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Effect of Coconut Shell as Filler Material on Hardened Properties of Concrete

Rahul NK[1], Chethan Y[2], Narasimha[3], Siddaroodh Kummi[4]
[1]Assistant Professor, Department of Civil Engineering, New Horizon College of Engineering, Bangalore.
2Student, Department of Civil Engineering, New Horizon College of Engineering, Bangalore.
3Student, Department of Civil Engineering, New Horizon College of Engineering, Bangalore.
4Student, Department of Civil Engineering, New Horizon College of Engineering, Bangalore.

Abstract: *Due to rapid growth of construction activities, conventional aggregate sources are depleting at a very fast phase, leading to significant increase in cost of construction. For sustainable development, these materials should be used wisely, and alternative cost effective and eco-friendly materials needs to be incorporated as building materials. Unique physical and chemical properties of the coconut shells made it use as an effective alternate construction material. In the present work, strength properties of coconut shell based concrete building blocks are investigated. Experimental studies were carried out on the hollow and filled coconut blocks with various options of shells orientations to understand its capability to use it as a filler material. Mechanical properties of the coconut shell based concrete is obtained by carrying out the tests on concrete cubes and cylinders. The study concludes that, coconut shell is a suitable composite and filler material for enhancing the strength of conventional solid and hollow concrete blocks.*

Key Word*: Coconut Shells, Arch Action, Hollow and Filled Coconut Concrete Blocks*

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I. Introduction

Due to rapid growth of construction activities, conventional aggregate sources are depleting at a very fast pace leading to significant increase in cost of construction activities. For sustainable development, these materials should be used wisely and alternative cost effective and eco-friendly materials need to be searched to replace conventional building materials. Variety of waste materials, organic and inorganic has been successfully used to produce various building materials such as concrete, building blocks, flush door, plywood etc. India being third largest producer of Coconut shells creates a major problem of solid waste too. But its non-biodegradable natural shell structure, with high strength and modulus properties imparted due to the chemical constituents (pentosans) and structural properties, it can be used as a filler and as an alternative in thermal insulating hollow blocks, other than as a coarse aggregate and reinforcement material in concrete technology (Olanipekun 2006, Abubakar and Abubakar 2011, Ramachandrudu 2012, Kulkarni *et. al.* 2013, Osei 2013, Ganiron 2013, Kambli and Sandhya 2014, Ahlawat and Kalurkar 2014, Shraddha and Varpe 2014).

II. Material And Methods

A. MATERILAS: General construction materials used in the preparation of coconut shell cement concrete blocks includes cement, course aggregate, fine aggregate, and coconut shell. The cement available in the local market (PPC) of grade 43 is used for preparation of conventional concrete and coconut shell concrete specimens. Coarse aggregate used in the present study is 20mm downsize granite chips. They are the particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter used in construction. Fine aggregate considered in the study pass through 4.75mm IS sieve and retained on 75 micron IS sieve. Present fine aggregate is free from organic matter and it is chemically inert, strong and durable.

Coconut shells are naturally available organic shells of non-biodegradable nature which is used in the present study as alternate construction material. Main Physical properties of coconut shells includes water absorption, specific gravity and bulk density. Coconut shell which is of organic origin have a water absorption of 26.69% and specific gravity of 1.03 with a bulk density of 515.53 kg/m^3. The chemical composition of coconut shell powder consists of Lignin (29.4%), Pentosans (27.7%), Cellulose (26.6%), Moisture (8%), Solvent Extractives (4.2%), Uronic Anhydrides (3.5%) and Ash (0.6%). It has an added advantage of high lignin content which makes the composites high weather resistant and low cellulose content makes it less water absorbent compared to other agricultural waste.

B. TESTS: To carry out the mix design for the specific grade of concrete, physical properties like specific gravity, water absorption, sieve analysis and normal consistency of materials are carried out. Specific gravity of the course and fine aggregate are obtained by standard test procedure as per IS 2386 (Part III)-1963. Similarly, Specific gravity of the cement is obtained as per IS 1489 (part 1) – 1991. Specific gravity of cement, course and fine aggregate are 3.08, 2.66 and 2.53 respectively. Similarly, sieve analysis of course and fine aggregate is performed as per standard procedure in IS 383-1970. Even the normal consistency of cement paste was calculated in order to control quality of concrete mix. Test was performed as per IS 1489 (part 1) – 1991.

C. MIX DESIGN: Based on the physical properties of cement, course and fine aggregates from above test results, mix design calculation of M25 grade of concrete was carried out as per IS code 10262: 2009. Based on mix design calculations, total quantity of materials (cement, water, course and fine aggregate) required to prepare the concrete to cast the sufficient number of cubes and cylinders. Table 1 represents the quantity of material required for casting single cube and cylinder.

Table no 1: Materials quantity details

Materials	Quantity Required in Kg	
	Cube	Cube
Cement	1.43	2.25
Water	0.68	1.07
Course Aggregates	3.77	5.93
Fine Aggregates	2.09	3.20

D. CASTING AND TESTING: Based on mix design calculation, quantities of each materials required to cast the sufficient number of cubes and cylinders are calculated. Designated grade of concrete is obtained by machine mixing. The moulds were oiled so as to prevent sticking of concrete. With proper orientation of the coconut shells, concrete is poured and cubs and cylinders were prepared. The mould is filled in 3 layers and being rammed for 35 times with tamping rod. After proper casting and curing of cubes and cylinders for sufficient days, compression test and split tensile test on cubes and cylinders were performed respectively. Figure 1a and 1b represents the casting of mould with coconut as filler material.


a


b

Fig 1a and 1b- Casting of cube and cylinder with coconut as filler.


a


b

Fig 2a and 2b- Compression and split tensile test on cubes and cylinders.

Compression test was performed as per IS: 516-1959. In compression test, the load was applied without shock and continuously at a rate of approximately 14N/mm2 until resistance of the specimen to the increasing load breaks, and no greater load can be sustained. Compressive strength is calculated by dividing the load by sectional area of the specimen. Similarly split tensile test on cylinder was performed as per IS: 5816-1976. Diametric lines are drawn on the two ends of specimen. Specimens were mounted on testing platform of compression testing machine. Two packing strips of plywood 12mm wide and 3mm thick is provided for each specimen. Apply uniform load and continue until breaking and reading is being noted. Split tensile strength of cylinders are calculated from formulae, Split tensile strength = $2P/\pi \times D \times L$, where 'P' is the load 'D'- diameter and 'L' length of cylinder. Figure 2a and 2b represents the compression test and split tensile test.

III. Result And Discussion

Figure 1 and 2 represents the compressive strength of hollow block cubes with single and double coconut shell orientation. In case of duel coconut shell, orientation will be opposite to each other. When strength comparison was carried out between conventional concrete and hollow coconut concrete block, strength in coconut concrete block was observed to be higher due to existence of arch action by shell due to its natural shape. Average 7 and 28 days compressive strength of coconut concrete block was 22.9 N/mm^2 and 23.8 N/mm^2 in single hollow block and 21.2 N/mm^2 and 25.4 N/mm^2 in duel hollow blocks respectively.

Figure 3 and 4 exebhits the comparison of compressive strength of dingle and duel filled coconut concrete block. It was observed that, filled coconut concrete blocks bears higher strength rather than the conventional concrete block. 20.88 N/mm^2 and 27.9 N/mm^2 for single and 22.2 N/mm^2 and 29.2 N/mm^2 for double were compressive strength for 7 and 28 days respectively.

From the above discussion it can be observed that, percentage of strength increased in the range from 10% to 20% for 7 days. Whereas overall percentage increase in strength varies from 10% to 28% for 28 days. Highest percentage increment in strength is around 19.29% in single hollow coconut block and 27.44% in filled duel coconut block for 7 and 28 days respectively.

Figure 5 and 6 explains split tensile of hollow and filled coconut concrete blocks respectively. It is evident from the graph that, tensile strength of both hollow and filled coconut concrete blocks were higher than the conventional concrete blocks. Split tensile strength of hollow and filled coconut concrete blocks were 4.85 N/mm^2 and 5.37 N/mm^2 against conventional concrete tensile strength of 3.88 N/mm^2 for 7 days respectively. Similarly tensile strength is 5.48 N/mm^2 for both hollow and filled concrete blocks against conventional strength of 4.15 N/mm^2 for 28 days respectively.

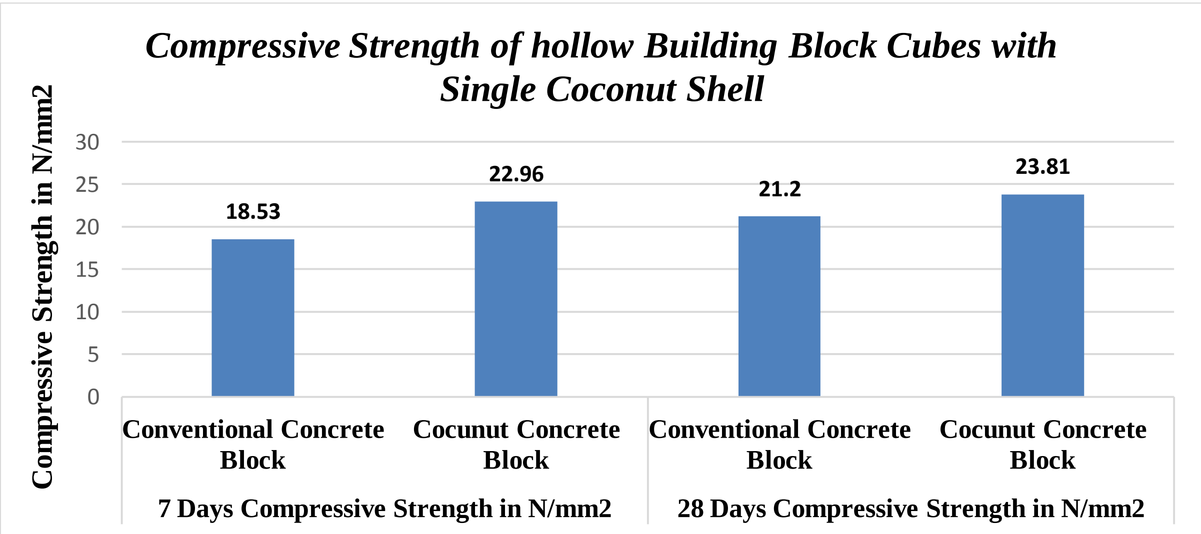

Figure 1: Compressive Strength of hollow Building Block Cubes with Single Coconut Shell

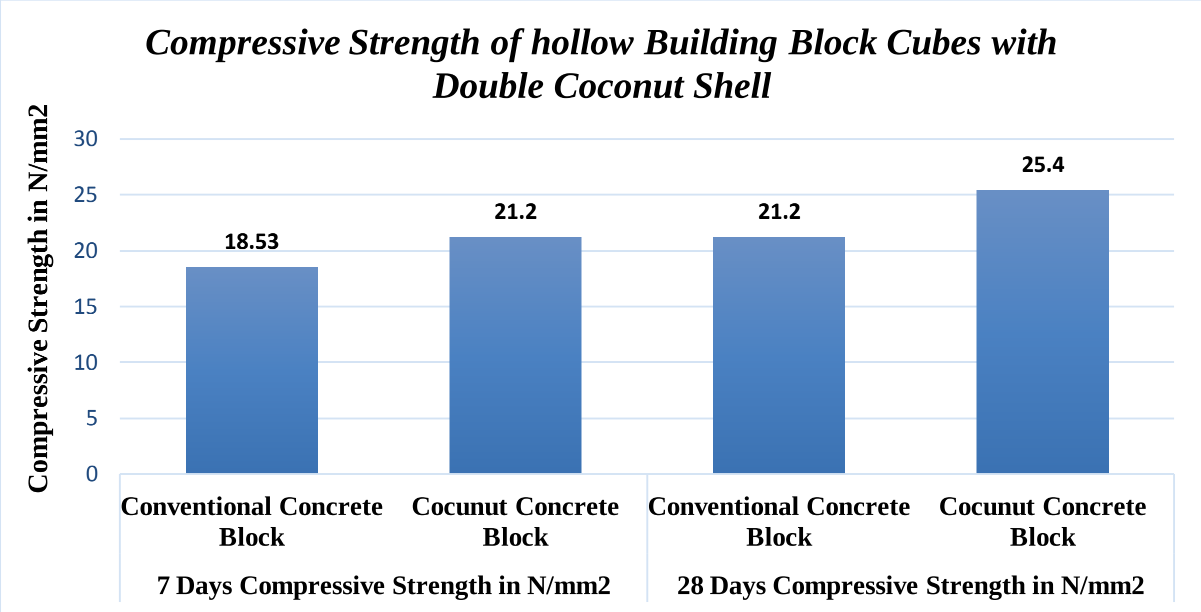

Figure 2: Compressive Strength of hollow Building Block Cubes with Double Coconut Shell

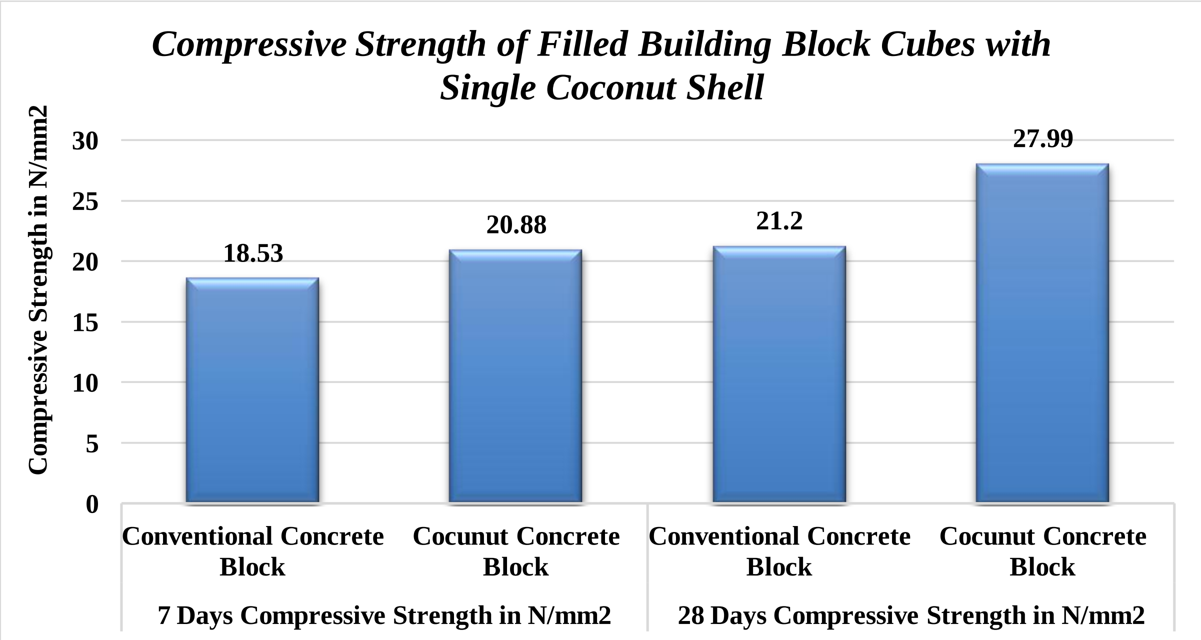

Figure 3: Compressive Strength of Filled Building Block Cubes with Single Coconut Shell

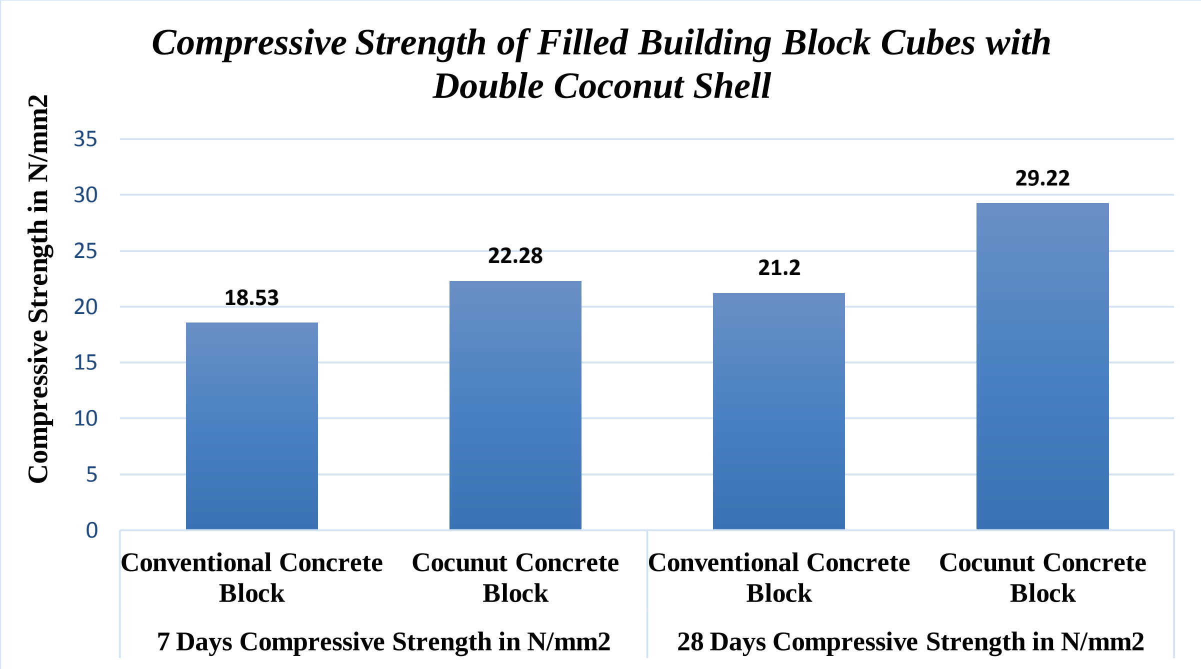

Figure 4: Compressive Strength of Filled Building Block Cubes with Double Coconut Shell

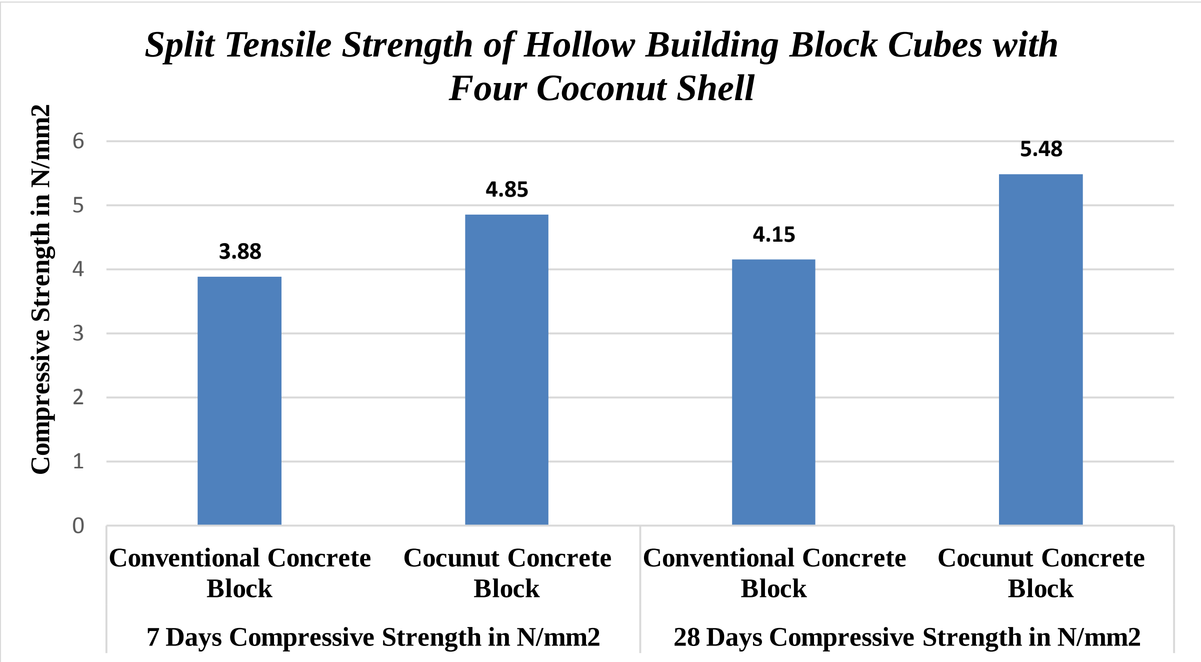

Figure 5: Split Tensile Strength of Hollow Building Block Cubes with Four Coconut Shell

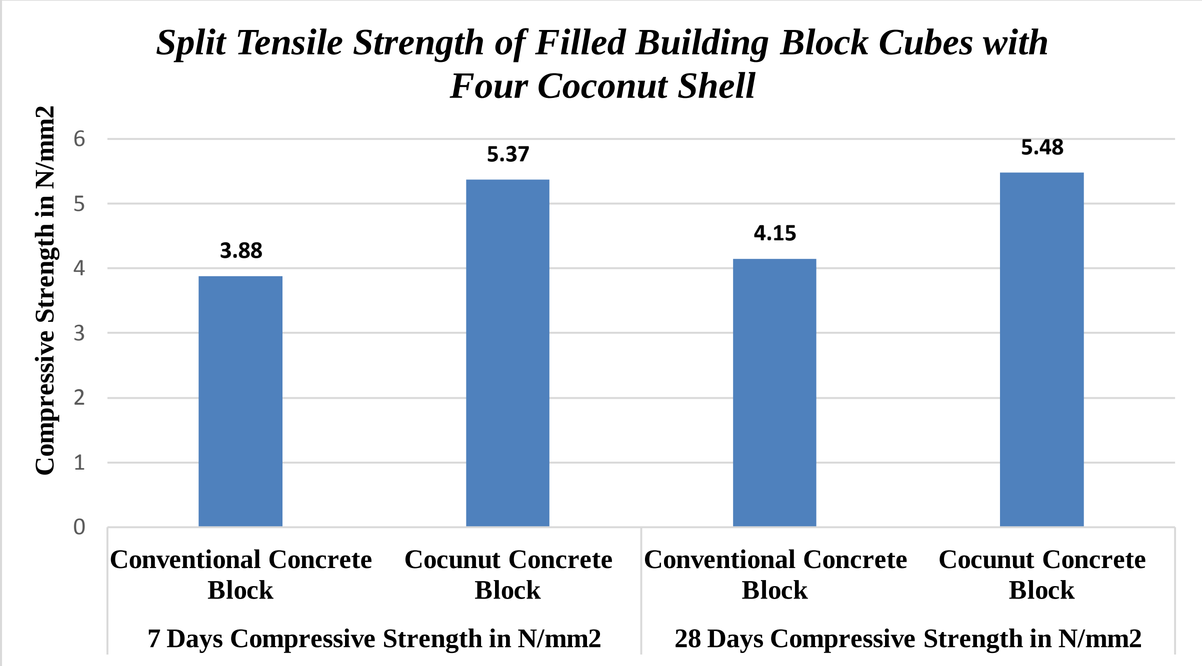

Figure 6: Split Tensile Strength of Filled Building Block Cubes with Four Coconut Shell

IV. Conclusion

1. Compressive strength of bare dome shaped coconut shells was found to be 15 KN indicating that it can be used as filler material because of its natural dome shape and chemical constituents. Moreover its pleasing finished look can even be used for slabs to give aesthetic appearance.

2. Average Compressive strength of hollow blocks for 7 days and 28 days curing found to be 22.96 N/mm^2 and 23.81 N/mm^2 for single coconut shell, 21.2 N/mm^2 and 25.40 N/mm2 for two shells in opposing orientation against 18.53 N/mm2 and 21.2 N/mm^2 for conventional concrete respectively. Similarly, Average Compressive strength of filled blocks for 7 days and 28 days curing found to be 20.8 N/mm^2 and 27.9 N/mm^2 for single coconut shell, 22.28 N/mm^2 and 29.22 N/mm^2 for two shells in opposing orientation against 18.53 N/mm^2 and 21.2 N/mm^2 for conventional concrete respectively. This indicates that the coconut shell is a suitable composite and filler for enhancing the strength of conventional solid and hollow concrete. Moreover, filled coconut shell concrete building blocks are more load bearing. This shows that with less concrete materials in hollow building blocks we can gain equal or more strength with coconut shells as filler.

3. Average Split tensile strength of hollow blocks for 7 days and 28 days curing gave 4.85 N/mm^2 and 5.48 N/mm^2 for cylinder with four dome shaped coconut shells oriented in perpendicular direction to the axis of the cylinder against 3.88 N/mm^2 and 4.15 N/mm^2 of normal concrete cylinders. Similarly, Average Split tensile strength of Filled blocks for 7 days and 28 days curing gave 5.37 N/mm^2 and 5.48 N/mm^2 for cylinder with four dome shaped coconut shells oriented in perpendicular direction to the axis of the cylinder against 3.88 N/mm^2 and 4.15 N/mm2 of normal concrete cylinders.

4. Comparison between cubes with completely filled shell and conventional solid concrete cube for 28 days curing shows an increase of 1.2 times in compressive strength.

5. Hollow building blocks with coconut shell as filler is cost effective since it saves cement and aggregate other than the thermal insulation it provides and effective management of solid waste utilization.

6. The study proved that the coconut shell hollow blocks are better cost effective alternative for building blocks thanks to its light weight, aesthetic hollow finish, high compressive strength, good thermal insulation capacity, etc., compared to the conventional concrete in construction industry.

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