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Performance of Waste Coconut Shell as Partial Replacement of Natural Coarse Aggregate in concrete

Abdullah Anwar, Sabih Ahmad, Syed Aqeel Ahmed

Abstract— Depletion of natural resources is a common phenomenon in developing nations like India due to rapid urbanization and Industrialization involving construction of Infrastructure and other conveniences. In prospect of this, people have begun researching for suitable other viable alternative materials for concrete so that the existing natural resources could be preserved to the possible extent, for the future generation. Lately, on the environmental issues, restrictions on local & natural access or sources and dispose of waste material are gaining great importance. Aggregate is a major ingredient for making concrete, occupy almost 70-80% part of concrete. The roles of structural grade lightweight concrete reduce considerably the self-load of a structure and permit larger precast units to be managed. Coconut Shell is a waste from the agrarian sector and is used in large quantities in the tropical areas. The waste coconut shell may be utilized to replace natural coarse aggregate. In this study, M 20 grade of concrete was produced by replacing natural coarse aggregates at 0%, 5%, 10%, 20%, 30%, 40% and 50% by weight with waste coconut shell. In all total Sixty Three (63) cubes were casted and their compressive strength was evaluated at 7, 14 and 28 days. The compressive strength of concrete was reduced as the percentage replacement increased. Concrete mixtures were tested and compared in terms of compressive strength of the conventional concrete at 28 days. The results showed that Coconut Shell Concrete (CSC) can be used in light weight concrete construction. Utilization of Coconut Shell will not only be cost effective and Eco friendly, but also resolve the issues related to shortage of conventional material and problem of disposal of waste material.

Index Terms— Coarse Aggregate, Concrete, Coconut Shell, Compressive Strength, Light Weight Concrete, Sustainable Development

1 Introduction

Concrete is world's most widely used construction material. The utilization of concrete is increasing at a higher rate due to development in infrastructure and construction activities all around the world [1]. In addition, Concrete is the 2nd most consumed substance in the world-behind water. About 7.23 billion tons of concrete is produced every year. Annual production represents one ton for every individual on the planet. Production of concrete is increasing due to high growth of infrastructure development and construction activities in the world [2]. However, there are some negative impacts of more production of concrete like continuous extensive extraction of aggregate from natural resources will lead to its depletion and ecological imbalance [3]. Researchers are in search of replacing coarse aggregate to form the concrete less expensive and to lead sustainable development [4]. This environmental reason has generated a lot of concern in the construction world. The role of sugarcane bagasse, wood chips, plastic waste, fabric waste, polyethylene, rice husk ash, rubber tires, vegetable fibers, paper and pulp industry waste, vegetable fibers, paper and pulp industry waste, peanut shell, waste glass, broken bricks are some cases of replacing aggregates in concrete [5].

Concrete is the best material of choice where strength, durability, impermeability, fire resistance & absorption resistance are required. Concrete production demands its constituents like aggregates, cement, water and mixtures. Sources of conventional aggregates occupy the major part of the concrete. The large scale production of concrete in construction activities using conventional coarse aggregate such as granite immoderately reduces the natural stone deposits and affecting the environment hence causing ecology imbalance. Increasing demand of natural aggregates shows that crushed stone demand will be 2050 million metric tonnes in 2020 [2]. This huge demand of natural aggregate raises a serious question about the preservation of natural aggregate sources for sustainable development. Extraction and processing of aggregates are also a major concern for the environment. Hence consumption of alternative waste material in lieu of natural aggregate in concrete production not only protects the environment, but also makes concrete a sustainable and environment friendly construction material. The high demand for concrete in the construction using normal weight aggregates such as gravel and granite drastically reduces the natural stone deposits and this has damaged the environment thereby causing ecological imbalance. Therefore, there is a need to explore and to find out suitable replacement material to substitute the natural stone. In developed nations, the construction industries have identified many artificial and natural lightweight aggregates (LWA) that have replaced conventional aggregates thereby reducing the size of structural members.

Coconut shell is categorized as light weight aggregate. The coconut shell when dried, contains cellulose, lignin, pentosans and ash in varying percentage [6]. Withal, in Asia the construction industry is yet to utilize the advantage of light weight concrete in the construction of high rise structures [7]. Coconut Shell (CS) is not commonly practiced in the construction industry, but are often dumped as agricultural wastes. Until now, Industrial byproducts and domestic wastes have been utilized in concrete, but the utilization of agricultural waste in concrete is in its early childhood phase. Coconut shell is an agricultural waste. The concrete with ground coconut shell was found to be durable in terms of its resistance in water, acidic, alkaline and salty. Coconut shell being a hard and not easily degrade material if crushed to size of sand can be a potential material to substitute sand. At present, coconut shell has also been burnt to produce charcoal and activated carbon for food and carbonated drinks and filtering mineral water use. However, the coconut shell is still under utilized in some places. The purpose of this research is to disseminate awareness of using coconut shell as partial replacement of coarse aggregate in concrete and determining its compressive strength.

2 Coconut Shell

Coconut is grown in more than 93 countries. India is the third largest, having cultivation in an area of about 1.78 million hectares for coconut production. Yearly output is close to 7562 million nuts with an average of 4248 nuts per hectare [8]. The coconut industry in India accounts for over a quarter of the world's total coconut oil output and is set to grow further with the global increase in demand. Nevertheless, it is likewise the primary contributor to the nation's pollution problem as a solid waste in the form of shells, which involves an annual production of approximately 3.18 million tonnes. It also presents serious disposal problems for a local environment, is an abundantly available agricultural waste from local coconut industries. Coconut shell being a difficult and not easily degrade material if crushed to the size of sand can be a likely material to substitute sand. At present, coconut shell has also been burnt to produce charcoal and activated carbon for food and carbonated drinks and filtering mineral water use. The chemical composition of the coconut shell is similar to wood. It contains 33.61% cellulose, 36.51% lignin, 29.27% and ash at 0.61%. In developing countries, where abundant coconut shell waste is discharged, these wastes can be used as potential material or replacement material in the construction industry. This will receive the dual advantage of reduction in the monetary value of construction material and also as a means of disposal of wastes.

Fig.1 Coconut Shell

Fig.2 Waste Coconut Shell

3 Properties of Coconut Shell

a) Coconut shell has high strength and modulus properties.

b) It has added advantage of the high lignin content. High lignin content makes the composites more weather resistant.

c) It has low cellulose content due to which it absorbs less moisture as compare to other agricultural waste.

d) Coconuts are being naturally available in nature and since its shells are non-biodegradable; they can be used readily in concrete, which may fulfill almost all the qualities of the original form of concrete.

Table 1: Availability of coconut shell [9]

S. No.	Country	Coconut Production 2012 (metric tonnes)	% of World Total
1.	Indonesia	18,000,000 t	30.0%
2.	Philippines	15,862,386 t	26.4%
3.	India	10,560,000 t	17.0%
4.	Brazil	2,888,532 t	4.8%
5.	Sri Lanka	2,000,000 t	3.3%

Source: FAOSTAT data, 2014 (last accessed by Top 5 of Anything: January 2014).

4 Literature Review

4.1 Olanipekun (2006) carried out the comparative cost analysis and strength characteristics of concrete produced using crushed, granular coconut and palm kernel shell as substitutes for conventional coarse aggregate. The main objective is to encourage the use of waste products as construction materials in low-cost housing. Crushed granular coconut and palm kernel was used as substitute for conventional coarse aggregate in the following ratios: 0%, 25%, 50%, 75% and 100% for preparing of mix ratios 1:1:2 and 1:2:4. Total 320 cubes were casted, tested and their physical and mechanical properties were determined. The result showed that the compressive strength of the concrete decrease as the percentage of the coconut shell increases in the two mix ratios, Coconut shell exhibited a higher compressive strength than palm kernel shell in the test. Moreover, there is a cost reduction of 30% and 42% for concrete produced from coconut shell and palm kernel shell respectively [10,11].

4.2 Siti Aminah Bt Tukiman and Sabarudin Bin Mohd (2009) replaced the coarse aggregate by coconut shell and grained palm kernel in their study. Percentage of replacement by coconut shell were 0%, 25%, 50%, 75% and 100% respectively. Conclusion is that the combination of these materials has potential of being used as lightweight aggregate in concrete and also has reduce the material cost in construction [12].

4.3 Olutoge (2010) studied the saw dust and palm kernel shells (PKS). Fine aggregates are replaced by saw dust and coarse aggregates by palm kernel shells in reinforced concrete slabs casting. Conventional aggregates were replaced by saw dust and PKS in same ratios of 0%, 25%, 50%,75% and 100%. Compressive and flexural strengths were noted at different

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time intervals. It was seen that at 25% sawdust and PKS can produce lightweight reinforced concrete slabs that can be used where low stress is required at reduced cost. 7.43% reduction can be achieved [13]

4.4 J. P. Ries (2011) observed that Lightweight aggregate plays important role in today's move towards sustainable concrete. Lightweight aggregates contributes to sustainable development by lowering transportation requirements, optimizing structural efficiency that results in a reduction in the amount of overall building material being used, conserving energy, reducing labour demand and increasing the life of structural concrete.

4.5 Abubakar and Muhammed Saleh Abubakar (2011) compared the physical and mechanical properties of coconut shell and crushed granite rock also a total of 72 concrete cubes of size 150x150x150mm with different mix ratios of 1:2:4, 1:1.5 :3 and 1:3:6 were casted and tested for evaluating different properties. Aggregate crushing value (ACV) for coarse aggregate was 21.84 and 4.71 for coconut shell. Elongation and flakiness index were 58.54 and 15.69 respectively for gravels, while for coconut shell, it was 50.56 and 99.19 respectively. Compressive strength of concrete cubes in N/mm^2 of coconut shell at 7,14,21 and 28 days with mix ratios of 1:2:4, 1:1.5:3, and 1:3:6 are (8.6, 8.9 ,6.4,), (9.6, 11.2, 8.7), (13.6, 13.1, 10.7) and (15.1, 16.5, 11) respectively, likewise (19.1, 18.5, 9.6), (22.5, 23.0, 10.4), (26.7, 24.9, 12.9) and (28.1, 30.0, 15) respectively for gravel. Since the concrete strength of coconut shell with mix ratio 1:1.5:3, attained 16.5 N/mm^2 compressive strength at 28 days it can be used in plain concrete works, cost reduction of 48% will be achieved [14].

4.6 Maninder Kaur & Manpreet Kaur (2012) published a review paper in which it is concluded that use of coconut shells in cement concrete can help in waste reduction and pollution reduction. It is also expected to serve the purpose of encouraging housing developers in investing these materials in house construction. It is also concluded that the Coconut Shells are more suitable as low strength giving lightweight aggregate when used to replace common coarse aggregate in concrete production [15].

4.7 Vishwas P. Kulkarni et al (2013) studied that Aggregates provide volume at low cost, comprising 66 percent to 78 percent of the concrete. M20 Concrete is produced by 0%, 10%, 20%, 30% replacement of coarse aggregate by coconut shell. There is no need to treat the coconut shell before use as an aggregate except for water absorption. No bond failure was observed, confirming that there was adequate bonding between the coconut shell aggregate concrete and the steel bars [16].

4.8 Daniel Yaw Osei (2013) in this experimental study coarse aggregate is partially replaced by coconut shell. Percentages of replacement by coconut shell were – 0%, 20%, 30%, 40%, 50%, 100%. He concluded that CS can be used to produce lightweight concrete and 18.5% replacement of crushed granite with coconut shells can be used to produce structural concrete [17].

4.9 Parag S. Kambli & Sandhya R. Mathapati. (2014) prepared three different Mix Designs for M20, M35, M50 grades of concrete. Percentage replacement by coconut shell varied as 0%, 10%, 20%, 30%, 40% respectively. It is concluded in this study that for M20 grade concrete cubes with 30% replacement of CS aggregates had given strength of 23 MPa at 28 days. Concrete cubes with 30% replacement of CS aggregates had given strength of 42 MPa at 28 days for M35. For M50 grade concrete cubes with 30% replacement of CS aggregates had given strength of 51 MPa at 28 days [18].

4.10 Dewanshu Ahlawat & L.G.Kalurkar (2014) explored the possibility of producing M20 grade of concrete by replacing conventional aggregate of granite by coconut shell. Forty five cubes were casted. Percentage of replacement of conventional coarse aggregate by coconut shell were 2.5%, 5%, 7.5%, 10%. Compressive strength were 19.71, 19.53, 19.08, 18.91 N/mm^2 respectively at 28 days. Workability and compressive strength had been evaluated at 7, 14 and 28 days. The compressive strength of concrete reduced as the percentage replacement increased. By these results it can be concluded that coconut shell concrete can be used in reinforced concrete

5 Experimental Materials

5.1 Cement

Commercially available Ordinary Portland Cement of 43 grades manufactured by the JP Cement Company confirming to IS 8112:1989 was used in the field [19] (Specification, Bureau of Indian Standards, New Delhi). The Physical Properties of OPC Cement are shown in Table 2.

Table 2: Physical Properties of Cement

Details	Normal Consistency (%)	Fineness of Cement (%)	Specific Gravity	Setting Time (min.)	
				Initial	Final
OPC (G-43)	27.65	6.5	3.15	80	260

5.2 Fine Aggregate

Fine aggregate normally consists of natural, crushed, or manufactured sand. Natural sand is the usual component for normal weight concrete. In some cases, manufactured light weight particles used for lightweight concrete and mortar. The maximum grain size and size distribution of the fine aggregate depends on the type of product being made. Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available river sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to the requirements of IS 383:1970 [20]

Table 3: Physical Properties of Fine Aggregate

S. No.	Parameters	Results
1.	Specific Gravity	2.60
2.	Fineness Modulus	3.30
3.	Water Absorption (%)	1.10
4.	Bulk Density (Kg/m^3)	
	Loose	1585
	Compacted	1760

5.3 Coarse Aggregate

Coarse Aggregate in concrete occupies 35 to 70% of the volume of the concrete. Smaller sized aggregates produce higher concrete strength. Particle shape and texture affect the workability of fresh concrete. Usually an aggregate with specific gravity more than 2.55 and absorption less than 1.5% (except for light weight aggregates) can be regarded as being of good quality. Where aggregates strength is higher, concrete strength is also higher. Fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse aggregate are obtained from a local quarry, conforming to IS 383:1970 is used [20].

Table 4: Physical Properties of Coarse Aggregate

S. No.	Parameters	Results
1.	Specific Gravity	2.75
2.	Fineness Modulus	6.50
3.	Water Absorption (%)	1.50
4.	Bulk Density (Kg/m^3)	
	Loose	1600
	Compacted	1790

5.4 Coconut Shell

Coconut shell particles are used as reinforcing material for investigation. Shell particles of size between 20 mm – 600 μ are prepared in grinding machine. Coconut shell has high strength and modulus properties. Coconut shells were collected from local shop in Lucknow to analyze its properties as shown in Table 5.

Table 5: Physical Properties of Coconut Shell

S. No.	Parameters	Results
1.	Specific Gravity	1.33
2.	Water Absorption (%)	25
3.	Bulk Density (Kg/m^3)	
	Loose	590
	Compacted	800
4.	Shell Thickness (mm)	2-7

Figure 3: Waste Coconut Shell,
(Source: Lucknow, Uttar Pradesh, India)

5.5 Water

Water is an important factor of concrete as it actually participates in the chemical reaction with cement. Potable water is employed in fusing of concrete.

6 Nominal Proportions

The concrete mix is designed as per IS: 10262-1982 [21], IS: 456-2000 [22] for the normal concrete. The grade of concrete, which we adopted, is M20. The concrete mix proportion (cement: fine aggregate: coarse aggregate) is 1:1.5: 3 by volume and a water cement ratio of 0.50.

7 Experimental Methodology

The study is conducted to analyze the compressive strength of concrete when the natural coarse aggregate is partially replaced with waste coconut shell respectively. Compressive strength tests were done on compression testing machine using cube samples. Three samples per batch were tested with the average strength values reported in this paper. The natural coarse aggregates were replaced as 0%, 5%, 10%, 20%, 30%, 40% and 50% by weight of M-20 grade concrete. In all total 63 cubes of OPC (150mm × 150mm × 150mm) were examined and results were analyzed after curing of 7days, 14days and 28 days. Due to high water absorption of coconut shell, they were pre-soaked in water for 24 hours, prior to mixing. Results obtained from the replacement are compared with data from a

Conventional concrete.

8 EXPERIMENTAL SET-UP

Subsequently, on a detailed study we have obtained the following outcomes for the compression tests as shown in the Table 6 to Table 8.

8.1 COMPRESSIVE STRENGTH OF CONCRETE AT 07 DAYS:

Table 6: Waste Coconut Shell Replacement; Compressive Strength of Concrete (M 20) at 07 days

S. No.	Specimen	Compressive Strength at 07 days (N/mm²)
1.	Conventional Concrete	15.12
2.	5%	14.30
3.	10%	13.83
4.	20%	12.11
5.	30%	11.65
6.	40%	10.75
7.	50%	10.05

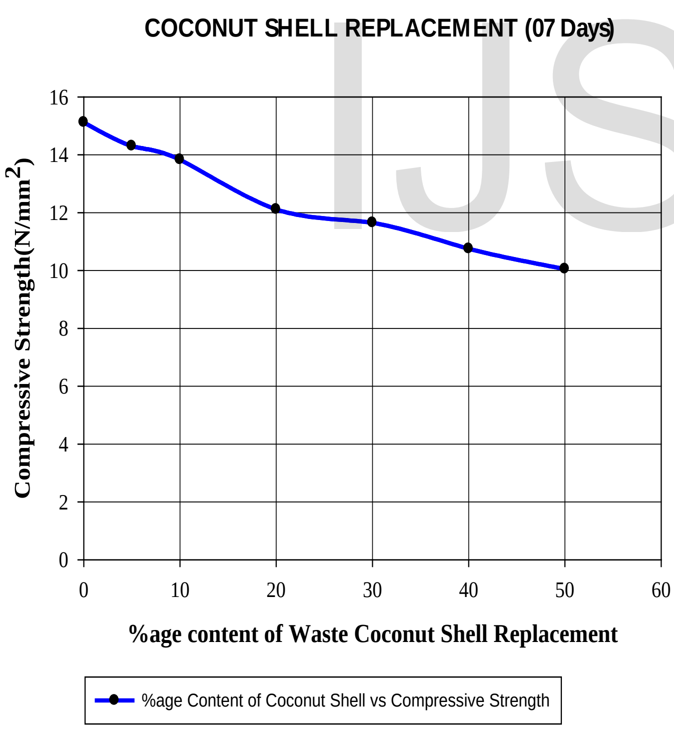

Fig.4: Percentage Replacement of Waste Coconut Shell vs Compressive Strength (N/mm^2) of Concrete for M 20 at 07 days

8.2 COMPRESSIVE STRENGTH OF CONCRETE AT 14 DAYS:

S. No.	Specimen	Compressive Strength at 14 days (N/mm^2)
1.	Conventional Concrete	18.63
2.	5%	18.15
3.	10%	17.78
4.	20%	16.77
5.	30%	15.90
6.	40%	15.33
7.	50%	14.58

Table 7: Waste Coconut Shell Replacement; Compressive Strength of Concrete (M 20) at 14 days

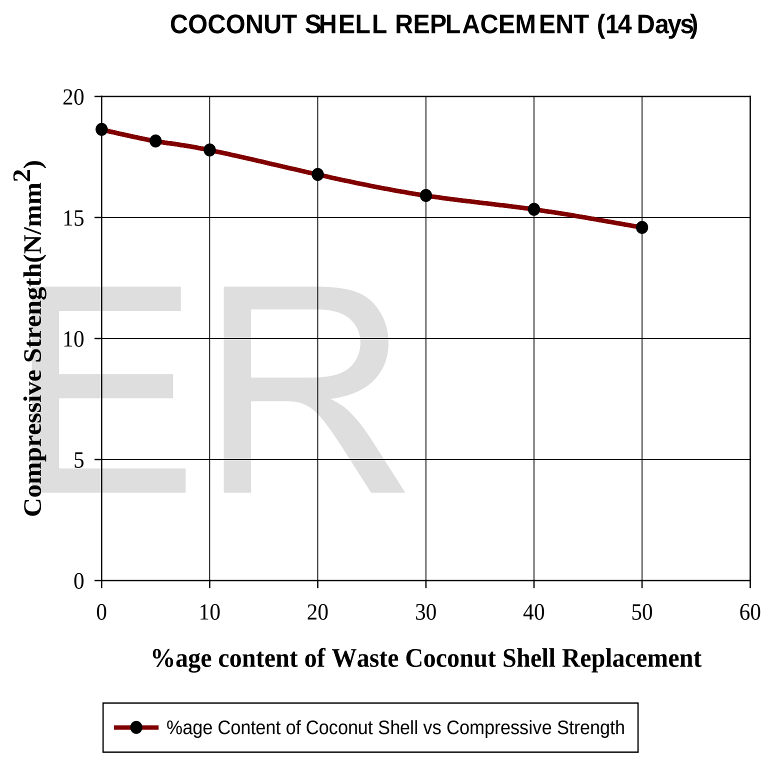

Fig.5: Percentage Replacement of Waste Coconut Shell vs Compressive Strength (N/mm^2) of Concrete for M 20 at 14 days

8.3 COMPRESSIVE STRENGTH OF CONCRETE AT 28 DAYS:

Table 8: Waste Coconut Shell Replacement; Compressive Strength of Concrete (M 20) at 28 days

S. No.	Specimen	Compressive Strength at 28 days (N/mm²)
1.	Conventional Concrete	23.25
2.	5%	21.45
3.	**10%**	**20.75**
4.	20%	19.63
5.	30%	18.67
6.	40%	17.03
7.	50%	16.20

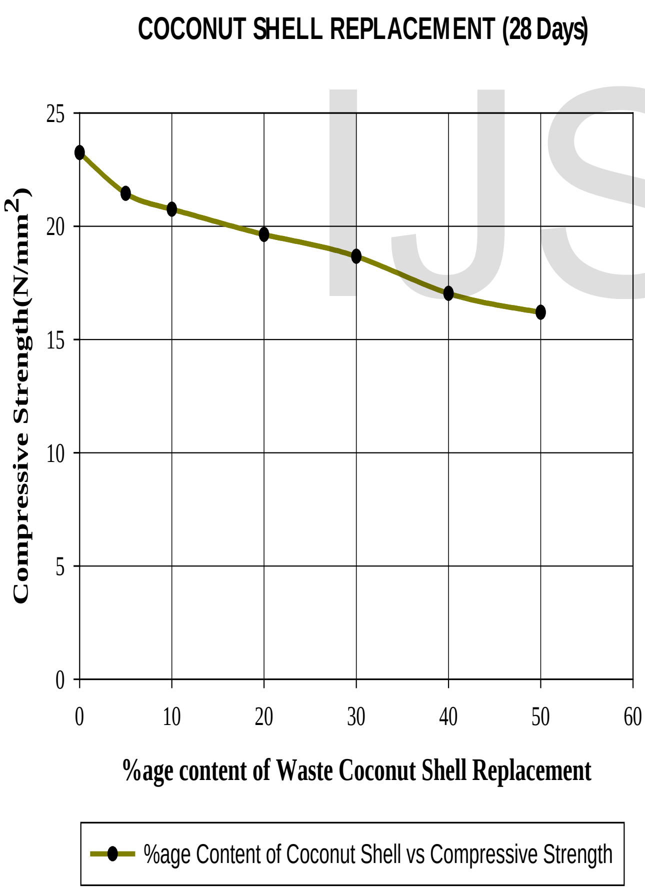

Fig.6: Percentage Replacement of Waste Coconut Shell vs Compressive Strength (N/mm²) of Concrete for M 20 at 28 days

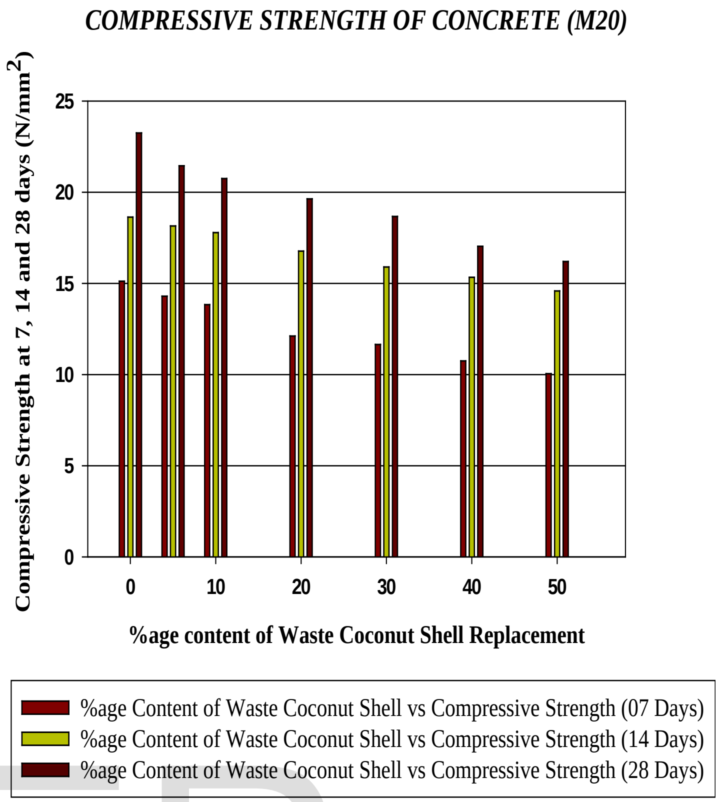

Fig.7: (BAR GRAPH) Percentage Replacement of Waste Coconut-Shell vs Compressive Strength (N/mm²) of Concrete for M 20 at 7, 14 and 28 days

9 RESULTS AND DISCUSSIONS

Experimental investigation is performed to determine the Compressive Strength of Coconut Shell Concrete on partial replacement of natural coarse aggregate and also to compare the behavior of concrete for more fruitful outcome. At different proportions, varying strength of concrete was observed, which are measured in N/mm². The results obtained for 28-day compressive strength confirms the optimal percentage requirement for substitute of natural coarse aggregate with Waste Coconut Shell as shown in Fig. 6 and Fig. 7 (Bar Graph).

10 CONCLUSION

The purpose of this research is to compare and find out the characteristic strength of M20 grade Coconut Shell Concrete at the water cement ratio of 0.50. Using the waste coconut shell by replacing fast depleting conventional aggregate source construction material and thereby getting the solution for social and environmental issues. Based on experimental investigations concerning the compressive strength of concrete, the following observations are drawn:

1. Concrete on 10% partial replacement of natural coarse aggregate with Waste Coconut Shell, Compressive Strength obtained is 20.75 N/mm^2 at 28 days. Thus, making the replacement both technically and economically feasible and viable (Table 8). On further replacement, decrease in the compressive strength of Coconut Shell Concrete has been observed. (Fig. 6 and Fig. 7).

2. Coconut shell can be grouped under lightweight aggregate because 28-day air-dry densities of coconut shell aggregate concrete are less than 2000 kg/m^3. Actual Density of coconut shell is in the range of 550 - 650kg/m^3 [23].

3. From the above experimental results and discussions of researches on coconut shell, the coconut shell has potential as lightweight aggregate in concrete. Also, using the coconut shell as aggregate in concrete can reduce the material cost in construction because of the low cost and its abundant agricultural waste.

4. The specific gravity of coconut shell is low as compared to the coarse aggregate and the water absorption is higher for coconut shell than coarse aggregate and hence the strength decreased in comparison with the conventional concrete.

5. Coconut Shell Concrete can be used in rural areas and places where coconut is abundant and may also be used where the conventional aggregates are costly.

6. Coconut shell concrete is also classified as structural lightweight concrete. It is concluded that the Coconut Shells are more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production.

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Abdullah Anwar was born in 1988 in Gorakhpur city, Uttar Pradesh. He received his Bachelor of Technology degree in Civil Engineering from U.P.T.U, Lucknow, in 2012. In 2016 he received his Master's Degree in Structural Engineering from Integral University, Lucknow. Presently he is Assistant Professor, in Department of Civil Engineering at Integral University, Lucknow. He has authored numerous research papers in National and International Journals/Conferences. He has also presented research papers in Conferences/Seminars. He is also an Associate Member of Institution of Engineer's (AM-IE), American Society of Civil Engineer's (AM-ASCE) and Indian Geotechnical Society-Delhi Chapter (AM-IGC)

E-mail Id: a.anwar14330@gmail.com ,
abdullah_amu786@yahoo.com

Sabih Ahmad was born in 1971 in Aligarh city, Uttar Pradesh. He received his B.Sc Engineering (Civil) from A.M.U, in 1994. In 2002 he received his Master's Degree in Structural Engineering from A.M.U, Aligarh and pursuing Ph.D from Integral University, Lucknow. He has a vide experience in teaching, research at UG and PG levels. Presently he is Associate Professor in the Department of Civil Engineering at Integral University, Lucknow. He has authored numerous research papers in National and International Journals/Conferences. He is also a Member of Institution of Engineer's and Indian Geotechnical Society-Delhi Chapter.

E-mail Id: sabihahmed10@gmail.com

Syed Aqeel Ahmad was born in 1975 in Lucknow city, Uttar Pradesh. He received his B.Sc Engineering (Civil) from Jamia Millia Islamia, New Delhi in 1996. He received his Master's Degree in Transport Planning from School of Planning and Architecture, New Delhi in 1999 and Ph.D from Integral University, Lucknow in 2015. He owns a vide professional experience and worked as Deputy Director (Technical) in the Ministry of Urban Development, Govt. of India, New Delhi. Presently he is Associate Professor, in Department of Civil Engineering at Integral University, Lucknow. He has authored numerous research papers in National and International Journals/Conferences. He is also a Member of Indian Road Congress (IRC), Institute of Town Planning of India (ITPI), Institute of Urban Transport (IUT), Institute of Rail Transport (IRT), American Society of Civil Engineer's (ASCE).

E-mail Id: syedaqeel@iul.ac.in