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An Experimental Investigation on Partial Replacement of Fine Aggregate by Manufacturing Sand and Cement by Steel Slag

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ABSTRACT

Concrete is a widely used material in the world. More than ten billion tones of concrete are consumed annually. Conventional concrete is a versatile material and it is a mixture of cement, fine aggregate, coarse aggregate and water. Aggregates occupy 65 to 80% of the total volume of concrete and affect the fresh and hardened properties of concrete. Out of the total composition of aggregate, the fine aggregate consumes around 20 to 30% of the volume. Sand is the most widely used fine aggregate in the process of manufacturing concrete. The river beds are the main sources for the natural sand. Periodic restrictions are being introduced by governmental authorities against the collection of river sand. Due to short supply of natural sand and the increased activity in the construction sector. There is an acute need for a product that matches the properties of natural sand in concrete. The manufactured sand which is available in abundance in various quarries is one of the major alternative materials that can be used instead of natural sand in concrete. The manufactured sand is a by-product of the crushing and screening process in the quarries. The scope of the present study is to investigate the effect of the physical and chemical properties of manufactured sand by using M60 grade of concrete. An effort has been made to focus on the replacement of natural sand with manufactured sand by 0%, 25%, 50%, 75%, and 100% on concrete properties. The steel slag is one of the alternative materials that can be used instead of cement as a partial replacement in concrete by 0%. 2.5%, 5%, 7.5%, 10%, 12.5%, 15%. The results are being calculated by testing the cubes, cylinder and prism.

Keywords: Manufactured sand sustainable replacement, Concrete Fine aggregate Strength, Steel slag sustainable replacement and Concrete cement.

1. INTRODUCTION

The manufactured sand which is available in abundance in various quarries is one of the major alternative materials that can be used instead of natural sand in concrete. The manufactured sand is a by-product of the crushing and screening process in the quarries. Production of aggregates from crushed rocks generates a large proportion of fines. Quarry fines consist of a graded mix of coarse, medium sand and fine sand sized particles, plus clay/silt fraction known as the ‘filler’ grade. Filler grade material is defined by the industry as the material less than 0.075mm (75 microns) in size. The filler grade content of these fine materials is reduced by washing it with water that produces a clean, saleable ‘sand’ product. The scope of the present study is to investigate the effect of the physical and chemical properties of manufactured sand towards the performance of grade of concrete. An effort has been made to focus on the replacement of natural sand with manufactured sand from 0% to 100% on concrete properties.

Preparation process of m-sand

The preparation of m-sand consists of five basic processes: natural decomposition, extraction, sorting, washing, and in some cases crushing. The first process, natural decomposition, usually takes millions of years. The other processes take considerably less time.

- Natural decomposition
- Extraction
- Sorting
- Washing
- Crushing

2. MATERIALS USED

The materials used were

Cement

Mineral admixture : Steel Slag

Fine aggregate : Natural Sand & M - Sand

Coarse aggregate

Water

Chemical admixture : Super plasticizer

Cement-The cement used for casting the specimens is of 53 grade ordinary Portland cement as per as per IS 12269-1987. The required quantity is procured, stored in airtight bags and used for experimental programme. Portland cement is a hydraulic binder and a finely grained inorganic material when mixed with water, it forms a paste which sets and hardens by means of hydraulic reactions.

Properties of cement:

Initial setting time – 30 min

Final setting time – 185 min

Specific gravity – 3.15

Coarse aggregate- Coarse aggregates are in the form of irregular broken stone or naturally occurring rounded gravel. The aggregates which are greater than 4.75mm are called as coarse aggregates. Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and efficient in economy. Coarse aggregates for structural concrete consists of broken stones of hard rock like granite and lime stone or river gravels. They should be clean and if dirty should be washed well before using.

Specific gravity and bulk density

Procedure

The weight of the container (W1) is determined

The container is filled with coarse aggregate and weighed (W2)

Then the container is filled with water up to the top surface level and weighed (W3)

The container is emptied and is filled with water and weighed (W4)

Specific gravity of coarse aggregate= (W2 – W1) / [(W4 – W1) – (W3 – W2)]

Specific gravity of coarse aggregate = 2.85

Bulk density of coarse aggregate = (W2 – W1) / (W4 – W1)

Bulk density of coarse aggregate = 1386 kg/m3

3.1 Properties of coarse aggregate:

Specific gravity - 2.85

Fineness modulus - 4.35

Fine aggregate- Sand between 0.50 mm and 4.75 mm is called as fine aggregate. Fine aggregate consists of natural sand, crushed sand or crushed gravel stone dust. The sand used for casting the specimen is natural river sand. It should be hard, durable chemically inert, clean and free from organic matter. Very fine sand is not recommended for structural concrete. Very fine sand shows difficulties in surface finishing of concrete but provides good strength and more cohesion. The fine aggregate used for casting was sieved through IS 4.75m sieve.

3.2 Specific gravity

In concrete technology specific gravity of aggregate is made use of in design calculations of concrete mixes. Indian standard specification in IS: 2386 (Part iii) of 1963 gives various procedure to find out the specific gravity of different sizes of aggregates.

Procedure

Weight of the Pycnometer is determined (W1).The Pycnometer is filled with 1/3 of its volume by sand and weighed (W2).The remaining portion of Pycnometer is filled with water and its weight is determined (W3). The Pycnometer is emptied and filled with water and the weight is determined (W4)

Specific gravity of sand = (W2 – W1) / [(W4 – W1) – W3 – W2)

Specific gravity of River sand = 2.65

Specific gravity of M-sand = 2.67

3.3 Bulk density

The bulk density of unit weight of an aggregate gives valuable information regarding the shape and grading of aggregate. For a specific gravity the angular aggregate show a lower bulk density. The bulk density depends on the particle size distribution and shape of the particles. One of the early methods of mix design makes use of this parameter bulk density in proportioning of concrete mix. The higher the bulk density the lower is the voids content to be filled by sand and cement. The sample which gives the minimum voids or the one which gives maximum bulk density is taken as the right sample of aggregate for making economical mix. The method of determining bulk density also gives the method for finding out void content in the sample of aggregate.

Procedure

Weight of the container is determined (W1)

The container is loosely filled (without compaction), the top level is trimmed and weight is found out (W2)

The container is emptied and it is filled in three layers and each layer being compacted for 25 times with ramming rod, the top level is trimmed and the weight is found (W3)

Empty the container, clean it with water and weigh it (W4)

Loose density of sand = (W2 – W1) / (W4 – W1)

Loose density of River sand = 1520 kg/m3

Loose density of M-sand = 1440 kg/m3

Rodded density of sand= (W3 – W1) / (W4 – W1)

Rodded density of River sand = 1632 kg/m3

Rodded density of M-sand = 1680 kg/m3

3.4 Properties of fine aggregate

Specific gravity	-	2.67
Fineness modulus of sand	-	2.80

Water-It is the least expensive but most important ingredient of concrete. It plays an important role in mixing, laying, compacting, setting and hardening of concrete. It influences the strength and durability of concrete. Water influences the strength development and durability of concrete. The pH value of water shall generally be not less than 6. Portable water available in the laboratory was used for making concrete.

Mineral admixture-Steel slag, a by-product of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling. Slag is the glass-like by-product left over after a desired metal has been separated (i.e., smelted) from its raw ore. Slag is usually a mixture of metal oxides and silicon dioxide. However, slags can contain metal sulfides and elemental metals. Basic slag is a byproduct of smelting ore. Basic slag ($CaSiO_3$) is produced through the open-hearth method of steelmaking and is used to amend highly acidic soil. Its pH-raising effect is similar to that of ground limestone. The bulk relative density of expanded slag is difficult to determine accurately, but it is approximately 70 percent of that of air-cooled slag. Typical compacted unit weights for expanded blast furnace slag aggregates range from 800 kg/m3 (50 lb/ft3) to 1040 kg/m3 (65 lb/ft3). Welding slag is a form of slag, or vitreous material produced as a byproduct of some arc welding processes, most specifically shielded metal arc welding (also known as stick welding), submerged arc welding, and flux-cored arc welding. ... Slag is the solidified remaining flux after the weld area cools.

Chemical admixtures -Chemical admixtures are the essential ingredients in the concrete mix, as they increase the efficiency of cement paste by improving workability of the mix and there by resulting in considerable decrease of water requirement.

Super plasticizers-Super plasticizers, also known as high range water reducers, are chemicals used as admixtures where well-dispersed particle suspensions are required. These polymers are used as dispersants to avoid particle aggregation, and to improve the flow characteristics (rheology) of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. Indeed the strength of concrete increase whenever the amount of water used for the mix decreases. However, their working mechanisms lack of a full understanding, revealing in certain cases cement-super plasticizer incompatibilities.

Here super plasticizer Conplast Sp430 is used as a chemical admixture. The super plasticizer Conplast SP430 is a chloride free, super plasticizing admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water. Conplast SP430 disperses the fine particles in the concrete mix, enabling the water content of the concrete to perform more effectively.

4. MIX PROPORTION

Design stipulations

i. Characteristics compressive strength-60N/mm2
ii. Type of cement-OPC 53 grade
iii. Minimum cement content- 300 kg/m3
iv. Maximum water-cement ratio-0.5
v. Workability-75mm (slump)
vi. Maximum size of aggregate-20mm (angular)
vii. Degree of workability-0.90 compacting factor
viii. Degree of quality control-Good
ix. Type of exposure-Mild

Test data for materials

i. Specific gravity of cement-3.15
ii. Specific gravity of coarse aggregates- 2.85
iii. Specific gravity of fine aggregates- 2.67

Table III.1 - Recommended Slump for Concretes With and Without HRWR

Concrete made using HRWR*	
Slump before adding HRWR	1 -2 in.
Concrete made without HRWR	
Slump	2 -4 in.

Table III.2 - Suggested Maximum-Size Coarse Aggregate

Required concrete strength	Suggested maximum-size Coarse aggregate
<62.035 N/mm2	3/4 - 1in.
>62.035 N/mm2	3/8- 1/2 in.

Maximum size of coarse aggregate= 3/8 –1/2 in.

Therefore select 12.5mm aggregate.

TABLE III.3- Recommended Volume of Coarse Aggregate per Unit Volume of Concrete

Optimum coarse aggregate contents for nominal maximum sizes of aggregates to be used with sand with fineness modulus of 2.5 to 3.2

Nominal maximum size	3/8	1/2	3/4	1
Fractional volume* of oven dry rodded coarse aggregate	0.65	0.68	0.72	0.75

Weight of coarse aggregate= (Bulk density of coarse aggregate x volume of coarse aggregate per unit volume of concrete)

Therefore weight of Coarse aggregate= 933.88 kg/m3

Total mixing water / m3= 189.245 kg/m3

Table III.4 - First Estimate Of Mixing Water Requirement And Air Content Of Fresh Concrete Based On Using Sand With 35 Percent Voids

Slump in.	Mixing water, lbs/yd3 Maximum-size coarse aggregate, in.			
	3/8	1/2	3/4	1
1 to 2	310	295	285	280
2 to 3	320	310	295	290
3 to 4	330	320	305	300
Entrapped	3	2.5	2	1.5
Air content	(2.5)	(2)	(1.5)	(1)

Table III.5- Recommended maximum w/c + p ratio for concretes made with HRWR

Field strength fcr’, psi		w/c + p Maximum-size coarse aggregate, in.			
		3/8	1/2	3/4	1
7000	28days	0.5	0.48	0.45	0.43
8000	28days	0.44	0.42	0.40	0.38
9000	28days	0.38	0.36	0.35	0.34
10000	28days	0.33	0.32	0.31	0.3
11000	28days	0.3	0.29	0.27	0.27
12000	28days	0.27	0.26	0.25	0.25

Calculation of cementitious material

Weight of cementitious material = mixing water / [w/c ratio]

per m3 of concrete = 321.49 / 0.32

= 591.38 kg/m3

5.VARIOUS PROPORTIONS IN THE MIX DESIGN

Cement content /m3

= 591.38kg/m3

Volume of materials used except fine aggregate,

Cement = (Weight of cement per m3) / (specific gravity of Cement x 62.4)

=1004.6/(3.15 x 62.4)

= 0.189 m3

Coarse aggregate= (Weight of Coarse aggregate per m3)/(Specific Gravity of Coarse aggregate x62.4)

=1586.49 / (2.85 x 62.4)

= 0.330 m3

Water = (weight of water per m3) / 62.4

= 321.49/ 62.4

= 0.191 m3

Entrapped air content

= (2/100) x 27

= 0.02 m3

Total volume = Volume of (Cement + CA + Water + Air)

= 0.730 m3

Required volume of sand per m3

= 27 -19.72

= 0.270 m3

Therefore volume of sand

= 7.28 x 62.4 x 2.64

= 705.95 kg/m3

Mix proportion

Cement: Fine Aggregate: Coarse Aggregate: w/(c+p)

= 591: 705.95: 933.88: 0.32

= 1: 1.2: 1.58:0.32

Table-5.6 concrete mix design

The mix proportion then becomes

Cement	Fine aggregate	Coarse aggregate	Water
591.38	705.95	933.88	321.49

Concrete mix design	= 1: 1.2: 1.58:0.32

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