Experimental Study on Heavy Weight Concrete Using Hematite and Laterite as Coarse Aggregate

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Abstract — *Heavy weight concrete or density concrete is commonly used for 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. Heavy weight concrete is designed by using heavy weight aggregates such as hematite, magnetite, barite etc. Here 2 heavy weight aggregates are used- hematite and laterite stone. First concrete mixes were prepared by replacing conventional aggregates with hematite (0%, 25%, 50% and 100 %). Then another set of mixes were prepared by replacing conventional concrete with laterite stones in the same percentage. Physical and mechanical properties of all the mixes were determined and then compared with the standard mix. The concrete with density up to 3004 kg/m3 was obtained for hematite concrete and density up to 2663 kg/m3 was obtained for laterite concrete.*

Keywords — *High density concrete, hematite, laterite, radiation shielding, density.*

I. INTRODUCTION

Concrete having a density greater than 2500 kg/m^3 is known as high density concrete or heavy weight concrete. High density concrete are widely used for radiation shielding in nuclear power plants, hospitals, ballast in offshore locations etc. Conventional concrete is also a good shielding material provided that space is not a consideration. But space is a definite consideration in many applications. In such cases it is not possible to place the desired amount of normal weight concrete in given space. In such cases heavy weight concrete is used. The key to heavy weight concrete is the aggregates. High density aggregates are used to get high density concrete. The quality and types of aggregates are the most important factors in the selection process of aggregates. The density of concrete is based on the specific gravity of aggregates and the properties of the other components of concrete. Hematite, magnetite, limonite, barite, steel punching and shot, etc are some materials which can be used as aggregates in high density concrete. Heavy weight concrete can be designed in the same way as that of conventional concrete, but the additional weight should be taken into account.

In the present experimental investigation hematite and laterite were used as high density aggregates. In this investigation conventional granite stones are replaced with hematite aggregate in percentage of 0%, 25%, 50% & 100% by mass and its physical and mechanical properties like compressive strength, tensile strength and flexural strength were studied. Hematite is scarcely available in Kerala. In the light of this, the scope of using laterite stone, which is rich in iron oxide, as a heavy weight aggregate is also checked in this investigation

II. MATERIALS

A. Cement

Ordinary Portland cement of grade 53 is used in the current study. The properties of cement were tabulated in table 1.

TABLE I
PROPERTIES OF CEMENT

Properties	Values
Specific gravity	3.015
Standard consistency	35%
Initial setting time	75 minutes
Final setting time	310 minutes

B. Fine Aggregate

In the current study, M sand is used as fine aggregate. The properties of fine aggregate are shown in Table II.

TABLE II
PROPERTIES OF FINE AGGREGATE

Properties	Values
Specific gravity	2.6
Bulk density ,kg/m^3	1830
Porosity,%	29.67
Grading zone	Zone II
Fineness modulus	3.13
Water absorption	1.02%

C. Hematite

Hematite is iron oxide (Fe2O3). Iron ore is a natural red, brown or black rock. Pure hematite has a density between 4.9 and 5.5g/cm^3. However, the physical properties of rocks in which hematite is the main constituent may vary considerably and the density of hematite ores can range between 3.2 and 4.3g/cm^3. Hematite stones are shown in Fig 1

Fig 1 Hematite

The physical properties of hematite stones are shown in Table III

TABLE III
PHYSICAL PROPERTIES OF HEMATITE

Properties	Hematite stone
Particle shape	Angular
Particle size	20mm
Specific gravity	4.33
Bulk density	2300 kg/m^3
Water absorption	2%

The chemical properties of hematite is shown in Table IV

TABLE IV
CHEMICAL PROPERTIES OF HEMATITE

Compound	Percentage %
Fe_2O_3	80.16
MnO	0.15
MgO	1.67
TiO_2	0.07
Al_2O_3	0.65
CaO	4.92
SiO_2	4.26
Loss of ignition	0.33

D. Laterite

Laterite stones rich in iron oxide are used here. Crushed well graded angular shaped aggregate of size 20mm as per IS 383-1970 is used and laboratory test on aggregates were conducted. Fig 2 shows Laterite stones.

Fig 2. Laterite stones

The physical properties are tabulated in Table V

TABLE V
PHYSICAL PROPERTIES OF LATERITE STONE

Properties	Laterite Stone
Particle shape	Angular
Particle size	20mm
Specific gravity	4
Bulk density	1460 kg / m^3
Water absorption	2.5%

The chemical properties of are shown in Table VI

TABLE VI
CHEMICAL PROPERTIES OF LATERITE STONE

Compound	Percentage %
Al_2O_3	19.4
MgO_3	4.6
Na_2O	0.3
Fe_2O_3	25.75
TiO_2	2.55
CaO	4.81
SiO_2	34.4
K_2O	8.80
Loss of ignition	0.45

III.MIX PROPORTIONING

The process of selection of materials and their required proportions is known as mix design. M30 grade concrete is used in this study. Mix design is done according to the relevant IS specifications. Proportion of different materials for 1 m^3 of standard concrete mix is given in Table VII.

TABLE VII
MIX DETAILS FOR M30 CONCRETE

Cement	Water	Fine Aggregate	Coarse Aggregate
355kg	142 litres	835 kg	1156 kg
1	0.4	2.35	3.25

We have a total of 7 mixes of concrete with different proportion of hematite aggregate and laterite stone aggregate on which the experimental investigation is carried out.

- STD – OPC + FA + NA
- HA 25 – OPC + FA +25% HA +75% NA
- HA 50 – OPC + FA + 50% HA +50 %NA
- HA 100 -- OPC + FA + HA
- LA 25 – OPC + FA +25% HA +75% NA
- LA50 – OPC + FA + 50% HA +50 %NA
- LA 100 – OPC +FA +LA

Where, OPC – Ordinary Portland Cement
FA - Fine Aggregate
NA – Natural Coarse Aggregate

HA – Hematite Coarse Aggregate
LA – Laterite Stone Aggregate

The procedure for mixing heavy weight concrete is similar to that of conventional concrete. The materials were mixed thoroughly in a drum mixer to produce fresh concrete. Water cements ratios of 0.4 were adopted. The specimen is prepared for compressive strength for cube size 150 x 150 x 150 mm. The cylinder of height 30 cm and 15 cm diameter was prepared for tensile strength and beam of size 10x10x 50cm was prepared for flexural strength. The specimens are tested for 7 days and 28 days with each proportion of conventional, lateritic and hematite stone filler.

IV. RESULTS AND DISCUSSIONS

A. *Workability*

Slump test was used to find the workability of concrete. Slump test for each mixes were done. The results are shown in Fig 3.

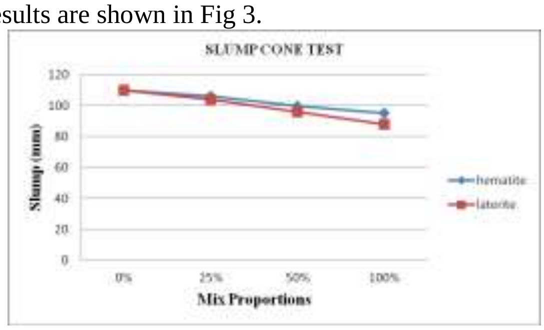

Fig 3 Slump test

The slump values show a decreasing tendency with increasing the percentage of heavy weight aggregate. The differences in the slump value may due to the differences in the rate of water absorption of aggregates. Water absorption value of laterite stones is greater than hematite and natural coarse aggregate. So the lowest slump value is for laterite concrete.

B. *Density*

Density of concrete is determined according to relevant IS codes. The results are shown in Fig 4 and Fig 5.

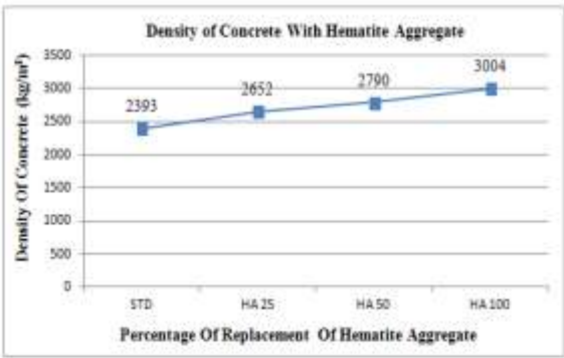

Fig 4. Variation of density of concrete with replacement of hematite aggregate

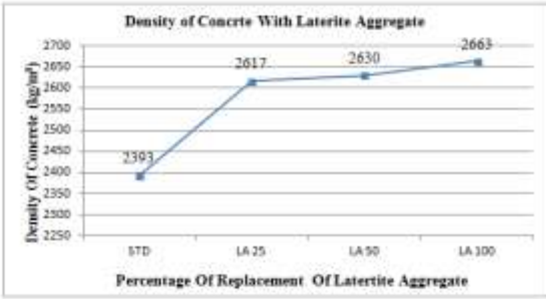

Fig 5. Variation of density of concrete with replacement of laterite aggregate

Results shows that density is directly proportional to the percentage of heavy weight aggregate i.e increasing the content of hematite or laterite density of concrete is increasing. Maximum density obtained for hematite concrete is 3004 kg/m^3 and that for laterite concrete is 2663 kg/m^3.

C. *Compressive strength*

Fig 6 and Fig 7 presents the results of compressive strength test.

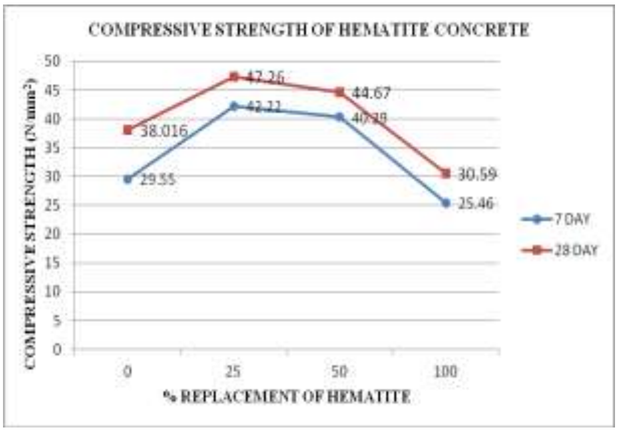

Fig 6. Variation of compressive strength of concrete with replacement of hematite aggregate

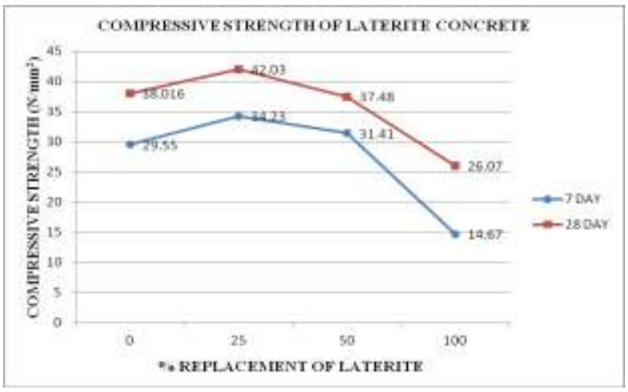

Fig 6. Variation of compressive strength of concrete with replacement of laterite aggregate

From the results obtained, it is seen that maximum compressive strength for hematite concrete is 47.26

N/mm^2 for 25% replacement of coarse aggregate with hematite stone and that for laterite concrete is 42.03 N/mm^2 for 25% replacement of coarse aggregate with laterite stone. Beyond 25% replacement compressive strength value shows a decreasing tendency for both hematite and laterite concrete. This may be because the porosity of both hematite and laterite are higher than natural coarse aggregate. Increasing the porosity decreases the strength of concrete.

D. Splitting tensile strength

The influence of coarse aggregate replacement by hematite stone and laterite stone on the splitting tensile strength is shown in Fig 8 and Fig 9 respectively.

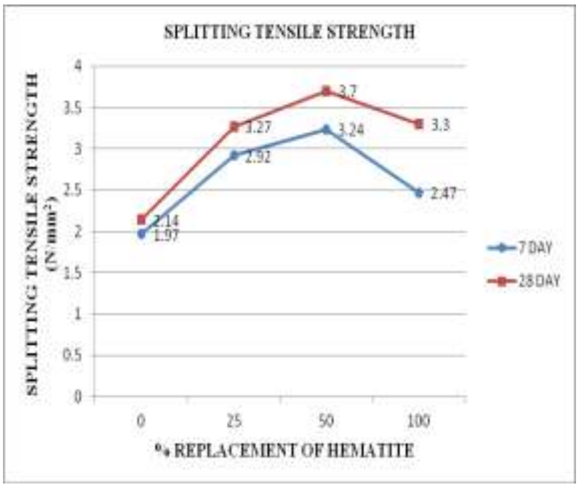

Fig 8. Variation of splitting tensile strength of concrete with replacement of hematite aggregate

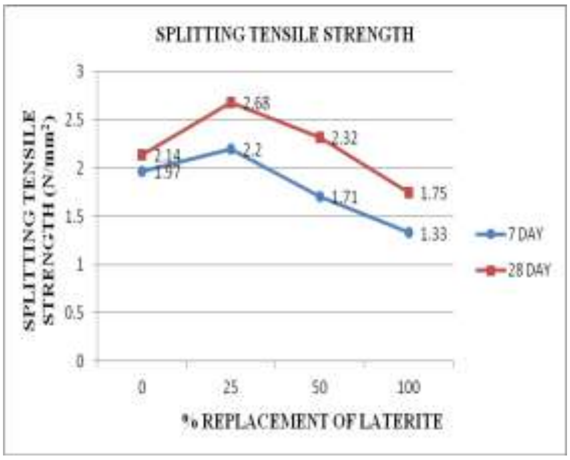

Fig 9. Variation of splitting tensile strength of concrete with replacement of laterite aggregate

From the results obtained, it is seen that maximum splitting tensile strength for hematite concrete is 3.70 N/mm^2 for 50% replacement of coarse aggregate with hematite stone and that for laterite concrete is 2.68 N/mm^2 for 25% replacement of coarse aggregate with laterite stone.

E. Flexural strength

The influence of coarse aggregate replacement by hematite stone and laterite stone on the flexural strength of concrete is shown in Fig 10 and Fig 11 respectively.

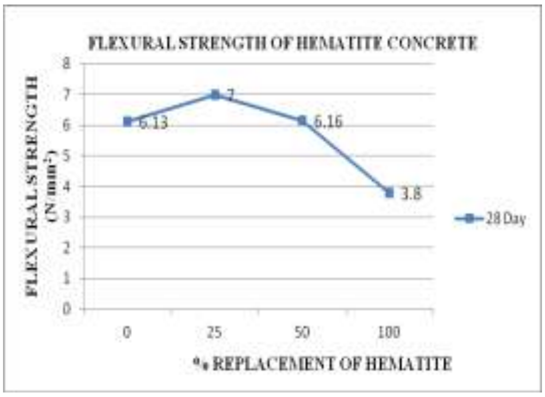

Fig 10. Variation of flexural strength of concrete with replacement of hematite aggregate

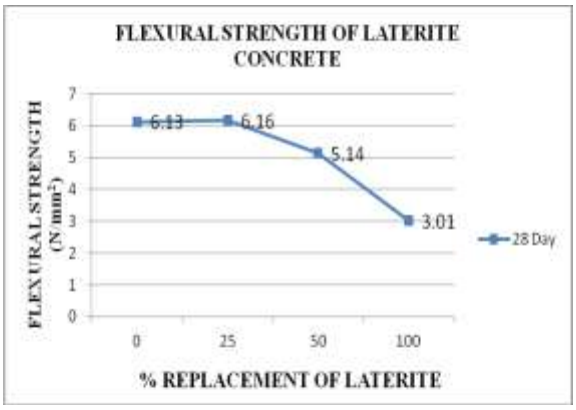

Fig 11. Variation of flexural strength of concrete with replacement of laterite aggregate

Maximum flexural strength for hematite concrete is 7 N/mm^2 for 25% replacement of coarse aggregate with hematite stone and that for laterite concrete is 6.16 N/mm^2 for 25% replacement of coarse aggregate with laterite stone.

V. CONCLUSIONS

In this study, experimental studies on replacement of coarse aggregate with heavy weight aggregates on the properties of concrete was investigated. For that purpose 2 high density aggregates are used in this study, Hematite Stone which having a density of 2300 kg/m^3 and laterite stone having a density of 1460 kg/m^3. Different test results were evaluated. Results show that density of concrete increases with increase in the percentage of heavy weight aggregate. In this study density up to 3004 kg/m^3 is obtained for hematite concrete and a density up to 2663 kg/m^3 is obtained for laterite concrete. Based on the results obtained in this study, it may be seen that hematite and laterite could be used for making heavy weight concrete, without affecting much the compressive strength, tensile strength, flexural strength of concrete.

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