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STUDY ON MECHANICAL PROPERTIES OF HIGH STRENGTH CONCRETE USING COCONUT SHELL AS COARSE AGGREGATE

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ABSTRACT

Lightweight aggregate concrete (LWAC) is an important and versatile material in modern construction. Many architects, engineers, and contractors recognize the inherent economies and advantages offered by this material, as evidenced by the many impressive lightweight concrete (LWC) structures found throughout the world. Use of mineral admixture in conventional concrete and light weight concrete mix has made a remarkable achievement in development and design of high strength in conventional concrete (HSC) and light weight concrete (HSLWAC). The use of high strength concrete (HSC) has many advantages such as a reduction in beam and column sizes, increased building height, greater span-depth ratio for beams in pre-stressed concrete construction and improved durability of marine concrete structures.It can be said that HSLWACs have a significant advantage over normal weight HSC because of the reduction of dead load and construction cost. Among many mineral admixtures available, Ground granulated blast furnace slag (GGBS), Silica fume (SF) andAlccofine(AF) are added to gain the high strength properties. Mineral Admixtures are added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. GGBS 50% and Silica fume or Alccofine 15% are added additive to cement and find the Mechanical properties such as compressive strength, flexural strength, split tensile strength and impact resistance can be studied.

Key words: Lightweight aggregate concrete (LWAC), Lightweight concrete (LWC), High strength conventional concrete (HSC), High strength light weight concrete (HSLWAC), Ground granulated blast furnace slag (GGBS), Silica fume (SF) and Alccofine (AF), Coconut shell (CS).

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INTRODUCTION

Concrete is the widely used number one structural material in the world today. The challenge in making a light weight concrete is decreasing the density while maintaining strength and without adversely affecting cost. Light weight concrete is typically made by incorporating natural or synthetic light weight aggregate or by entraining air into a concrete mixture. Although, coarse aggregate usually take about 50% of the overall self-weight concrete. And also, the cost of construction material is increasing day by day because of high demand, scarcity of raw material and high price of energy, from the stand point of energy saving and conservation of natural resources, the use of alternative constituents which should be light in weight to reduce the self-weight of concrete in construction materials is now a global concern.

From the studies, the use of coconut shell as a coarse aggregate is effective and having the double advantage of reduction in the cost of construction material and also as a means of disposal of wastes. Hence coconut shell is used as a replacement for coarse aggregate[1-3].

EXPERIMENTAL

Light weight concrete

Lightweight aggregate concrete (LWAC) has gained popularity due to its lower density and superior thermal insulation properties[1]. One such alternative is coconut shell (CS), which is one of the most common agricultural solid wastes in many tropical countries. Around 14,000 million coconuts are being produced annually in India. After the coconut is scraped out, the shell is usually discarded as waste. This has good potential to use in areas where coarse aggregate costly.

The bulk density of coconut shell is about 500 to 600 kg/m^3, producing concretes of about less than 2000 kg/m^3 in density, which makes them light weight. Light weight concrete has low density than the conventional concrete. Purpose of using light weight concrete in building is to reduce the self-weight of the building. It has been found that coconut shell concrete easily attains the strength of more than 17 MPa, which is requirement for structural light weight concrete as per ASTM C330.

Need for high strength light weight aggregate

Ordinary concrete, made with natural aggregate, has a low strength–weight ratio compared to steel. Therefore, in using it there is an economic disadvantage when designing structural members for tall buildings and floating structures. One of the ways to resolve this problem is through using high strength lightweight aggregate concrete[10].

Materials used

In this project, the material used are Cement, Fine aggregate, Coarse aggregate and Mineral admixtures like GGBS, SF or AF for manufacturing the concrete.

Cement

Ordinary Portland Cement (OPC) is a most commonly used cement for wide range of application. 53 grade OPC is a higher strength cement to meet the needs of the for higher strength concrete.

Fine aggregate

The material, which is passed through IS test sieve No. 4.75 mm is termed as a fine aggregate. Fine aggregate is of angular grains, clean and free from dust, dirt and organic matters.

Coarse aggregate

The material which is retained on IS test sieve No. 12.5 mm -10 mm is termed as a coarse aggregate. The coarse aggregate used in pavement block generally hard, durable and of acceptable shape, free from flaxy elongated particles.

Ground granulated blast furance slag (GGBS)

GGBS is used to make durable concrete structures in combination with ordinary portland cement. Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions.

Alccofine (AF)

Alccofine performs in superior manner than all other mineral admixtures used in concrete within India. Alccofine also consumes by product calcium hydroxide from the hydration of cement to form additional C-S-H gel, similar to pozzolans. The computed blain value based on PSD is around 12000 cm^2/g and is truly ultra-fine.

Micro silica fume (SF)

Silica fume (SF) is a mineral admixture, ultrafine material with spherical particles less than 1 μm in diameter. The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (undensified) to 600 kg/m^3. When pozzolanic materials are incorporated to concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C – S – H), which improve durability and the mechanical properties of concrete.

Super plasticier

A high performance concrete super plasticiser, based on polycarboxylic technology. Structuro 203 is a high performance super plasticiser intended for applications where increased early and ultimate compressive strengths are required.

Coconut shell

The collected coconut shells were stacked in the SRM University premises. The coconut shells were well seasoned and free from vegetative matter. After crushing the CS, they were sieved and the aggregate passing 12.50 mm sieve size was used for CS concrete. The aggregate used were in saturated surface dry (SSD) condition to prevent absorption taking place during mixing[1]. The physical and mechanical properties of CS aggregate are shown in Table 1.

Table 1 Physical properties of cement

Physical properties	Coconut shell
Maximum size	12.5
Specific gravity	1.14
Bulk density (kg/m^3)	620
Fineness modulus	6.54
Shell thickness (mm)	2-8
Water absorption	24%
Crushing value	2.56%
Impact value	3.125

The low bulk density is advantageous as the resultant of this hardened concrete will be much lighter compared to conventional concrete. This reduces the self-weight of the product[1].

Material properties

The physical properties of cement, coarse aggregates and fine aggregates used in this study are shown in Table 2, 3 and 4, respectively.

Table 2: Physical properties of cement

Tests types	Test results
Specific gravity	3.1
Initial setting time (min)	45
Final setting time (min)	540

Table 3: Physical properties of coarse aggregate

Tests types	Conventional aggregate
Maximum size (mm)	12.5
Specific gravity	2.67
Bulk density (kg/m^3)	1656
Fineness modulus	6.77
Crushing value	20.03%
Impact value	22.13%

Table 4 Physical properties of fine aggregate

Tests types	Fine aggregate
Maximum size (mm)	< 4.75
Specific gravity	2.59
Fineness modulus	2.72
Bulk density	36%

From the above test results the coconut shell exhibits more resistance against crushing, impact when compared to conventional aggregate. Also the density of coconut shell is about 620 kg/m^3, which is lesser to conventional aggregate and reduce the weight of concrete. Further the water absorption of coconut shell is found to be about 24, which is more compared to the conventional aggregate. Thus there is no to treat the coconut shell before use as an aggregate except for water absorption.

Experimental Investigation

Mix design

For the production of concrete mix, the design mix proportion for conventional concrete is 1:0.5:1.1 whereas water content as 0.28. The design mix proportion for coconut concrete is 1:0.5:0.55 whereas water content as 0.28. In the above two mix proportions include GGBS 50% and SF or AF 15% and 825 kg/m^3 of cement binders content.

RESULTS AND DISCUSSION

Fresh concrete properties

Workability is one of the important properties of fresh concrete, which is directly or indirectly responsible for quality of concrete as a whole. Adequate workability on one hand improves the desirable properties of concrete such as, finish ability, degree of compaction and strength, etc. whereas; on the other hand it reduces the undesirable properties like segregation and bleeding of concrete. The fresh concrete properties of both conventional concrete and coconut shell concrete of the mix used are shown in Table 5.

Table 5: Fresh concrete properties

S. No.	Description		Fresh concrete density (kg/m^3)	Slump (mm)	Compaction factor	Demoulded density (kg/m^3)
1.	Conventional concrete	GGBS + SF	2560	30	0.91	2420
		GGBS + AF	2550	35	0.92	2432
2.	Coconut concrete	GGBS + SF	2028	25	0.85	1980
		GGBS + AF	2030	30	0.86	1990

Hardened concrete properties

Compressive strengths were measured using a compression testing machine (CTM) with a maximum capacity of 2000 kN. For all tests, each value was taken as the average of three samples. Test results for conventional concrete and coconut shell concrete for 3 days, 7 days and 28 days curing are tabulated in Table 6.

Table 6: Compressive strength results

S. No.	Description		Density (Kg/m^3)			Compressive strength f_{ck} (N/mm^2)		
			3 days	7 days	28 days	3 days	7 days	28 days
1	Conventional concrete	GGBS + SF	2410	2420	2486	42.1	61.9	69
		GGBS + AF	2400	2440	2526	43.1	62.8	70.3
2	Coconut concrete	GGBS + SF	1988	1983	1987	30.9	33.9	41.2
		GGBS + AF	1969	1967	1970	30.7	34.9	43.2

Flexural strength test (IS 516 1959)

Flexural test is conducted for concrete beam with dimension of 500 mm × 100 mm × 100 mm. Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a materials ability to resist deformation under load. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point flexural test technique. The flexural strength represents the highest stress experienced with the material at its moment of rupture. It is measured in terms of stress, here given the symbol σ.The results are shown in Table 7.

Table 7: Flexural strength results

S. No.	Description		Flexural strength in kN			Flexural strength in N/mm^2		
			3 days	7 days	28 days	3 days	7 days	28 days
1	Conventional concrete	GGBS + SF	15.6	19	26	6.24	7.6	10.4
		GGBS + AF	18	22	26	7.2	8.8	10.4
2	Coconut concrete	GGBS + SF	11	15	19	4.4	6	7.6
		GGBS + AF	12	15.5	20	4.8	6.2	8

Split tensile strength

Split tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. Split tensile test is conducted for concrete cylinder with dimension of 200 mm of length and 100 mm of diameter. The split tensile test on cylinders was also carried out at the age of 3,7 and 28 days by placing the cylinders horizontally on a compression testing machine of 200 tones capacity as shown in Fig. 1.

Fig. 1: Impact strength test

The reported strengths are the averages of three test specimens. The split tensile strength are shown in Table 8.

Table 8: Split tensile strength results

S. No.	Description		Split strength in kN			Split strength in N/mm^2		
			3 days	7 days	28 days	3 days	7 days	28 days
1	Conventional concrete	GGBS + SF	105	126	142	6.24	4.01	4.52
		GGBS + AF	138	153.5	166	4.39	4.89	5.28
2	Coconut concrete	GGBS + SF	75	91	101	2.38	3.24	3.21
		GGBS + AF	64	93	108	2.04	2.96	3.43

Impact test (IS 516 1959)

Impact test is conducted for concrete specimen with dimension of 150 mm diameter and 60 mm. The specimen placed carefully on the plate of Drop weight machine. Iron ball is placed over the specimen and weight is dropped carefully over the iron ball. The impact test results are shown in Table 9.

Table 9: Impact test results

S. No.	Description		Impact strength in blows					
			3 days		7 days		28 days	
			Initial	Final	Initial	Final	Initial	Final
1	Conventional Concrete	GGBS +SF	496	499	678	680	943	948
		GGBS + AF	480	486	661	666	950	954
2	Coconut concrete	GGBS + SF	398	403	716	720	1098	1105
		GGBS + AF	403	409	712	725	1123	1125

CONCLUSION

The Coconut shell has better workability due to the smooth surface on one side and size of the coconut shell used in this study. The 28th day density of the coconut shell1960 to 1990 kg/m^3 and these are within the range of structural lightweight concrete of density less than 2000 kg/m^3. Compressive strength of conventional concrete increases to 26.5% and 28.7% at 3rd day, 45% and 44.4% at 7th day, 41.8% and 39.5% at 28th day, compared to coconut concrete and density of the conventional concrete is also increased compared to the coconut concrete. The flexural strength of conventional concrete increases at 29.5% and 33.3% at 3rd day, 21% and 29.5% at 7th day,26.9% and 23% in 28th day. The Split tensile strength of conventional concrete increases to 28.5% and 53.6% at 3rd day, 27.7% and 39.4% at 7th day,28.8% and 34.9% at 28th day. The impact strength of coconut shell concrete is greater than the conventional concrete at 5.5%, 8% at 7th day and 14.5%, 15.2% at 28th day.

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