycled concrete aggregate
- Mix 6- OPC + FA + CA + 10% Fly ash
- Mix 7- OPC + FA + CA + 10% Fly ash + 5% Micro silica + 5% Recycled concrete aggregate
- Mix 8- OPC + FA + CA + 10% Fly ash + 10% Micro silica + 10% Recycled concrete aggregate
- Mix 9- OPC + FA + CA + 10% Fly ash + 15% Micro silica + 15% Recycled concrete aggregate
- Mix 10- OPC + FA + CA + 15% Fly ash
- Mix 11- OPC + FA + CA + 15% Fly ash + 5% Micro silica + 5% Recycled concrete aggregate
- Mix 12- OPC + FA + CA + 15% Fly ash + 10% Micro silica + 10% Recycled concrete aggregate
- Mix 13- OPC + FA + CA + 15% Fly ash + 15% Micro silica + 15% Recycled concrete aggregate

Where
OPC: Ordinary Portland cement
FA: Fine aggregate
CA: Coarse aggregate

11. Tests on Fresh Concrete

The tests conducted on fresh concrete are shown in table 7

Table 7: Test on fresh concrete

Test	Value
Slump	17 mm
Compacting Factor	0.9

12. Tests on Hardened Concrete

- Compressive Strength Test
- Split Tensile Test

The compression test on hardened concrete was conducted as shown in fig. 1 and 2 and the results are tabulated in table 8

Fig 1: Compression test on Concrete cube (Before load is applied)

Fig 2: Compression test on Concrete cube (After load is applied)

The table 8 below gives the compressive strength of cubes after 28 days of curing in water for all mixes.

Table 8: Compression test on Concrete cubes

Mix	Compressive Strength, N/mm^2
1	30.55
2	31.73
3	34.84
4	31.15
5	27.93
6	32.09
7	35.61
8	33.30
9	27.79
10	31.05
11	35.42
12	31.43
13	30.07

The fig. 3 below gives the compressive strength of concrete after 28 days of curing in water

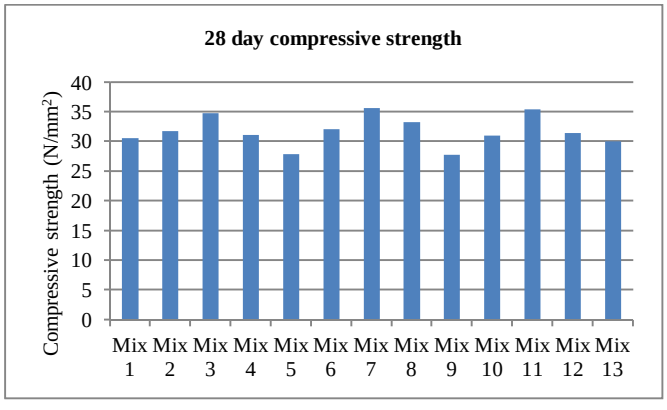

Fig.3: shows the compressive strength of concrete cubes for 28 days

The split tensile test on hardened concrete was conducted as shown in fig. 4 (a, b) and the results are tabulated in table 9

Fig. 4 (a) tensile test

Fig. 4 (b) cylinder after tensile test

The table 9 below gives Tensile strength of cylinders of Mixes 1 – 13, after 28 days of water curing.

Table 9: Tensile test on Concrete cylinders

Mix	Tensile Strength, N/mm^2 (28 days)
1	2.880
2	2.975
3	3.055
4	2.960
5	2.848
6	3.326
7	3.437
8	3.278
9	2.928
10	3.580
11	3.771
12	3.246
13	2.912

The fig.5 below shows the Tensile strength of concrete cylinders after 28 days.

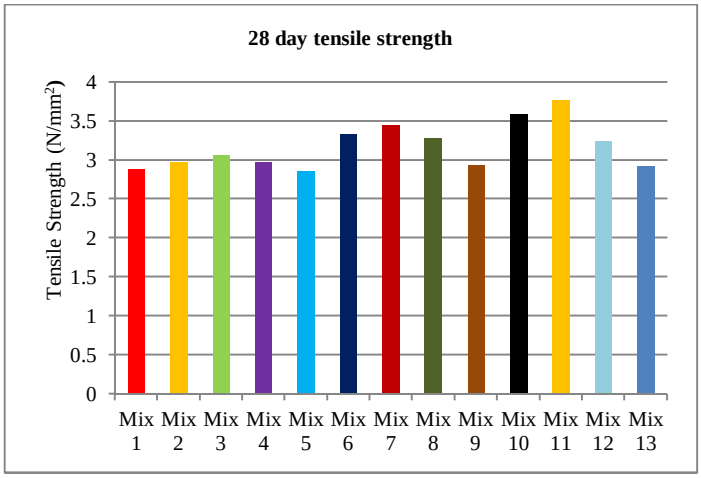

Fig. 5 Tensile strength of cylinders

Conclusion

Fly ash and micro silica increases the strength of concrete more than 17% due to their pozzolanic properties. In addition Micro silica reduces the permeability of the concrete when it is used in combination with fly ash and recycled concrete aggregate. But when the percentage of recycled concrete increases the permeability also increases and the strength decreases. So from economical point of view the two materials fly ash and micro silica can be used in partial replacement of cement up to 15% without any adverse effect on the strength of concrete. But recycled concrete aggregate must be limited up to 10% of coarse aggregate, so that there is no adverse effect on strength and permeability of concrete.

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