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Study on The Significance of Various Coarse Aggregates and Silica Fume in the Development of High Density Concrete

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***Abstract*-- Engineers usually need just a normal-weight concrete that will carry a heavy load, but there would be requirement of dense and heavy concrete. This dense and heavy concrete are in general used for radiation shielding purposes, ballasts for offshore pipelines, breakwater structures or in counterweights. In general, the density of these concrete will be more than 2600 kg/m^3. This study deals with finding an optimal locally available coarse aggregate for the production high density concrete. Magnetite, shonkinite and dolerite were identified through consultation with geologists in salem. All the mentioned aggregates had its specific gravity more than that of conventional aggregate. The aggregates were then manually crushed to the required size**

A mix design was arrived for the different aggregates and the cubes were casted. The slump was around 50mm for all the three mixes, but the compressive strength and density were not the same. Magnetite mix had the highest compressive strength and density, followed by dolerite mix and finally shonkinite mix. Taking into consideration the availability and quality of the aggregates, the dolerite mix was selected, Split tensile strength and flexural strength was found for the dolerite mix. Further the microstructural and durability studies were done for the dolerite mix.

***Keywords* – High density concrete , Dolerite, Durability**

I. INTRODUCTION - HDC

A. General - SCC

High density concrete or heavy weight concrete is the concrete, which should have density greater than 2600kg/m3. High density concrete can be made from natural heavy weight aggregates such as barites, magnetite, hematite etc. Apart from the replacement of aggregates, the other way to produce HDC is by the addition of Iron balls, this increases the density of concrete significantly proportionately the cost of manufacturing HDC would also increase. Heavy weight or high density concrete can be designed in same way as normal weight concretes, but its higher weight must be considered with respect to the load-rated capacities of transport vehicles, roadways and installation cranes. Transporting high-density concrete for extended periods of time can result in excessive consolidation or packing. So, additional density means that smaller volumes can only be transported and placed. The formwork for conventionally placed high-density concrete must be carefully selected and inspected, as it will be subjected to considerably higher stresses than comparable forms for ordinary concrete.

B. Applications of HDC

- Nuclear power plants, Nuclear weapon development and Radiotherapy treatment rooms to shield radiation.
- Precast concrete used in storage facilities of radioactive wastes.
- Ballasts for offshore pipelines.
- Breakwater structures
- Counterweights
- Sound or vibration attenuation walls

II. PROPERTIES OF MATERIALS USED

A. Cement

Ordinary Portland cement of 43 grade confirming IS 8112 : 1989 was used in the experimental work and properties as mentioned in the table below.The brand used is Dalmia cements obtained from the Salem locality.

S.No	Types of Test	Cement
1	Specific gravity	3.15
2	Consistency	31 %
3	Initial setting time	32 minutes
4	Final setting time	260 minutes
5	Fineness	2 %

B. Fine Aggregate

The sand used for the experimental programme was locally procured and conformed to grading zone II as per IS: 383 (1970).The sand was first sieved through 4.75mm sieve to remove any practices greater than 4.75mm and then was washed to remove the dust. Properties of the fine aggregates used in the experimental work are tabulated below.

S. No.	Characteristics	F.A.
1	Specific gravity	2.47
2	Zone	II
3	Water absorption	0.3 %
4	Fineness modulus	2.27
5	Shape	Rounded

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C. Magnetite

Magnetite used in this study is obtained from kanjamalai, salem. The rocks obtained from the above location were of varied sizes and was broken to the required size manually. The rocks obtained were in a weathered condition. The magnetite was found to be in an impure form, as quartzite was found to exist in a combined state, resulting in the formation of bands in the stone and it was also found that while breaking the rock to the required size it tends to crack exactly at the place were quartzite was present. The material being an ore for iron was found to be very dense and heavy in nature. After the rock was obtained in the required size it was tested to find the specific gravity, water absorption, flakiness index and elongation index. Sieve analysis was also done and the results are as follows

S.No	Characteristics	Magnetite
1	Appearance	Black or Grey with brownish tint in reflected sun
2	Specific gravity	4.5
3	Water absorption	0.52 %
4	Flakiness index	25.3 %
5	Elongation index	26.5 %
6	Shape	Angular

Fig 1: Magnetite

D. Shonkinite

Shonkinite is a rock, which is either in Black or dark green in appearance. It is hard and its specific gravity varies from 2.8 to 3.0. Shonkinite was identified in salem near Kurumbapatti zoo and was found to be in a weathered state.. the graded aggregates were tested to find its properties and its suitability in developing HDC and the results have tabulated.

S.No	Characteristics	Shonkinite
1	Appearance	Black or Dark green
2	Specific gravity	2.94
3	Water absorption	0.55%
4	Flakiness index	9.2 %
5	Elongation index	12.5 %
6	Shape	Angular

Fig 2: Shokinite

E. Dolerite

Dolerite, an igneous rock has good physical and chemical properties of the rock make it suitable for a wide variety of uses. Crushed rock is used as aggregate in concrete, as road sub-base and in flush seals, as facing stone in building construction, and as armour stone and rip-rap. As per a geological survey conducted by geologists, it was found that a good amount of this material is found to be available in salem and its neighbouring districts.

Its density is in the range of 2.9 to 3.3. The Aggregate was obtained through manual crushing from the left-over rocks obtained from KMB Granite, near Periyar University. Tests were conducted and the corresponding results are as follows:

S.No	Characteristics	Dolerite
1	Appearance	Dark grey or Black
2	Specific gravity	3.37
3	Water absorption	0.47%
4	Flakiness index	15.2 %
5	Elongation index	13.3 %
6	Shape	Angular

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Fig 3: Dolerite

F. Conventional coarse aggregate – Blue metal

In the present investigation, crushed hard blue granite aggregates were obtained from the locally available and approved quarries were used. Testing was done on the aggregates and the results were tabulated.

S.No	Characteristics	Blue metal
1	Appearance	Metallic blue
2	Specific gravity	2.7
3	Water absorption	0.5 %
4	Flakiness index	8.9 %
5	Elongation index	11.1 %
6	Shape	Angular

G. Silica fume

The American Concrete Institute (ACI) defines silica fume as "very fine non-crystalline silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon". It is usually a grey coloured powder, somewhat similar to Portland cement or some fly ashes. Silica fume is usually categorized as a supplementary cementitious material. Silica fume used was conforming to ASTM-C (1240-2000) and was supplied by "ELKEM INDUSTRIES" was named Elkem – micro silica 920 D. The Silica fume is used as a partial replacement of cement. The properties of Silica fume are as follows.

S.No.	Characteristics	Silica Fume
1	Specific gravity	2.2
2	Bulk density	576 kg/m3
3	Size	0.1 µ
4	Surface area	20000 m^2/kg
5	SiO_2	90 – 96 %
6	Al_2O_3	0.5 – 0.8 %

H. Water

Water is used in the mix was tap water that was free from all types of harmful chemicals, organic material,oil, chloride, silt and suspension, confirming to IS 456-2000.

III. Mix Design

The concrete mix is designed as per IS 10262 – 2009 and IS 456- 2000 for the conventional concrete and then followed by the complete replacement of coarse aggregates with dolerite, shonkinite and magnetite. The water cement ratio is 0.43. OPC 43 grade cement was used. Further to make the HDC denser by filling in the voids, mineral admixture, silica fume is added at 10 %. Trial mixes are tabulated below.

Table 1:
Trial Mix

Trial	Cement (kg/m^3)	Sand (kg/m^3)	Coarse aggregate (kg/m^3)	Water (kg/m^3)	w/c ratio
M1	370	661.57	1231.35	159.1	0.43
M2	390	647.31	1204.82	167.7	0.43
M3	410	633.97	1231.35	176.3	0.43

From the above mix designs, the second trial yielded the required strength. The mix design of the second trial mix is then taken and converted from weigh batching to volume batching, to replace the conventional coarse aggregate with the dense aggregates magnetite, shonkinite and dolerite with 10% replacement of silica fume for comparative study.

Table 2:
Weigh batch to volume batch conversion

Mix	Cement	Fine aggregate	Coarse aggregate	Water
Weigh Batch	1	1.66	3.09	0.43
Volume Batch	1	2.11	3.61	1.35

Table 3:
Magnetite Mix (MT1)

Mix	Cement	Fine aggregate	Coarse aggregate	Water
Volume Batch	1	2.11	3.61	1.35
Weigh Batch	1	1.66	5.16	0.43

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Table 4:
Shonkinite Mix (S1)

Mix	Cement	Fine aggregate	Coarse aggregate	Water
Volume Batch	1	2.11	3.61	1.35
Weigh Batch	1	1.66	3.37	0.43

Table 5:
Dolerite Mix (D1)

Mix	Cement	Fine aggregate	Coarse aggregate	Water
Volume Batch	1	2.11	3.61	1.35
Weigh Batch	1	1.66	3.86	0.43

IV. Properties Of Concrete

Table 6:
Trial mix properties

Trial	Slump (mm)	Compressive strength	
		7-day (N/mm^2)	28-day (N/mm^2)
1	65	29.8	37.25
2	58	31.2	39.6
3	49	32.6	40.5

Table 7:
HDC properties

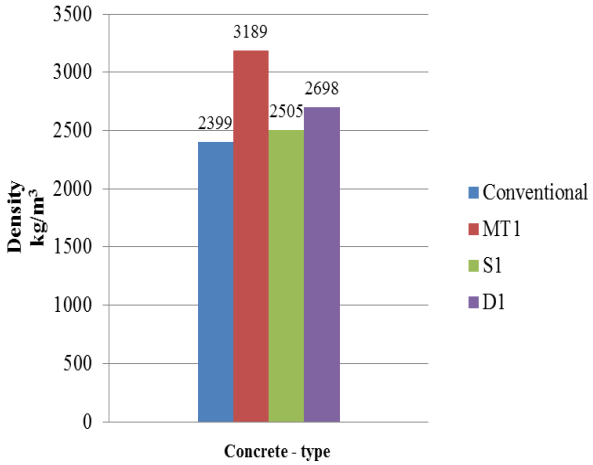
Trial	Slump (mm)	Compressive strength	
		7-day (N/mm^2)	28-day (N/mm^2)
MT1	33	33.9	41.7
S1	47	30.5	37.9
D1	45	32.7	40.7

Fig 4: Slump test

Fig 5: Compressive strength test

Table 8:
Concrete density

Mix	Hardened Concrete Density (kg/m3)
Conventional	2399
MT1	3189
S1	2505
D1	2698



S.No	Mix	Split tensile strength N/mm^2	Flexural strength N/mm^2
1	M2	4.02	6.42
2	D1	4.12	6.67

Fig 6: Split tensile strength test

Fig 7: Flexural strength test

V. Corrosion Test

To assess the corrosion protection efficiency under accelerated test conditions, concrete cylinders of specified size were cast and having steel rods embedded in the cylinders.

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Concrete cylinders were cast of size 150 mm diameter and 300 mm length, with centrally placed steel rod of 12 mm dia. The steel rod is placed in such a way that a constant cover is maintained all round (i.e. 75mm). The specimens were cured for a period of 14 days.

Fig 8: Corrosion test

Corrosion rate after 3 days for control specimen = 0.0002604 mm/year

Corrosion rate after 3 days for Dolerite Mix = 0.0002672 mm/year

VI. Durability Studies

Acid attack test and permeability test is in progress.

VII. Conclusion

The following conclusions are drawn from the study

- The heavy aggregates that can be used for HDC which are found in salem district are magnetite, shonkinite and dolerite.
- Magnetite though available in abundant quantity in salem, it exists in a combined state with quartzite makes it vulnerable and also the restrictions in procuring the aggregate for commercial purposes from the source almost eliminates its option.
- Shonkinite is the other dense aggregate available in salem, but not in an abundant nature, it is a small deposit. The nature of aggregate found is weathered; hence the rock is not as hard as it was supposed to be.
- Dolerite is the third heavy aggregate found in high volume at salem. And also the quality of the material is high, since is taken from the waste of granite slabs manufacturing factory.
- After conducting preliminary tests on the aggregates, the mix was designed and cubes were casted. The results of the compressive strength and the density of the HDC tested were along expected line, the density and compressive strength of MT1 mix was highest followed by D1 mix and finally S1 mix.
- Due to the procurement limitations and the quality of the aggregates, both shonkinite and Magnetite has been omitted from further study.
- Compressive strength, split tensile strength and flexural strength of both the conventional mix and the dolerite mix were compared.
- Corrosion test was conducted on the dolerite mix and the conventional mix.

REFERENCES

[1] "Development of high-performance heavy density concrete using different aggregate for gamma-ray shielding", Ahmed S. Ouda, Progress in nuclear energy, 48-55,(Nov-2014)

[2] "Mechanical properties of heavy weight concrete using heavy weight coarse-aggregate as hematite", B. Sagar Singh and K.V. Ramana, International journal of research in engineering and technology, 264-269 (Sept-2014).

[3] "Mechanical properties of shielding concrete with magnetite aggregate subjected to high temperature", Elzbieta Horszczaruk, Pawel Sikora, and pawel Zaporowski, 7th Scientific-technical conference material problems in civil engineering (MATBUD-2015).

[4] "Gamma-ray shielding of concretes including magnetite in different rate", B. Oto and A. Gur, International journal of physical sciences, 310-314 (Feb-2013).

[5] "Shielding properties of heavyweight, high strength concrete", M. Mahdy, P.R.S.Speare, A. H. Abdel-Reheem, 2nd Material speciality conference of the canadian society for civil engineering (Jun-2002).

[6] "High density concrete using Fly ash Micro silica and recycled aggregate – an Experimental study", Mudasir Hussain Pandit, Mrs. D. Renuka Parameswari, International journal of engineering trends and technology, 29-33 (Apr-2014)

[7] "Production of an economic high-density concrete for shielding megavoltage radiotherapy rooms and nuclear reactors", S.M.J. Mortazavi , M.A. Mosleh-Shirazi, M.R. Maheri, H.Yousefnia, S. Zolghadri, A. Haji-pour, Iranian journal of radiation research, 143-146 (Jan-2007).

[8] "Utilizing recycled cathode ray tube funnel glass sand as river sand replacement in the High-density concrete", Hui Zhao, Chi Sun Poon, Tung Chai Ling, Journal of cleaner production, 184-190 (Feb-2013).

[9] "The use of high-density concretes in radiotherapy treatment room design", A. Facue and A.X. Silva, Applied radiation and isotopes, 1023-1028 (Apr-2007).

[10] Concrete technology- theory and practice, M.S.Shetty.

[11] IS 10262 – 2009: Recommended guidelines for concrete mix design, Bureau of Indian standards, New Delhi.

[12] IS 2386 – 1963: Methods of test for aggregates for concrete, Bureau of Indian standards, New Delhi.

[13] IS 383 – 1970: Specification for coarse and fine aggregates from natural sources for concrete (Second revision), Bureau of Indian standards, New Delhi

[14] IS 456 – 2000: Plain and Reinforced Concrete Code of Practice, Bureau of Indian Standards, New Delhi.

[15] IS 8112-1989, Indian standard for ordinary Portland cement, 43 grade — specification (first revision), Bureau of Indian Standards, New Delhi.