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Properties of Pavement Quality Concrete for Partial Replacement of Natural Coarse Aggregates with Coconut Shell Aggregates

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Abstract
This paper presents the results of an investigation carried out on the comparative cost analysis and strength characteristics of concrete produced using crushed, granular coconut shells as substitutes for conventional coarse aggregate in gradation of 0%, 5%, 10%, 15% and 20% for M30 grade of concrete. Experimental study includes 7, 14 and 28 days density, compressive strength, flexural strength and fatigue strength. As expected, when the percentage of coconut shell decreases, the density and compressive strength of concrete are increased and vice versa. The changes in the properties of control mix were compared. From the study it is found that an effective replacement of 10% coconut shell aggregates for M30 grade. The compressive strength is found to be 34.30 N/mm2, the flexural strength is 9.28N/mm2and fatigue life is found to be 345238 number of cycles. When the results were compared with control mix the compression strength is reduced by 1.29%, flexural strength is reduced by 4.5% and fatigue life is reduced by 3.8% only. After the studies it can be concluded that there is a marginal decrease the strength within the allowable limits. Hence, this investigation gives encouraging results for coconut shell to be used as coarse aggregate in concrete.

Keywords: Agricultural waste, coconut shell, fatigue strength, flexural strength and pavement quality concrete.

Introduction

Performance of rigid pavement majorly governs by concrete slab than the sub grade support. Rigid pavements are majorly used in low volume roads in airports roads etc., the initial construction of rigid pavement is comparatively high but maintenance cost is low. Major cost is required for concrete slab construction. The surface layer of rigid pavement consists of a concrete layer called as Pavement Quality Concrete (PQC). In the present scenario, no construction activity can be imagined without concrete. It is one of the most commonly used materials in construction industry and is the 2nd most consumed substance in the world after water. More than 10 billion tons of concrete is produced every year. Annual production represents approximately 1.5 ton for every person on the planet. Aggregates are the largest constituent in the concrete. About 70–80% of the volume of structural concrete is occupied by aggregates, in which 25–30% is occupied by fine aggregate and 40–50% is occupied by coarse aggregate [1].

Reddy et al.,[7] stated that the consumption of the primary aggregate was 110 million tons in the U.K. during 1960 and reached nearly 275 million tons in the year 2006. Similarly, 2 billion tons of aggregate are produced each year in the United States and it is expected to increase to more than 2.5 billion tons by the year 2020. It has been predicted that the demand for concrete is expected to grow approximately upto18 billion tons a year by 2050. Such heavy demands draw attention and preservation of natural aggregates, which are a matter of grave concern. Since aggregates contribute about 60–80% of the volume of the concrete, effective and efficient use of agricultural waste contributes to energy saving, conservation of natural resources and reduction of the cost of construction materials. Agricultural wastes in the form of aggregate for concrete production can be considered as one of the environmental benefits and has shown better thermal property with the proven recognition by most of the sustainability rating systems. Sustainable development is a challenge that civil engineers have an opportunity to address. It is necessary to look for sustainable solutions for concrete constructions in future. Sustainable concrete can be produced by using green materials having less energy consumption and which could be recycled and replenished. With reference to previous studies most of the studies were concentrated on properties of fresh and hardened concrete when the aggregates are replaced by agro wastes only. Hence it is required to study the replacement scheme with reference to PQC as per Indian Road Congress(IRC) specifications.

Methodology and materials

The study methodology involves collection of different materials such as coarse aggregates, fine aggregates, coconut shells and cement from suitable source. Then materials were subjected to various tests as per IS:383-2016 and IRC:15-2017 specifications. The concrete mix is prepared as per IRC:44-2017 specifications and were subjected to various properties such as slump value test, density test, compression strength test, flexural strength and fatigue strength test as per the IS standards.

Table 1. Physical properties of Coarse aggregates

Sl No.	Characteristics	Result Obtained	Allowable Limit	Reference
Coarse Aggregates				
1	Specific Gravity	2.654	-	IRC44 – 2017
2	Water Absorption	2.04%	5%	
3	Combined Index	19.35%	35%	
4	Crushing Test	27.86%	30%	IS: 383-2016
5	Impact Test	16.68%	30%	
6	Abrasion Test	20.48%	35%	
Coconut shell Aggregates				
1	Specific Gravity Test	1.293	1.05-1.25	K.Gunashekaran[1]
2	Impact Test	4.41	7.00-8.50%	
3	Abrasion Test	2.592	1.50-1.65%	
4	Shell Thickness	2-5mm	2-8mm	

Results and Discussions

The analysis results were presented in the form of tables and graphs in this part.

Workability Test

Table 2. Workability test on concrete

Percentage of replacement	Slump in "mm"	Compaction Factor Value
0%	27	0.89
5%	28	0.89
10%	29	0.9
15%	31	0.91
20%	33	0.92

As per the tests on fresh concrete the slump and compaction factor values have increased with increase in the percentage of coconut shells in concrete and the slump results are 27mm,28mm,29mm,31mm and 33mm and compaction factor results are 0.89, 0.89, 0.9, 0.91, 0.92 with a replacement of 0%,5%,10%,15% and 20% respectively. The results indicate that as the percentage of coconut shells increases the workability of concrete also increases.

Density Test

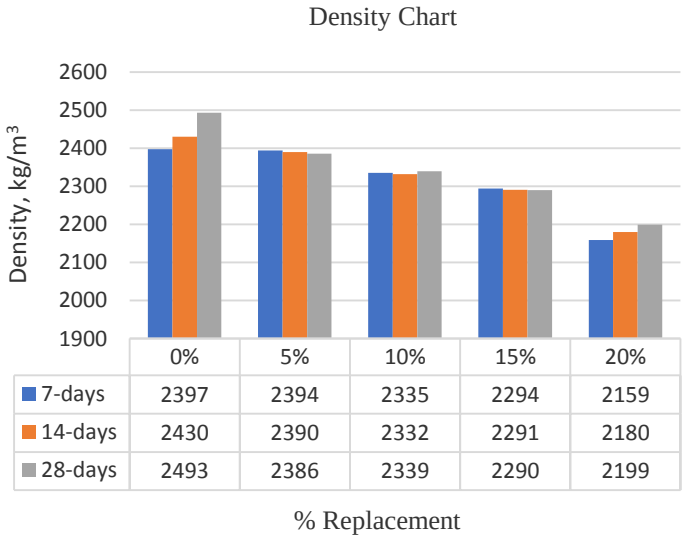

Figure 1. Density test on concrete

As per the density test on concrete, obtained results are 2397kg/m^3, 2394kg/m^3, 2335kg/m^3, 2294kg/m^3 and 2159kg/m^3 of 7 days density test, 2430kg/m^3, 2390kg/m^3,2332kg/m^3, 2290kg/m^3 and 2180kg/m^3 of 14 days density test, 2493kg/m^3, 2386kg/m^3,2339kg/m^3,2290kg/m^3 and 2199kg/m^3 of 28 days density test. This shows the density of concrete decreases with increase in percentage of coconut shell aggregates. This indicates it is light weight concrete.

Compression Strength Test

The results are 27.4N/mm^2, 18.68N/mm^2, 18.83N/mm^2, 18.83n/mm^2 and 17.7N/mm ^{2} in 7 days of curing, 29.84N/mm^2,23.28N/mm^2,23.99N/mm^2,23.99N/mm^2 and 22.12N/mm^2 in 14 days of curing, 34.73N/mm^2,32.48N/mm^2,34.43N/mm^2,34.30N/mm^2 and 30.97N/mm^2 in 28 days of curing for 0%, 5%, 10%, 15% and 20% respectively. From the above results the 7 days compressive strength of concrete decreases with increase in the percentage of coconut shell aggregate, 14days and 28 days compressive strength of concrete also decreases with increase in coconut shell aggregate as same as 7days strength. But when compare to 5%, 10%, 15% and 20% replacement, 10% replacement gives good result.

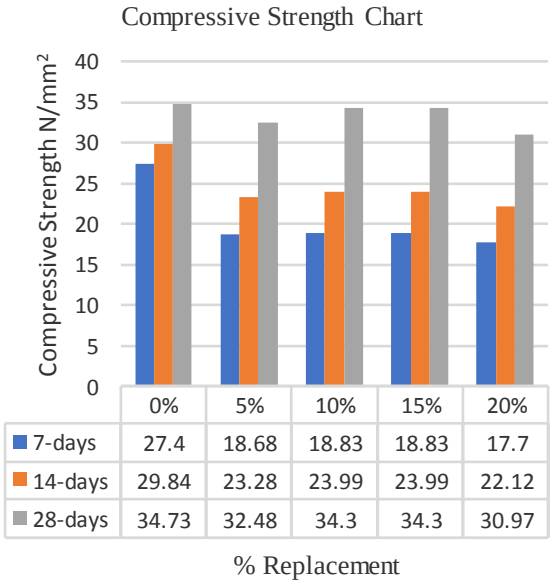

Figure 2: Compressive strength results

Flexural Strength Test

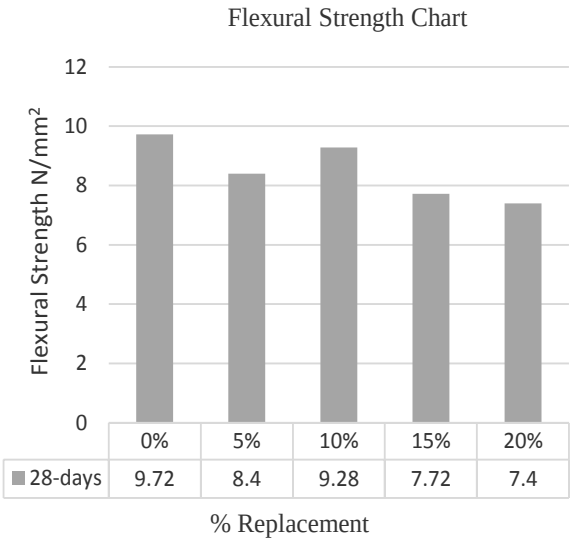

Figure 3: Flexural strength results

The results of flexural test were 9.72N/mm^2,8.4N/mm^2,9.28N/mm^2,7.72N/mm^2 and 7.4N/mm^2 in 28 days strength. From this test results the flexural strength of concrete decreases with increase in percentage replacement of coconut shell aggregate days strength. But when compared to 5%,10%,15% and 20% replacement of coconut shell, 10% replacement will provide good flexural strength of concrete.

Fatigue Test

The results of fatigue test were 701712, 355238, 345238, 332882 and 331629 no. of cycles for 28 days for 0%, 5%, 10%, 15% and 20% replacement respectively. But when compared to 5%,10%,15% and 20% replacement of coconut shell, 10% replacement provide good compression and flexural strength and also fatigue cycles are more than the specified repetitions it can be considered as optimum dosage of replacement.

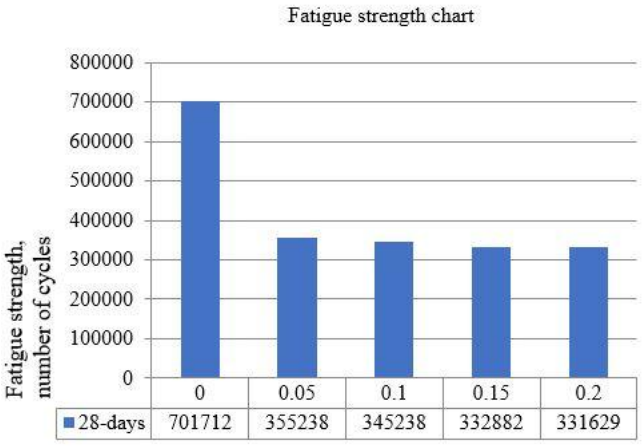

Figure 4: Fatigue Strength Results

Conclusions

Since the use of natural aggregates in cement concrete results in increase in the cost of the material as well as it is depleting the natural resources like quarries, river bed from which the materials are obtained. So, the agro waste like coconut shells are used in partial replacement of coarse aggregate in the concrete and it has been discussed in this project. Based on the results obtained by different tests conducted on concrete like basic properties tests, tests on fresh concrete and harden concrete are made

- Large production of non-decaying waste coconut shell leads to disposal problem.
- As the percentage of replacement increases workability of the concrete also increases without any addition of admixtures.
- The specific gravity of the coconut shells is 1.29.
- As the percentage of replacement increases density of the concrete decreases which leads to light weight concrete. For 10% replacement density reduced by 2.6%.
- The optimum dosage of replacement is 10%.
- The compression strength of optimum dosage is 34.3 N/mm^2 which is reduced by 1.23% of the control mix.
- The flexural strength of optimum dosage is 9.28 N/mm^2 which is reduced by 4.52% of the control mix.
- The fatigue strength of the optimum percentage replacement of coconut shell is 345238 number of cycles.

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