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Self-Compacting Concrete Using Industrial Waste Red Sand (Bauxite Residue) As Fine Aggregate

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ABSTRACT- Self-compacted concrete (SCC) is cast within the formwork without compaction and it fulfills the formwork because of its personal weight. SCC is taken into consideration to have many benefits in contrast with traditional concrete like improved construction, economic and time saving, quicker construction activity etc. SCC is produced with the same materials of ordinary concrete. Cementatious materials are adopted to replace the cement content in SCC so that waste materials (bauxite) from industries and agricultural products can be used. Further improvement in the performance of SCC is done by using different types of fibers to produce fiber reinforced SCC and to diffuse the crack propagation which improves mechanical properties. The foremost goal of this paper is to collect the literature to recognize the use of cement alternative materials (bauxite) and fibers for reducing the environmental hazards. This paper discusses the environmental implications due to the technology of diverse solid wastes, and highlights their recycling potentials and viable use for generating productive materials.

KEYWORDS: SCC, Compaction, Bauxite, Fiber Reinforcement, Environmental implications, recycling.

I. INTRODUCTION

Self-compacting concrete (SCC) is a kind of concrete that's produced without compacting attempt. It settles via its personal weight with none bleeding and segregation and behaves cohesive enough [1]. The use of SCC is thought to offer diverse benefits like decreased construction time, exertions value and noise pollution, ease to fill the congested and skinny sections. It additionally allows casting in congested regions of construction. In current years, one of kind styles of filler as a partial cement alternative had been broadly utilized in SCC. With this alternative, SCC may be an extra sustainable fabric [2]. The excessive waft and resistance to segregation skills of SCC may be carried out via including big portions of tremendous plasticizer and filler materials in it. Though there are numerous filler materials which have been utilized in SCC manufacturing, the normally used fillers are silica fume, fly ash, iron slag etc. [3]. SCC organized with micro-fillers and mineral mixtures as a partial alternative of cement turns into economical [4]. Normally SCC is produced with smaller water cement ratio which ends up in excessive strength, low permeability and extra durability as compared to ordinary concrete produced with compaction with the usage of vibrators[5]. The constructions of SCC are in addition progressed via the addition of fiber.

However, the workability of SCC reduces with the addition of fibers and this discount relies upon the kind, form, length and dosage of fibers used [6]. The conventional construction materials consisting of concrete, bricks, whole blocks, solid blocks, pavement blocks and tiles are being comprised of the prevailing natural sources [7]. This is detrimental the environment because of non-stop exploration and depletion of natural sources. Moreover, diverse poisonous materials consisting of excessive attention of carbon monoxide, oxides of sulfur, oxides of nitrogen, and suspended particulate subjects are continuously emitted to the environment at some stage in the producing procedure of construction materials. The emission of poisonous subjects contaminates air, water, soil, flora, fauna and aquatic life, and for this reason impacts human fitness in addition to their dwelling widespread [8]. Therefore, the troubles associated with environmental conservation have won extraordinary significance in our society in current years (Xue et al., 2009). The decision-makers in political, monetary, and social sectors are actually critically supplying extra interest to the surrounding troubles. Consequently, foremost adjustments concerning the conservation of sources and recycling of wastes via right control are taking place. Many government and investigators are currently running to have the privilege of reusing the wastes in environmentally and economically sustainable approaches (Aubert et al., 2006). The usage of solid wastes in construction materials is certainly considered one among such efforts [9].

II. RESEARCH NEEDS

The use of solid wastes is numerous. They may be used as coarse aggregates, fine aggregates, or supplementary cementing fabric for the manufacturing of construction materials. Many studies were carried out using solid wastes. Most of those studies work targeted the outcomes of solid wastes at the physical and mechanical behavior of construction products. Some of these studies tried to research the durability, overall performance of numerous construction materials inclusive of solid wastes. However, extra studies are wanted to verify the useful outcomes of solid wastes on the durability of latest construction products [10]. These challenge pursuits to lessen the effect of bauxite tailing at the environment, via investigating potential industrial applications for this by product as a construction material. Successfully demonstrating that red sand concrete meets the applicable Australian Standards will successfully convert a byproduct right into a valuable construction material [11]. This might substantially lessen the quantity of bauxite residue that calls for disposal, storing and tracking. Furthermore, with the ever growing call for fine construction materials, material consisting of natural sand is getting scares. If red sand may be proven to be a suitable alternative for natural sand, it's going to offer valuable new material for construction industry; and could enhance the sustainability of construction operations via lowering the want to mine an natural resource [12]. Using concrete may even lower the want for making conventional concrete that makes use of cement, which performs a key function in freeing carbon dioxide emissions to the environment. In this context, the following research needs have been identified for further investigation to enforce the use of solid wastes in construction materials:

- Commercial usage of various solid wastes within side the manufacturing the construction material
- Optimization of the content of diverse solid wastes to provide sound and beneficial construction materials.
- Comprehensive study on potential use of various solid wastes to provide load-bearing construction material.
- Feasibility evaluation for the usage of diverse solid wastes in the manufacturing of environment friendly and sustainable construction materials.
- Systematic study of the outcomes of various solid wastes at the overall durability performance of construction products under various exposure conditions.
- The cost benefit analysis of the solid waste based construction materials considering their lifetime performance.

III. PROJECT METHODOLOGY

This paper focuses primarily to determine whether red sand and its derivatives can be used as an alternative to natural sand as fine aggregate M20 grade concrete. Six different mixes, each with a characteristic strength of 20 MPa which is suitable for footing and residential application were used [13].

The constituents of the concrete consisted of cement, coarse aggregate (10 mm, 12.5 mm and a grading of both), fine aggregate (NS and RS) and water. NS was selected as it is already widely accepted and used within the construction industries as a fine aggregate in concrete. Each mix of concrete was tested and evaluated for different physical, mechanical and durability properties [14]. Table 1 shows the quantities of cement, Fine aggregates . coarse aggregates and water.

Table 1: Shows the quantities of cement, Fine aggregates

Mixture	Cement	Fine Aggregate		Coarse	Water	W/C ratio
No.	Kg/m³	Sand Kg/m³	Red sand Kg/m³	Aggregate Kg/m³	Lit/m³	
1	440.76	612.00	0.00	1148.60	185.12	0.42
2	440.76	459.00	153.00	1148.60	185.12	0.42
3	440.76	306.00	306.00	1148.60	185.12	0.42
4	440.76	153.00	459.00	1148.60	185.12	0.42
5	440.76	0.00	612.00	1148.60	185.12	0.42
6	475.55	0.00	503.99	1050.21	214.00	0.45

A. Mixing

Laboratory work was done using concrete lab for mixing the concrete, a rotatory pan mixer was used.

B. Casting

Soon after mixing, the concrete mix was made to cast into cylinder mould of 10cm C/S and 20cm height. The inside of the mould was layered with a thin layer of a water-based release agent to facilitate remolding of the samples after curing.

C. Curing

After casting, next day high temperature curing was done. For steam curing, the mould had been taken to the steam curing room and located below a thick plastic tent. A boiler produced steam to offer warmth and humidity. In this manner, samples had been cured in excessive humidity environment in conjunction with an excessive temperature. Dry curing was carried out by means of setting samples in an oven. Specimens had been sealed with covers at some stage in curing to make sure there is no lack of moisture. After curing, the specimens had been left within side the laboratory environment for five-six hours for remolding.

D. Mix Design

Mixture proportions were primarily based on mix design process for conventional concrete, previous studies (Hardjito & Rangan 2005a) the ratio of activator solution to fly ash was decided 0.36. Like traditional concrete mix design, aggregates comprised 70-75 percentage of the entire mass. As the foremost goal of the studies was to identify the role of red sand as fine aggregate, this percentage was altered to best proportion [15]. Also, the ratio of fine-to-coarse aggregate varied for a few mixtures, so as to research its impact on workability and strength of concrete. To improve the workability of concrete, more water was added to the mix. Likewise, the mass of super plasticizer decided on 1.5% of the fly ash. Throughout these studies two groups of mixture had been organized. Mixtures 1 to 9 comprised 14molar sodium hydroxide, while as mixture 10 to 12 used 8molar Sodium hydroxide. Within every group, diverse ratios had been used in line with the experimental objectives. Each collection was examined for mechanical and durability properties.

IV. CHOSEN TESTS

Each mix had a sequence of tests. These tests had been selected to evaluate the characteristic of the aggregates in addition to its workability, strength and durability signs of the concrete. To determine workability of the fresh concrete mixes, slump test was used.

- Tests to Assess the Characteristics of the Various Concrete Mixes
- Test to assess the characteristics of the various Fine aggregate and Concrete Mixes.
- General Specification for Ordinary Portland Cement Find the target mean strength.

A. Slump Test

The standard equipments for the test were used to determine the flow of concrete and its workability. The SCC mixes confirmed good outcomes of a slump for the workability. These slump values are used to visualize the overall performance of SCC at the stage in placement.

B. V-Funnel Test

Standard equipment for the V-funnel was used to perform the test. The time of flow in this test was recorded with a stopwatch. The V-funnel allows us to investigate the flow pattern of concrete via the congested bars of steel reinforcement within side the structure.

C. J-Ring Test

For the evaluation of fresh properties of SCC, we used the J-Ring test for the assessment of flowability of concrete in the lab made according to BS standards. Distance span is cautiously examined. This allows us to overview the pattern of the concrete inside steel bar reinforcement.
Figure 1 shows the apparatus for J-Ring Test

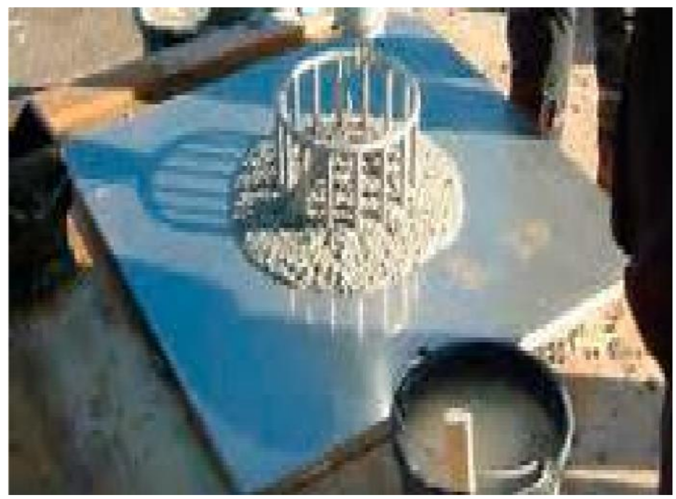

Figure 1: Compressive Strength

The compressive strength test was done according to AS1012.9-1999. Figure 2 is the image of compressive testing machine

Figure 2: the image of compressive testing machine

The compressive test samples of dimensions 100X200mm cylinders were used. The specimens had been cured after 24 hour preset time. After curing, the samples had been remolded and transferred to the laboratory to be exposed to excessive humidity situations till the day of testing. The compressive strength test included capping the samples with a restricted natural rubber capping system before setting the specimens within the testing machine. As we know the compressive strength is the capacity of material or structure to bare loads tending to reduce size. Some material may fracture while others deform irreversibly so a given amount of deformation may be considered as the limit for compressive load. Table 1 shows the value of Compressive strength of different mixes at 3 Days, 7 Days & 28 Days.

Table: 1 Compressive Strength measures for different mixes

RS CONTENT %	SAMPLE	3 DAYS N/MM2	7 DAYS N/MM2	28 DAYS N/MM2
0	M1	8	13.5	21
25	M2	9	15	23
50	M3	11	16.5	25.5
75	M4	13.5	19	28
100	M5	15	21	32

A load of 20± 2 MPa/min was applied until it reached the MAX force and the failure of spiceman was seen. The compressive strength was determined by: Figure 3 shows the loading on Concrete specimen

Figure.3: shows the loading on Concrete specimen

A concrete specimen under load

$f_{cu}=P/A$

Where:

f_{cu} = compressive strength of specimen

P = maximum force applied by machine

A =cross-sectional area

The testing was carried out 3, 7, 14, 28 and 56 days after casting. For each testing, three samples were tested and their average was considered as compressive strength.

D. Indirect Tensile Strength

Indirect tensile tests were done in accordance with AS 1012.10-2000. The specimens were 150×300 mm cylinders. Three specimens were tested for each mixture 28 days after casting.

The tests process started with fixing two hardboard bearing strips between the top and bottom platen of the cylinder when placed in the Centre of the testing setting. Force was applied at the rate of 1.5 ± 0.15 MPa / min until no further increase in load was achieved. The indirect tensile strength of the specimen was measured based on equation

T =2000 PπLD

Where:

T = indirect tensile strength, in MPa

P = maximum applied force indicated by the testing machine, in KN

L = length, in mm

D = diameter, in mm

E. Modulus of Rupture (Flexural Strength)

The flexural strength of concrete specimens decided with reference to AS 1012.12-2000. Beams had been made 400mm length and a 100x100 mm cross section; steam cured at the day after casting for twenty-four hours, then transferred to the curing room, remolded and left there till the day of testing. The specimens had been examined on the age of 28 days. Figure 4 shows the flexural strength testing machine.

Figure 4: The flexural strength test

The testing equipment was a frame containing two supporting rollers and two loading rollers. The sample was placed on its side with respect to its position as moulded and then was centered on the supporting rollers. A sitting load was applied to bring loading rollers into contact with the upper of the specimen. The pressure was applied without shock and increased continuously at a rate equivalent to 1 ± 0.1 MPa/min extreme fiber stress until no gain in force was achieved. With regard to the fraction location on the specimen, three situations may occur,

If the fracture occurs in the tension surface within the middle third of the span length, the modulus of rupture is calculated according to equation

$$R = \frac{PL}{bd^2}$$

Where:

R = modulus of rupture, MPa,

P = maximum applied load indicated by the testing machine, N

L = span length, mm

b = average width of specimen, mm

d = average depth of specimen, mm

If the fracture occurs in the tension surface outside of the middle third of the span length by not more than 5 % of the span length, the modulus of rupture is calculated by equation

$$R = \frac{3Pa}{bd^2}$$

Where:

a = average distance between the line of fracture and the nearest support.

Measured on the tension surface of the beam, mm if the fracture occurs in the tension surface outside of the middle third of the span length by more than 5 % of the span length, no calculation is made and the sample is rejected.

F. Modulus of Elasticity and Poisson's Ratio

Determining the modulus of elasticity and Poisson's ratio was accomplished according with AS 1012.17, 1997. The specimens, 100 X 200 mm cylinders just like the compressive strength specimens, had been subjected 24 hour preset period after casting. After that, they underwent steam curing for a day and transferred to curing room to be kept in excessive humidity till the day of testing. Before the day of testing, samples had been capped with a layer of sulfur mixture to remove surface roughness and to apply load evenly and continuously. Two linear variable displacement transducers (LVDT) had been connected vertically to the edges of the specimen to degree the longitudinal displacement. Another LVDT connected horizontally to the center of the sample measuring the lateral displacement. The LVDTs had been connected to a PC record the data during test. According to AS 1012.17 1997, the test load was decided on as 40 % of the compressive strength of the samples. Three specimens had been examined for compressive strength previous to a modulus test and the average used to decide the test load. Three different samples had been examined to decide the modulus of elasticity and Poisson's ratio.

G. Apparent volume of permeable voids

The test for determining the water absorption and Apparent Volume of Permeable Voids (AVPV) in hardened concrete was done according to AS 1012.21 – 1999.

The test specimens were 100 × 200 mm cylinders which were cast and cured as compressive strength specimens and cut into four equal slabs. The top surface of the samples was trimmed to 3 mm to remove irregularities. The average of 4 slabs was taken as the result.

The test procedure started by weighing the samples to the nearest 0.1 g, and then drying them in an oven in the concrete laboratory. The samples were dried for several days in the oven at a temperature between 100 to 110°C until the weights showed no difference in specimen weight. After taken out from oven, slabs were cooled in a desiccator containing silica gel to the temperature of 23 ± 2°C and weighed (M1). Afterwards, the samples were dripped in a water bath at a temperature of 23 ± 2°C for more than 2 days and weighed (M2i). After weighing of surface-dried samples there was no increase for two times. The procedure was followed by weighing the specimens after boiling them in a water bath for 6 hours (M3b) and determining the suspended weight of samples (M4ib). The calculation of AVPV results was based on the following equations:

Specimens tested for immersed absorption:

$$Ai = \frac{M_{2i} - M_1}{M_1} \times 100\%$$

Specimens tested for boiled absorption:

$$Ab = \frac{M_{3b} - M_1}{M_1} \times 100\%$$

Specimens tested for apparent volume of permeable voids

$$\text{AVPV} = \frac{M_{3b} - M_1}{M_{3b} - M_{4ib}} \times 100\%$$

Drying shrinkage

The drying shrinkage of concrete was done according to AS 1012.13 – 1992. For each mix, three specimens were lined. The specimens were 75×75×285 mm prisms which were steam cured for 24 hours after one day preset period. Moulds were exposed with a water-based release agent before casting. Each mould was packed in two layers, each layer getting thirty strokes with a tamping bar. The fresh concrete mixture was then vibrated for 10s on a vibrating table. The specimens underwent 24 hour preset period before being transferred to the steam curing chambers. Circulation of air was provided using a wire mesh and spacing the specimens. Temperature and humidity with laboratory was kept within the AS1012.13-1992 criteria at all times. The test consisted of measuring the length difference between the specimen and a reference bar at specific periods after demoulding. The drying shrinkage (indicated as micro strains) is the ratio of length change to the initial length of the sample. For measuring the length, a horizontal comparator in the Concrete Laboratory was used. A reference bar was used each time a sample was tested to check the precision of the apparatus. Each specimen was tested at least three times for each testing and the average of readings was taken. For each mixture, three specimens were made and samples tested for a period up to six months.

Figure 4: The Drying Shrinkage test

V. RAPID HARDENING

Rapid setting was the major challenge which needed to be addressed during the lab work. Throughout the experimental work, mixtures set a short time after mixing had begun or even inside the mixer; sometimes the mix was so stiff that the pan mixer stopped rotating.The rapid setting did not occur only in mixes with RS but with NS mixes also, but it was noticeable that the mixtures having higher amount of water (mixtures having lower concentrations of sodium hydroxide solution) did not show the rapid hardening. However addition of extra water to the mixture appeared to be advantageous in workability. But it was ruled as an option as extra water in the mixture would have affected the mix design and strength. Figure 5 shows Rapid hardening at the time of mixing.

Figure 5: shows Rapid hardening at the time of mixing

VI. RESULTS & DISCUSSION

Results offered in this study consist of the control mixes plus mixes that incorporated red sand. Results of mechanical characteristics of the concrete specimens, including compressive, indirect tensile, the durability testing result (water absorption) are included. Test results for various mixes are presented and discussed.

All bauxite residue variants are characterized in terms of chemical analysis, physical properties, mineralogical composition, alkali aggregate reaction, aggregate soundness and other properties. The results obtained from compressive testing for mixes 2-6 (mixes with high proportions of red sand) have been included, the excess water demand the fine red sand concrete mixes required, and hence significant increases in water cement ratio.

A. Characterization of Fine Aggregates

Some characteristics of fine aggregates used in this research are summarized in Table. The similarity of natural sand properties with red sand are noteworthy. Red sand contain pH value of 8.98 where neutralized red sand pH value given in the table. Due to a higher percent of fines in red sand, its surface area is greater than natural sand and it can be concluded that the workability of concrete mixes incorporating red sand as a fine aggregate. Table 2 shows the pH value of Sand and Red Sand

Table 2: shows the pH value of Sand and Red Sand

Parameters	Specific gravity	Bulk density ,[kg/m3]	Moisture content, [%]	pH
SAND	2.2	1.61	36	7-7.5
RED SAND	2.45	1.43	42	8.07

As the table shows, NS and RS lie outside the BIS grading limits for crushed aggregates, with an excess amount of fines. However, since the standard allows a certain amount of deviation within each sieve aperture, the grading of the NS and RS are still in the acceptable range. The excess amount of fines in NS and RS does not mean that the sands are not suitable for use in concrete. Table 3 shows Sieve Analysis of Fine Aggregate

Table 3: shows Sieve Analysis of Fine Aggregate

Is Sieve Size In mm	Weight Retained (Red Sand)	Cumulative Weight Retained For Red Sand	Cumulative % Weight Retained For Red Sand	Cumulative % Weight Passing For Red Sand
4.75	0	0	0	100
2.36	0	0	0	100
1.18	15	15	0.75	99.25
1	30	45	2.25	97.75
0.6	90	135	6.75	93.25
0.3	935	1070	53.5	46.5
0.15	665	1735	86.75	13.25
0.09	110	1845	92.25	7.75
<0.09	115	1960	98	2

VII. CONCLUSION

The application of SCC cannot be over emphasizes specially in post tension and pre tension structures because of the property of being moulded in any shape even in congested reinforcement areas, were the equipments used for compaction are difficult to be used, thus reducing the time of construction, cost of structure, gives uniform surface finish, better consolidation near reinforcement, good pumping ability and numerous other advantages are as under:

- A wide variety of waste materials is used as cement replacement in SCC.
- Most studies are carried out in order to investigate the effect of these materials on fresh properties (flow ability, passing ability and segregation resistance) and mechanical properties (compressive, tensile and flexural strength). In addition, durability characteristics also have been one of the studied parameters. .
- The fresh properties are significantly affected by the addition of cementitious materials. However, the effect depends upon the type, dosage and combination of adopted cementitious materials.
- Mechanical properties were also remarkably affected by the cementitious materials used. The effect is significant on certain types of waste materials such as silica fume and fly ash.
- Different fibers added as fiber reinforcement in SCC were used.
- Fibers exhibit pronounced effect on both fresh and hardened properties of SCC.
- In most of the cases the fresh properties of concrete (flow ability, passing ability and segregation resistance etc.) decrease with the addition of fibers but the mechanical properties increased significantly particularly when the specimen are tested in tension and bending. The Type,shape of fiber, aspect ratio and volumetric fraction have been observed to be major factors regarding the performance of SCC.
- The waste materials obtained from different resources are also used as replacement of fine aggregates.

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