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EXPLORATORY STUDY OF CRUSHED COCONUT SHELL AS PARTIAL REPLACEMENT FOR FINE AGGREGATES IN CONCRETE.

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ABSTRACT

An exploratory study of crushed coconut shell (CCS) as partial replacement for fine aggregate in concrete was carried out. Mechanical and Physical properties of the CCS and fine aggregate (river sand) were determined and compared. A total of 36 concrete cubes of size 150 x 150 x150mm with mix ratio of 1:2:4 and water/cement ratio of 0.5 using proportions, 0:100, 25:75, 50:50 and 100:0 CCS to fine aggregate (river sand) were cast, cured and tested for compressive strength after 14, 21 and 28 days. Compressive strength for 0:100, 25:75, 50:50, and 100:0 CSS: river sand proportions for the 14, 21 and 28 days are (23.85, 24.8, 32.0), (12.29,12.73, 13.80), (15.17, 15.40, 16.44) and (3.23, 3.70, 4.78) respectively. The trend shows a decrease in strength as the quantity of CCS in the concrete cubes increases. The workability of the concrete decreased as the quantity of CSS increased with the mould slumping at 100% CSS. Aggregate Crushing Value (ACV) for CSS is 8% and that for fine sand is 17.89%,, while Aggregate Impact Values (AIV) for the CCS is 1.22% and that for river san is 11.8%. Sieve analysis, moisture content, and bulk densities of the CCS, rivers sand and coarse aggregates were also determined. The unit weight of the concrete cubes decreased as the quantity of the CSS increases in the concrete. The compressive strength of the 50:50 sand: CSS replacement at 28 days for the 1:2:4 mix ratio is 16.44N/mm^2. It therefore follows that at 50% CSS replacement, the concrete produced can be used as lightweight concrete. It is estimated that cost reduction of 50% will be achieved.

Key Words: crushed coconut shell, concrete, fine aggregate, workability, compressive strength and slump.

INTRODUCTION:

The ingredients of normal concretes world-wide are cement, water, fine and coarse aggregates. This mixture when placed in mould or formwork and allowed to cure becomes hard like stone. The hardening is caused by chemical reaction between the water and cement. The fine and coarse aggregates bond with cement and strengthen after curing.

The strength, durability and other features of this conglomerate material depend on the properties of the mix, its constituents, the method of compaction and other controls during placing, curing etc. All concretes made with lightweight aggregate exhibit a higher moisture movement than is the case with normal weight concrete (Neville et al.,).

Fine and coarse aggregates are the two major types of aggregates normally used in concrete production. Fine aggregate is generally natural sand and is graded from particles of 5mm in size down to the finest particles but excluding dust. Coarse aggregate is natural gravel or crushed stone usually larger than 5mm and less than 16mm in ordinary structure (Olufemi at al., 2009).

Currently, different varieties of lightweight concrete are being manufactured. In earlier years, the Romans established the durability of light weight concrete by using natural aggregates from volcanic deposits. After the development of Portland Cement in the early 1800s, it took the discovery and development of manufactured lightweight aggregates in the early 1900s to bring structural lightweight concrete to full maturity. The primary aim of lightweight concrete is to reduce the dead weight of concrete to be used in a structure which then allows a designer to reduce the sizes of structural elements. (columns/beams) and size of foundation as well (Javed et al, 2012).

The decreasing depletion of materials for making concrete has challenged engineers and scientists to seek new materials to replace the depleting materials. For instance, sludge from treatment of industrial and domestic waste water has been found very suitable for as partial replacement for cement in concrete, while other similar effect in the direction of waste management includes structural performance of concrete using crushed periwinkle shell as partial replacement for fine aggregate in concrete (Otunyo et al., 2014).

Abdulfatah et al., (2011) carried out an exploratory study of coconut shell as coarse aggregate in concrete. Falade, (1992) studied the use of palm kernel shell as coarse aggregate in concrete.

Abdullah, (1984 and 1999), Okafor, (1988), Basri et al., (1999), Mannant et al., (2011) and Teo et al., (2007) have also carried out exploratory studies on the use of palm kernel shells as light weight aggregate concrete. Topco, (1977) investigated the use of volcanic slag as coarse aggregate in the production of semi-light weight concrete. Javed et al., (2012) undertook an exploratory study of on the suitability of machine crushed animal bones as partial replacement of coarse aggregate in light weight concrete. These alternative light weight aggregates are therefore being adopted for non-load bearing walls and non-structural floors in buildings in order to reduce cost.

This work is an exploratory study of the use of crushed coconut shell as partial replacement of fine aggregate in concrete.

MATERIALS AND METHODS

Study Area

The study areas are Warri in Delta State and Port Harcourt in Rivers State. The coconut shells were collected from corn sellers in

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Warri while other materials used were obtained from Port Harcourt.

Materials:
The following materials were used for the experiment:

i) **Coconut shell (Fine Aggregate):** Coconut shell was collected in jute bags from Diobu in Port Harcourt, Rivers State, Umutu and Warri in Delta State, Nigeria.
ii) **Cement:** Ordinary Portland Cement (OPC) locally available in Nigeria (the DANGOTE CEMENT Brand Name) in 50kg bags was used for the experiment.
iii) **Water:** Potable water from the Civil Engineering Laboratory of the Rivers State University of Science & Technology was used to prepare the moulds and cubes as well as washing of the coconut shells.
iv) **Fine Aggregate (River Sand): Naturally occurring river sand** was obtained from the banks of Imo river at Obigbo in Rivers State.
v) **Coarse Aggregate (Gravel):** Crushed granite stones were obtained from Crushed Rock Industries quarry in Ishi-Agu, Ebonyi State, Nigeria.

Specific Gravity of Cement and Aggregates:
The pyconometer test method (BS:1377) was used to obtain the specific gravity of the cement, river sand, CCS, and gravel.

Bulk Density:
The Bulk density of the cement, river sand, CCS and gravel was obtained using (BS 812 Part 2).

Moisture Content:
The gravimetric method was employed to determine the moisture content of the river sand, CCS and gravel.

Gradation Test:
Sieve analysis (using BS:410:1969), was carried out on the river sand, CCS and gravel. The CCS, were washed, oven dried before passing them through the various sieves.

Workability Test:
Slump test was carried out to determine the workability of the concrete made with partial replacement of fine aggregate (river sand) with CCS (BS 1881 Part 102 ,1983).

Compressive Strength Test:
Metal moulds measuring 150mm x150mm x150mm were used to cast the concrete cubes. A total of 32 cubes were prepared for the mix ratios of 1:2:4 and 1:3:6 by weight and the following proportions of (CCS:river Sand), 0:100, 25:75, 50:50, and 100: 0. The samples were left to cure for 14, 21 and 28 days, respectively.
The concrete cubes were loaded to failure using compression machine in the laboratory. The tests were performed in a room with 90% humidity and room temperature of between 25^{o}Cand 29^{o}C.
The weight of each cube of concrete for the compressive strength test was 2.5kg.

Chemical Analysis:
Standard chemical analysis was conducted on the CCS sample to determine the chemical properties.

RESULTS

Table 1 shows some of the physical properties of the CSS and sand, such as maximum aggregate size, Bulk Density, Specific Gravity, Aggregate Crushing Value, Aggregate Impact Value, unit weight, moisture content, Coefficient of Uniformity and Coefficient of Curvature..

Table 1: Physical properties of Aggregates

Properties	CCS fine Aggregates	Normal fine aggregate
Normal aggregate size (mm)	2.50	5.0
Bulk Density (kg/m^3)	1428	1636
Specific Gravity (SSD) kg/m^3	229	2640
Aggregate Crushing Value (%) (ACV)	8	17.89
Aggregate impact value (%)	1.22	11.83
Unit Weight (N/m^3)	14.00	16.05
Moisture content (%)	16.69	7.9
Coefficient of Uniformity	4.0	2.87
Coefficient of Curvature	0.95	1.23

The average compressive strength of concrete at 14, 21 and 28 days for 1:2:4 mix ratio and water/cement ratio of 0.5 for the various replacement levels of fine aggregate with CSS, are shown in Table 2.

Table 2: Average Compressive Strength of Concrete at 14, 21 and 28days For 1:2:4 mix ratio and w/c = 0.5

% of CCS in concrete	% of sand in concrete	Compressive strength N/mm^2		
		14days	21days	28days
0	100	23.85	24.00	32.00
25	75	12.29	12.73	13.18
50	50	15.11	15.40	16.40
100	0	3.23	3.70	4.70

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The slump test result for the concrete for the 1:2:4 mix ratio and water/cement ratio of 0.5 for the various replacement levels of fine aggregate with CSS are as presented in Table 3.

Table 3: Slump Test Result for 1:2:4 mix ratio and w/c = 0.5

% of CCS in concrete	% of sand in Concrete	Slump (mm)	Category	Workability
0	100	30	True	Low
25	75	7	True	Low
5	50	4	True	Low
100	0	0	True	Low

The variation of the density (unit weight) with CSS replacement in concrete is shown in Table 4.

Table 4: Variation of Density of Concrete with CCS replacement in concrete for 1:2:4 mix ratio and w/c = 0.5

% of CCS in concrete	% of sand in concrete	Density Kg/m^3		
		14days	21days	28days
0	100	2.50	2.53	2.66
25	75	2.04	2.12	2.33
50	50	2.48	2.49	2.54
100	0	1.90	1.93	1.95

The Chemical analysis of the crushed coconut shell is shown in Table 5.

Table 5 Chemical Analysis of CSS

S/No	Parameter	Test Method	Result	Standard	Comment
1	pH	ASTMD 51-77	5.53	>5	Good
2	Specific Gravity	ASTMD 58	2.24	2.2 – 2.6	Good
3	Carbonate (%)	BS 3921	0.40	1	Acceptable
4	Silicon (%)	BS 1377	16.60	20	Acceptable
5	Iron (%)	ASTM 632	0.03	0.5	Acceptable
6	Salinity (%)	BS 1377	0.06	1	Acceptable
7	Aluminium (%)	BS 1377	0.91	0.05	Good
8	Sulphure (%)	BS 1377	0.015	2.0	Acceptable
9	Magnesium (%)	BS 1377	2.38	0.5	Good
10	Manganese (%)	BS 1377	0.32	0.5	Acceptable
11	Calcium (%)	BS 1377	36.14	70	Acceptable
12	Potassium (%)	BS 1377	0.006	0.5	Acceptable
13	Phosphate (%)	BS 1377	0.027	0.05	Acceptable

The plot of variation of the compressive strength with age against the various replacement levels of fine aggregate with CSS is shown in Fig.1.

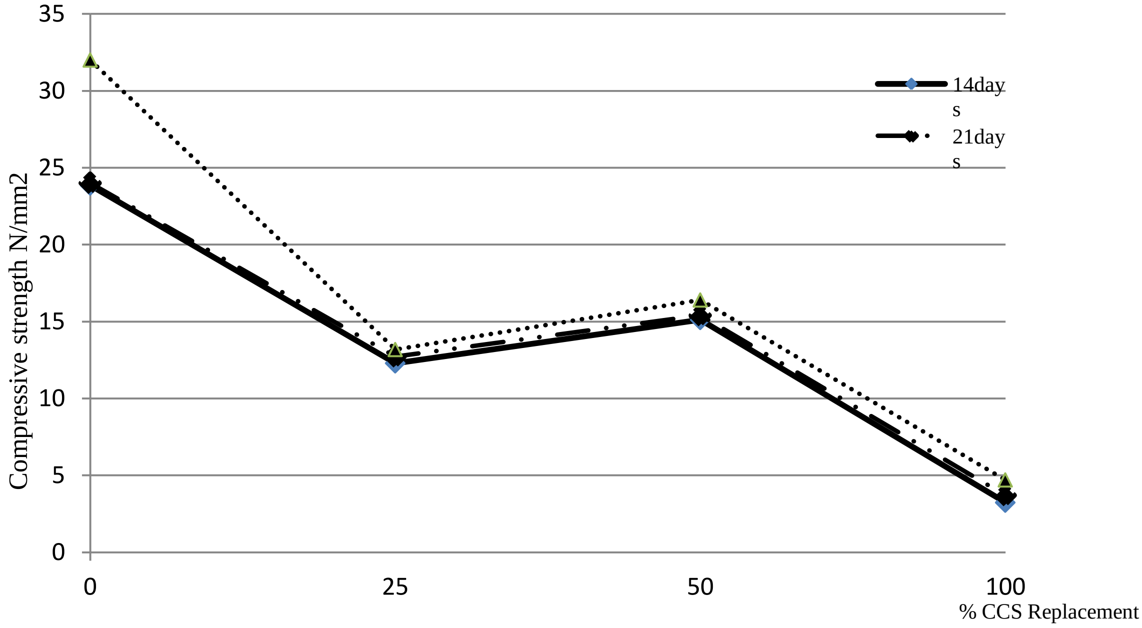

Fig. 1: Variation of Compressive strength with age in days ofr 1:2:4 (for sand/Coconut shell)

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The plot of the Slump test result versus the replacement levels of fine aggregate with CSS is shown in Fig.2.

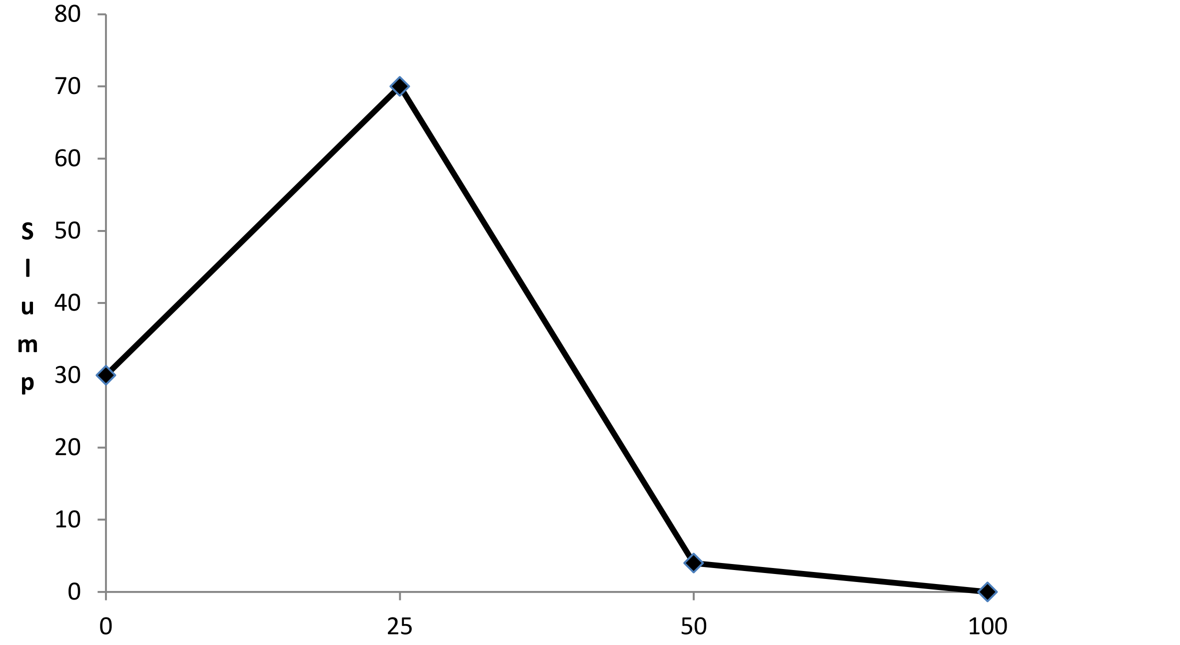

Fig. 2: Slump Test result curve for 1:2:4 (mm)

The plot of the variation of density (unit weight) against the various replacement levels of fine aggregate with CSS is shown in Fig. 3.

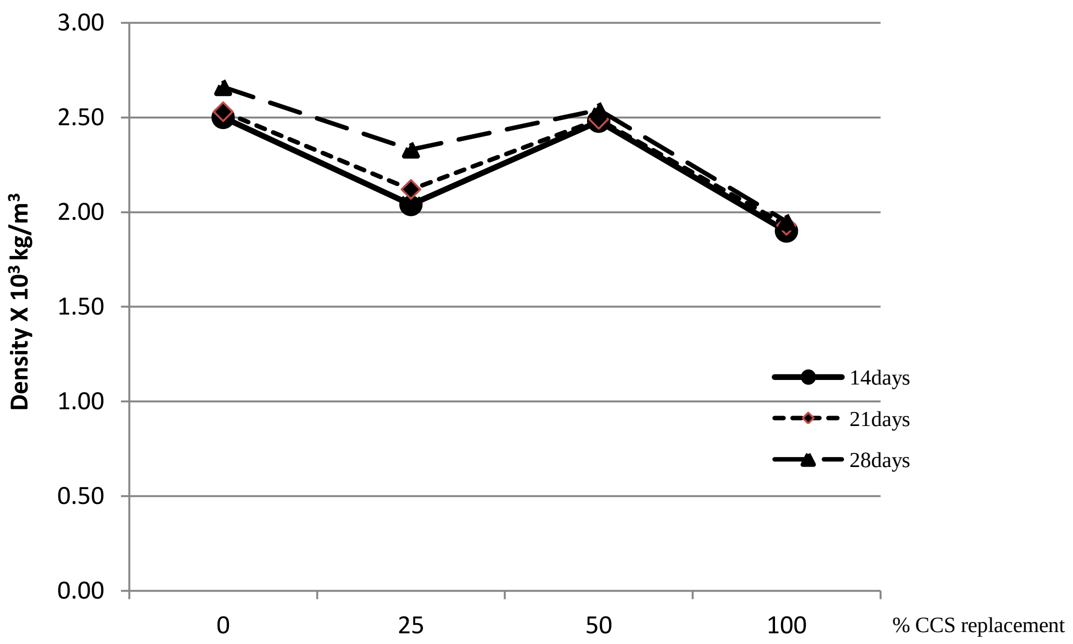

Fig. 3: Variation of Density with age in days

The plot of the particle size distribution for the CSS, fine aggregate (river sand) and gravel is shown in Fig. 4.

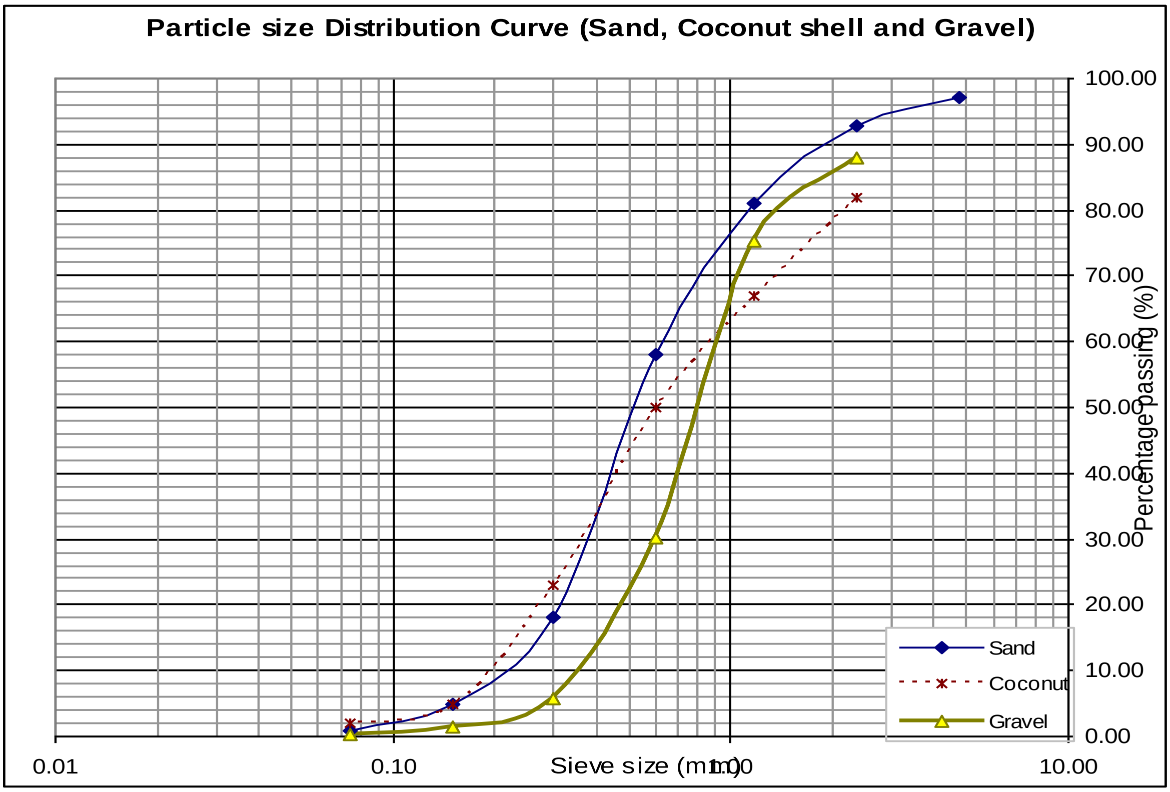

Fig. 4. Particle Size distribution curve (sand, coconut shell and gravel)

DISCUSSION

Physical Properties of Aggregates;

The maximum aggregate sizes for the CSS and fine aggregate are 2.5mm and 5.0mm respectively. The particle size distribution of CCS and normal fine aggregate as shown in Fig. 4 indicates well graded particle size distribution in both aggregates. The crushing value of CCS is lower than that of the fine aggregate, which indicates a higher strength of CCS compared to fine aggregate. The bulk unit weight of the CCS and the fine aggregate are 14.00 kN/m^3 and 16.05 kN/m^3, respectively. Aggregates with unit weight less than 12.0 kN/m^3 are lightweight aggregates therefore CSS and the sand used are slightly heavier than normal aggregates.

The Aggregate Crushing Value (ACV) of CCS is 8%, the Aggregate Impact Value (AIV) is 1.22%, while the ACV and AIV of the river sand are 17.89% and 11.83%, respectively. ACV values of less than 10% signifies an exceptionally strong aggregate, therefore both the CSS and river sand used are exceptional strong aggregate. The AIV values are well within acceptable limits.

Compressive Strength;

As is shown in Fig.1, the compressive strength of the concrete decreased with increase in replacement of fine aggregate with CCS. At 50:50 CCS:river sand replacement, the compressive strengths

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obtained at 14, 21 and 28 days are 15.17 kN/m^3, 15.40 kN/m^3 and 16.44 kN/m^3, respectively. Lightweight concretes have compressive strength of between 15.0 – 16.0 kN/m^3, therefore it can be concluded that CCS can be used to produce lightweight concrete when combined with 50% river sand. The values of the ACV and AIV in Section 3.1 supports the appreciable values of the compressive strengths obtained above at 50% CCS replacement.

Workability:

The workability of the concrete decreased as the percentage of CCS replacement increased as presented in Fig.2. This is as expected and is attributed to the fact that normal aggregates are heavier (denser) than CCS, and the replacement of the river sand with CCS is by weight. The specific surface area increases as the aggregate content is increased. Thus increase in the specific surface area due to lightness of CCS aggregates and greater amount of water needed for the mix ingredients to get closer packing, results in decrease in workability of the mix. (Javed et al., 2012).

Unit Weight;

Table 4 and Fig. 3 show the reduction in unit weights of the CCS concrete for the various percentages of CCS aggregate and the river sand at 14, 21 and 28 days. Values of the unit weights (1900kg/m^3 – 2660 kg/m^3) obtained for the various CCS:river sand replacements compare favourably with the unit weight of lightweight concrete whose dry density varies from 1418 kg/m^3 to 2026 kg/m^3 (Chen et al., 2005).

Chemical Analysis

Table 5 shows the chemical analysis of the CCS. Calcium (36.14 %) and Silicon (16.60 %) are the major ingredients of the CCS.

This confirms the reason why at 50 % CCS replacement properties of concrete obtained compare with those of normal lightweight concrete.

Gradation Analysis

The sieve analysis result revealed that both the CCS and the river sand are poorly graded aggregates as demonstrated from the values of coefficient of uniformity C_u and Coefficient of curvature C_v in Table 1.

The following conclusions have been drawn on the basis of this study.

1) The compressive strength of the concrete using CCS as partial replacement of fine aggregate at 50:50 CCS:river sand at 14, 21 and 28 days is 15.17kN/m^3, 15.40kN/m^3 and 16.44kN/m^3, respectively It follows that at 50% river sand (fine aggregate) replacement with CCS, the concrete attains strength similar to that of a lightweight concrete.
2) Workability and unit weight decreases with increase in CCS in the concrete.
3) Economy in construction can be achieved by reducing the weight of the structure at 50% replacement of fine aggregate with CCS.

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