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EXPERIMENTAL STUDY ON STRENGTH OF CEMENT MORTAR USING SHALE AS FINE AGGREGATE

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Abstract - *Cement mortar is an important material in construction industry, acting as a bonding element which holds masonry units together and also used for plastering. Demand of natural sand to satisfy rapid infrastructure growth is high in developing countries like India, facing shortage in good quality of natural sand. Efforts are made to check the possibility of utilizing the shale, a sedimentary rock material as a fine aggregate, by partially replacing with crushed stone sand in cement mortar mix. Various tests were conducted to know the behavior of cement mortar mix with shale as fine aggregate. This study may help in current and future use of shale as a fine aggregate in cement mortar mix.*

Key Words: Cement mortar, Portland slag cement, Alternative building material, Shale, Crushed stone sand, Compressive strength, Splitting tensile strength Flexural strength

1.INTRODUCTION

Cement mortar is a mixture of cement (binder), fine aggregate and water. It plays an important role in the construction of masonry walls and plastering. It should be of good strength if used in case of bonding of the masonry units and enough durable when used for plastering works. Sand is the most important ingredient for the preparation of cement mortar. In today's scenario it is important to have an alternate material which possesses the properties as that of the sand, so that it can be replaced with natural sand in the cement mortar and concrete. So, some of the waste materials which are produced in other industries can be checked for the replacement of fine aggregates in the cement mortar.
Shale is a waste product, dumped to the landfills after its extraction, produced majorly during the process of drilling the earth for extraction of oil and natural gas. This study is to know the usage of crushed shale as a partial replacement of fine aggregates with different percentages of 0, 25, 50, 75 and 100 in the cement mortar mix.

2. MATERIALS USED

Materials used for the experiment as follows -

2.1 Portland Slag cement (PSC)

It is a factory blended cement, with combination of up to 45% slag, 50% clinker and 3-5% gypsum. IS: 455-1989 [6] gives the specifications for using slag-based cements. Some of the advantages of PSC are better compatibility with all types of admixtures, low risk of cracking, improved workability, superior finish, better resistance against alkali-silica reaction, chloride & sulphate attacks, minimized shrinkage cracks. Physical properties of Portland slag cement are shown in Table -1.

Table - 1: Physical properties of Portland slag cement

Properties	Test results	Requirements as per IS 455:1989
Specific gravity	3	-
Normal consistency (%)	32	-
Initial setting time (min)	185	Not less than 30
Final setting time (min)	290	Not more than 600
Compressive strength (MPa)		
3 days	24.15	Not less than 16
7 days	38.58	Not less than 22
28 days	48.35	Not less than 33

2.2 Crushed Stone Sand (CSS)

It is an alternative for river sand, also known as manufactured sand (m-sand), produced by crushing of hard granite stone with maximum size of 4.75mm. Main advantage is that it can be zone graded to required proportion based upon the area of usage. As this type of sand is produced manually it is likely to have lesser presence of impurities, hence increasing the quality and durability of concrete. It does not contain organic and soluble compound that affects the setting time and properties of cement, thus the required strength of concrete can be maintained

2.3 Crushed Shale (CS)

Shale is a fine-grained sedimentary rock that is formed from the compaction of silt and clay-size mineral particles which is commonly called as mud. This composition places shale in a category of sedimentary rocks known as mudstones. It is distinguished from other mudstones because it is fissile and laminated. In this attempt, shale was crushed manually (using hammer) so as to pass through IS sieve 4.75 mm and retained on IS sieve 150 µm were collected and used as fine aggregate and used in cement mortar. Chemical composition of shale is shown in Table - 2.

Table - 2: Chemical composition of shale

Constituents	Percentage
Silicon (Si)	17.56
Aluminium (Al)	7.8
Iron (Fe)	4.77
Magnesium (Mg)	1.7
Calcium (Ca)	2.26
Sodium (Na)	1.43
Potassium (K)	3.44
Oxygen (O)	53.33
Sulphate (S)	0.58
Carbon (C)	7.1

2.4 Super-plasticizer

Use of super-plasticizer in concrete or mortar allows reduction of the water to cement ratio without negatively affecting the workability of the mixture, and enables the production of self-consolidating concrete and high-performance concrete. Here, super-plasticizer used is Conplast P211, a chloride free water-reducing admixture addition.

2.5 Grade, Curing and Testing age of mortar

Mortar specimens of grade MM 7.5 were prepared with cement and sand in 1:3 proportions with flow consistency of 110±5%. Water cement ratio of 0.6 is kept constant throughout the casting. Cement mortar specimens such as cubes, cylinders and prisms were casted. The casted specimens were de-moulded after 24 hours and cured by immersing the specimen in potable tap water under laboratory condition. The strength properties of mortar were determined for age period of 28, 56 and 90 days.

3. TESTS ON FRESH CEMENT MORTAR

Flow table test for mortar is performed as per IS: 4031-1988(part-6) [5]. The test is carried out to determine the amount of water required for gauging of cement mortar. In this test, water cement ratio of 0.6 is kept constant and amount of plasticizer used is varied to obtain the required flow consistency.

4. TESTS ON HARDENED CEMENT MORTAR

For test on hardened cement mortar Compressive, splitting tensile and flexural test was carried out for an age period of 28, 56 and 90 days for 0, 25, 50, 75 and 100 percent replacement of crushed stone sand by crushed shale. The compressive strength was conducted on cement mortar cubes of size 50mm as per IS 2250:1981 [8], splitting tensile strength test was conducted on cylindrical mortar of 50.8mm diameter and 101.6mm height and determined as per ASTM C 780-2006 [11] and flexural strength was conducted on the prism mortar of (40 x 40 x160) mm specimens and determined in accordance with ASTM C 348-2002 [10].

5. TEST RESULTS

5.1 Grain size distribution of fine aggregates

The graphical variations of percentage of passing of CSS and CS by sieve analysis are shown above in Chart - 1. From the test results, both CSS and CS confirm to Zone II according to specification of IS 383:1970 [7].

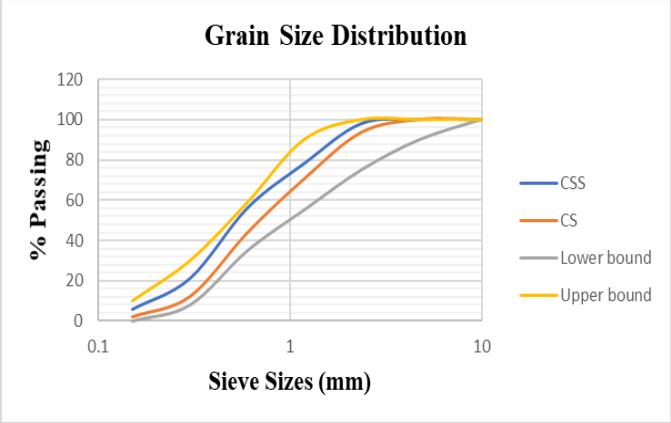

Chart - 1: Grain size distribution of fine aggregates

5.2 Physical properties of fine aggregate

The test results of physical properties of fine aggregates are listed in Table - 3.

Table - 3: Physical properties of fine aggregate

Particulars	CSS	CS
Specific gravity	2.64	2.46
Water absorption (%)	2.1	5.2
Fineness modulus	2.4	2.7
Relative bulk density (kg/m^3)	1743	1301

From the test results, it has been observed that the specific gravity of the CSS is higher compared to CS and also the percentage water absorption in CS is more compared to CSS.

5.3 Flow table test

Variations of results of flow test are shown in Chart - 2. From the test results, it has been observed that the percentage of addition of super-plasticizer increases with the increasing percentage replacement of CS.

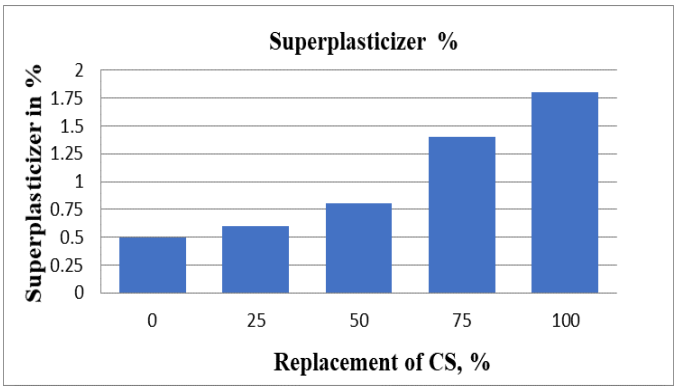

Chart - 2: Dosage of Super-plasticizer with replacement levels of Crushed shale

5.4 Compressive strength test

Variations of results of compressive strength test are shown in Chart - 3. From the test results, it is evident that compressive strength of mortar cubes decreases with the increase in percentage replacement of CS with CSS.

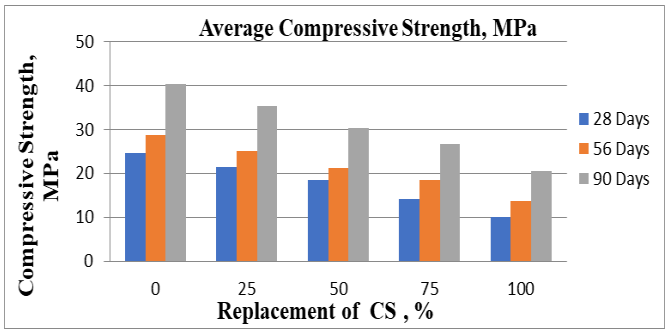

Chart - 3: Average compressive strength of cement mortar

Percentage reduction is listed in Table - 4 in comparison with 0% CS.

Table - 4: Percentage reduction in compressive strength of cement mortar

% Replacement of CS	% Reduction		
	28 days	56 days	90 days
25	13.05	12.45	11.40
50	26.40	25.81	24.86
75	42.40	35.75	33.47
100	58.70	52.52	48.69

5.5 Splitting tensile strength test

Variations of splitting tensile strength test are shown in Chart - 4. From the test results, it is evident that splitting tensile strength of mortar cubes decreases with the increase in percentage replacement of CS with CSS.

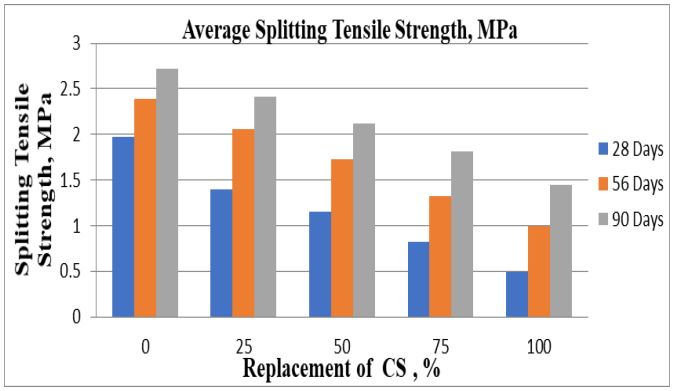

Chart – 4: Average splitting tensile strength of cement mortar

Percentage reduction is listed in Table - 5 in comparison with 0% CS.

Table - 5: Percentage reduction in splitting tensile strength of cement mortar

% Replacement of CS	% Reduction		
	28 days	56 days	90 days
25	28.93	13.80	11.02
50	41.62	27.62	22.06
75	59.39	44.76	33.06
100	75.12	58.57	46.71

5.6 Flexural strength test

Variations of flexural strength test are shown in Chart - 5. From the test results, it is evident that flexural strength of mortar cubes decreases with the increase in percentage replacement of CS with CSS.

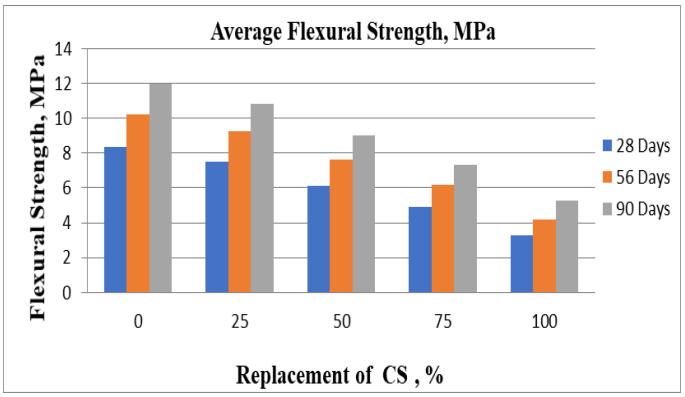

Chart - 5: Average flexural strength of cement mortar

Percentage reduction is listed in Table 6 in comparison with 0% CS.

Table - 6: Percentage reduction in flexural strength of cement mortar

% Replacement of CS	% Reduction		
	28 days	56 days	90 days
25	9.84	9.58	9.37
50	26.41	25.22	24.52
75	40.67	39.49	38.58
100	60.38	59.14	56.01

6. CONCLUSIONS

From this study, the following conclusions can be drawn-

Physical Properties of Fine Aggregate: Since the specific gravity of crushed shale is less than that of crushed stone sand, weight of the cement mortar with crushed shale as fine aggregate is lower than that of the cement mortar with crushed stone sand as fine aggregate. Also, as the percentage replacement of crushed shale increase there is decrease in overall weight of the mortar specimen.

The water absorption is higher in case of crushed shale compared to crushed stone sand because shale has a very small particle size, although the interstitial spaces in shale are very small, they can take up a significant volume of the water, gas or oil but will not be able to effectively transmit them because of the low permeability.

Strength Test: The compressive strength, splitting tensile strength, Flexural strength of cement mortar specimens decreases with the increase in percentage replacement of the fine aggregates by the crushed shale. The decrease in strength may be due the lack of bonding between shale and surrounding cement pastes and also due to reduction in overall density of mortar. For same percentage of replacement, the strength is found to increase with increase in the age of the specimen. As per IS 2250-1981[8] compressive strength for 28 days for grade of cement mortar MM 7.5 is to be more than 7.5 MPa, the compressive strength for 28 days obtained for 25%, 50%, 75% and 100% replacement is more than 7.5 MPa. As the results obtained is more than permissible limit so can be used with replacement as per requirements.

In recent years, there is shortfall in availability of natural sand against the existing demand in the market. The crushed stone sand commonly known as manufactured sand are in existence. But nowadays there are lot of troublesome during blasting of hard rocks and crushing it to required gradation consumes more energy and time and becomes laborious by the time end-product is obtained. So, at the end of this study, it can be said that shale can be used in cement mortar as a fine aggregate with lesser partial replacement. In small storey building, it can be used as a binder mortar in brick, size stone or concrete block masonry. Having less density, it reduces the dead weight transferred to the foundation of structure.

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