Resistance to Degradation in Cantabro Test on Low-cost Concrete Specimens

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Abstract. Production of low-cost concrete has been a major parameter to reduce the overall cost of construction by using alternate materials. For this, coconut shells which are abundantly available near the local temples, oil industries are used for the present study to make use of the Agro waste. Along with coconut shells, another waste byproduct from combustion power plants namely fly ash has been used for the study. In the present work, fly ash was replaced with cement and coconut shells by conventional mineral aggregates both with 10% and 20%. Generally, the rural villages which have a huge dump of Agro waste or which are closer to a combustion power plant may use this low cardon emitted materials in road constructions. Use of alternative material in village pavements would not only reduce the carbon footprint but may also save in depletion of natural resources. This paper presents a comparative study of resistance to disintegration loss of cantabro test for specimens made with low-cost concrete and also illustrates how the mechanical and microstructural characteristics of concrete made with coconut shell aggregate and fly ash are affected. The experimental data disclosed that the mechanical properties of concrete replaced with fly ash and coconut shells was found to be optimum at 10% replacement and with further increase it is found that the strength has decreased drastically. Cantabro loss has been analyzed to assess the amount of pavement degradation and found that the loss is higher for combination use of Fly ash and coconut shells.

Keywords: low-cost concrete · Cantabro loss · Agro waste · Conventional min eral aggregate

1 Introduction

India has one of the world's largest economies, and its energy sector is expanding quickly at a greater pace. Currently, combustion power plants in India produce a significant amount of fly ash, which has an adverse impact on the ecosystem. And also, the challenge of how to preserve the sources of natural aggregate is raised by the use of natural aggregate at such a high rate. Additionally, the main causes of environmental issues are activities related to the extraction and processing of aggregate [1].

In light of this, modern construction uses alternative resources in place of conventional aggregate to produce concrete, making it a more environmentally friendly and

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sustainable building material. The quality of the concrete was tested with various supplementary cementitious materials and industrial byproducts substituted for Cement and natural aggregates [2–7]. According to research, Coconut shells an Agro waste can also be used as aggregate in concrete, in addition to industrial byproducts [8].

Depletion of natural reserves and the effects of pollution on the environment can both be reduced by using fly ash and alternative aggregates in concrete. Several researchers have discovered in recent studies that adding supplementary materials (like fly ash, coconut shells) to concrete makes it more reliable and economical. Even today forty-eight percent of the total fly ash obtained from combustion power plants is used in manufacturing of cement and 12% is majorly used in construction of roads and embankments as a major application [9]. The research here therefore substitutes coconut shells for aggregates and fly ash for cement to understand its abrasion loss, mechanical, and micro structural properties.

2 Methodology

2.1 Materials

Commercially available OPC 43 grade manufactured as per code **IS:269–2015** was used in this study (Table 1).

Crushed Coconut Shells of size between 4.75 mm - 12.5 mm and lengths were limited to an utmost of 12 mm by crushing of coconut shells as shown in Fig. 1 and Table 2.

Locally sourced potable water was utilized for all the mixtures in the experiment with a W/C ratio of 0.45. Fly ash having specific gravity 2.4, collected at NTPC Ramagundam, Telangana, India.

Table 1. Physical Properties of OPC

Description	Normal Consistency	Fineness of cement	Sp Gravity	Setting time (min)	
				Initial	Final
43 Grade	30%	2.5%	2.94	40	600

Table 2. Physical properties of aggregates

Type	Abrasi on %	Density (kg/m3)	Water Absorption (%)	Crushing Value (%)	Shell Thickness (mm)	SG	FM
Coconut shell	1.65%	605	23%	1.53%	2–6 mm	1.2	6.15
Coarse	27%	1660	0.6%	23.68%		2.85	6.925
Fine		1560	1.29%			2.60	2.62

Fig. 1. Showing the crushing technique, crushed Coconut Shells and Cantabro specimens

Table 3. Concrete mix proportions

Mix	CC	CCF10	CCF20	CSF10	CSF20
Cement (kg/m3)	380	342	304	342	380
River Sand (kg/m3)	620	620	620	620	620
Coarse Aggregate (kg/m3)	1250	1250	1250	1125	1000
Fly Ash	0	38	76	38	76
Coconut Shell	0	0	0	125	250

Coconut shell replacement (%) – 10% & 20%

2.2 Mix Proportions

The mix ratio for concrete of M40 grade is 1:1.63:3.28 by weight was used for the design according to IS: 10262-2019 (Table 3).

2.3 Statistical Analysis

The findings are represented as average values or ± standard error of duplicates and are analyzed using IBM SPSS 21.0 software. The strength values of lightweight coconut

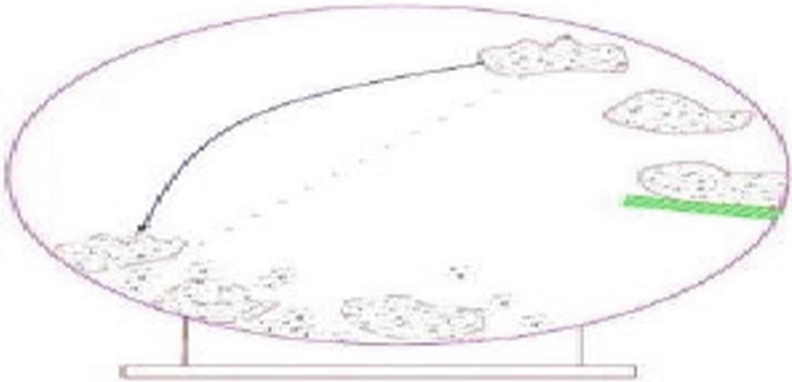

Fig. 2. Illustration of Cantabro Loss test

shell concrete for different time zones and macro structures are analyzed using non-parametric Friedman test. Only 95% level of confidence with p = 0.05 values were considered for analyzing the results.

2.4 Analytical Methods

Compressive strength on cube of size 150 x150x150 mm was conducted according to IS 516:1959 [11]. Concrete's split tensile strength was performed on cylinders D = 100 mm, H = 200 mm according to IS 5816:1999.

Figure 2 shows the equipment for Cantabro loss test is performed on los angles abrasion testing instrument as per ASTM C1747. According to ASTM C1747, this test was performed using abrasion testing apparatus with steel balls as abrasive charges.

The machine was setup with the three cylindrical specimens, each measuring D = 150 mm and H = 115 mm.

Preliminary weight of each sample before placing into the apparatus was recorded. Later, the apparatus with the specimens was allowed to rotate for 50,100,150,200,250 and 300 revolutions.

Figure 3 shows the eroded samples were checked thoroughly and free material at each level of revolution was precisely weighed to determine the final weight M2. The weight loss percentage was determined equation below:

Percentage Cantabro loss (CBL%) = $(M1 - M2) / M1 \times 100$.

M1 and M2 are average initial and final weights of the test specimens.

3 Results

3.1 Comparing Compressive Strength of Conventional and Low-cost Concrete

Compressive strength is a deciding factor for the performance of concrete. From Fig. 4 The compressive strength of conventional aggregate concrete for 28 days curing is 49.33 Mpa. When fly ash is replaced by 10% and 20% in cement the strength has decreased

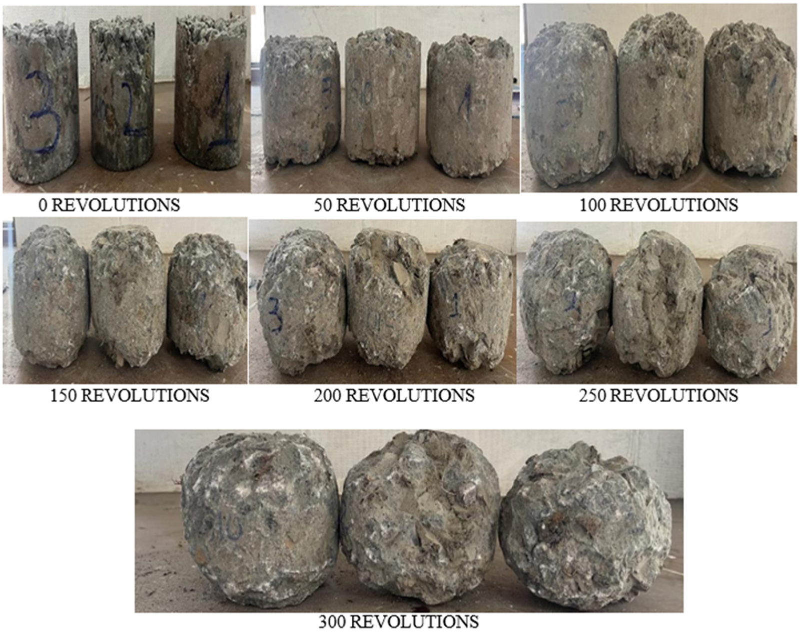

Fig. 3. Shapes of specimens in Cantabro loss test for every 50 revolutions

to 47.56 Mpa and 36.44 Mpa respectively. The decrease of 3.58% and 26.13% for 10% and 20% fly ash concrete is observed respectively for 28 days. The decrease in the strength is because fly ash has a tendency to gain more strength than conventional concrete at later ages and is observed after curing period of 56–90 days. And as the percentage of fly ash is increasing compressive strength is decreasing. Similar trend was also observed in coconut shell aggregate concrete along with fly ash for 10% and 20% replacement. With a combination of replacing both aggregates by coconut shells and cement by fly ash for 10% and 20% the strength has further reduced to 24.44 Mpa and 13.33 Mpa. The decrease in strength here is because of the bond between coconut shells and aggregates and also because of fly ash tendency to give high strength at later ages. Results showcased that increase in strength of fly ash-based concrete is due to delayed hardening. As the percentage of fly ash increases in conventional concrete there is a curtailment in concrete's strength because the secondary hydration process is slower in fly ash-based concrete due to its pozzolanic action. Low-cost concrete can help in the development of a society with affordable homes and rural roads where the Agro waste and fly ash is abundantly available.

3.2 Comparing Split Tensile Strength of Conventional and Low-cost Concrete

It can be inferred from Fig. 5 that spilt tensile strength of conventional concrete is 2.86 Mpa. Fly ash when substituted by 10% and 20% of cement the strength has increased to 3.18 Mpa. The increase of 11.2% for 10% and 20% fly ash concrete is observed respectively for 28 days. The voids in the concrete mix at the interface of aggregates and

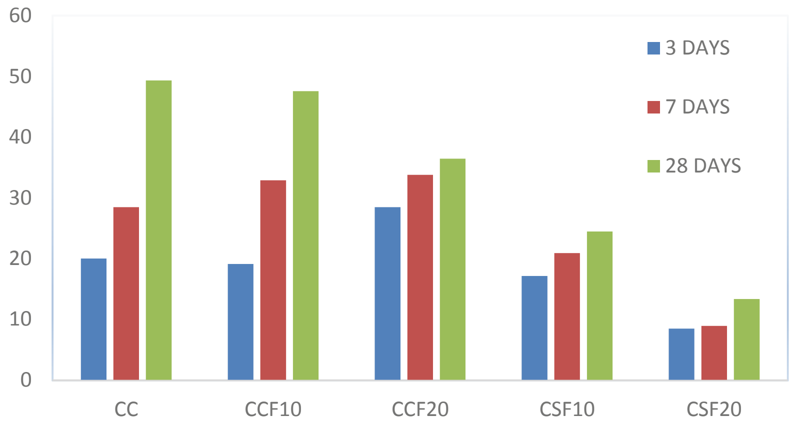

Fig. 4. Plot of Compressive Strength of Conventional and Low-cost Concretes

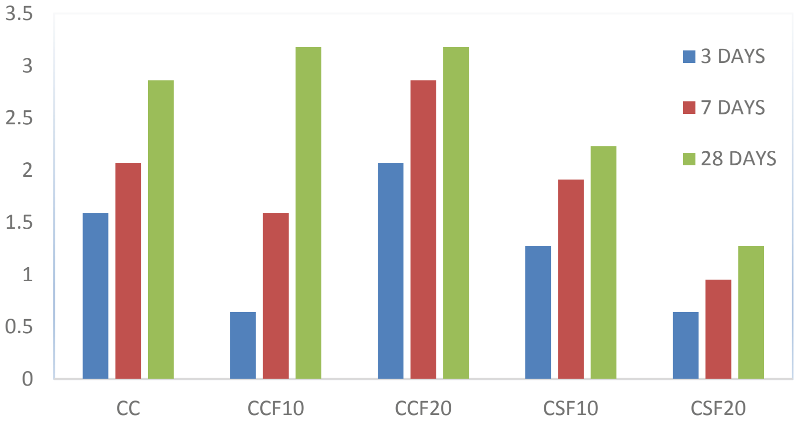

Fig. 5. Plot of Tensile Strength of Conventional and Low-cost Concrete

cement are filled by fly ash because particle size of fly ash is lower than that of cement which is a main reason for increase in strength. And for the combination of fly ash with coconut shell aggregate for 10% and 20% substitution, there was a decrease in tensile strength of 22% and 55% respectively.

3.3 Effect of Fly Ash and Coconut Shell Aggregate on Average Cantabro Loss

Cantabro loss for the conventional concrete, fly ash-based concrete and coconut shell aggregate concrete was good compared to the combined use of fly ash and coconut shells. The loss was highest for 10% Fly Ash + 10% Coconut Shells. Inside the machine, the samples collided with one another and also the edges of the abrasion machine. This was utilized to evaluate pavement degradation (Table 4).

Table 4. Cantabro values for various mixes at 7,14 and 28 days

MIX	CBL @7 (%)	CBL@14 (%)	CBL@28 (%)
Conventional Concrete (%)	14.04	13.19	12.60
10% Fly Ash	17.69	16.03	14.87
10% Coconut Shells	27.95	25.11	22.74
10% Fly Ash + 10% Coconut Shells	54.37	52.69	51.80

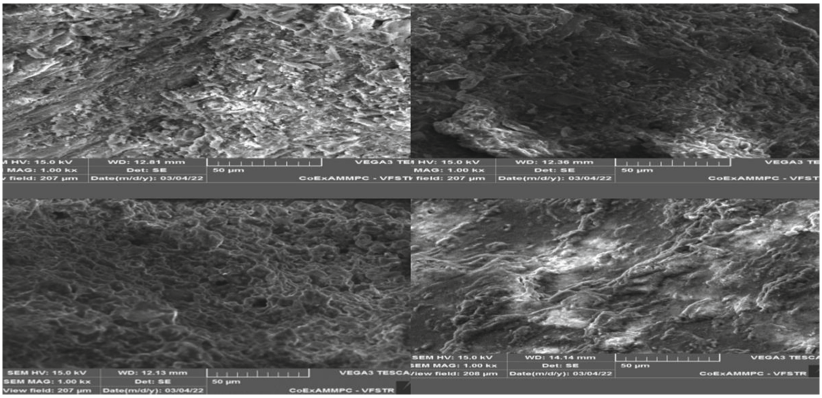

Fig. 6 Shows the SEM images of (a) Conventional concrete (b) 90% Cement + 10% Fly ash (c) Concrete with 10% coconut shell (d) 90% Cement + 10% Fly Ash + 90% Coarse aggregate + 10% Coconut shells.

3.4 Microstructure Properties of Low-cost Concrete in Comparison to Conventional Concrete

Figure 6 provides the microstructure of the low-cost concrete prepared from coconut shells and fly ash in comparison with conventional concrete. It is very clear from Fig. 6 that According to SEM analysis, the voids in concrete are filled with fly ash which in turn has enhanced C-S-H, which is the product after hydration. Microstructure of concrete have been enhanced when OPCis substituted with 10% fly ash. And as mineral aggregates are replaced with coconut shell, provided a higher water absorption and incomplete hydration of concrete leading to slightly weaker bonding.

3.5 Mineral Composition of Low-cost Concrete in Comparison Conventional Concrete

The mineral composition of fly ash-based concrete has shown direct proportion increase of elements like Calcium, Aluminium, Silicon, Potassium and Iron. Whereas the coconut shells influence has further increase of elements like Aluminium, Silicon, Potassium along with increase Sodium, Carbon, and Fluorine (Fig. 7).

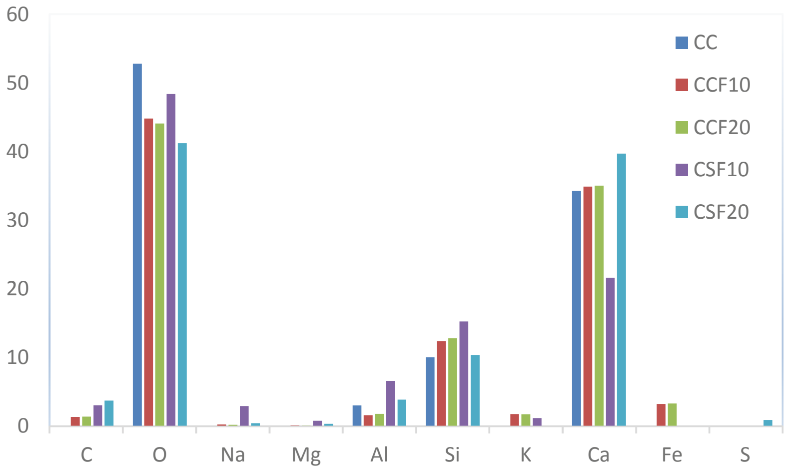

Fig. 7. Mineral composition of low-cost concrete in comparison conventional concrete

4 Conclusions

The strength of concrete substituted with fly ash is increasing with the curing age and less in the initial stages when compared to conventional concrete. Cantabro loss for the conventional concrete, fly ash-based concrete and coconut shell aggregate concrete with 10% replacement was better compared to the combined use of fly ash and coconut shells. Optimum replacement of fly ash and coconut shell was found to be 10%. SEM analysis showed that the microstructure of concrete has been enhanced when conventional concrete mix was replaced with 10% fly ash. Conventional aggregates replaced with coconut shells have provided a higher water absorption leading to incomplete hydration of concrete. Agricultural waste and fly ash can be recommended for the usage in road construction where the material is available in excess. Fly ash fills in the spaces at the cement-aggregate interface because it has a smaller particle size than cement there by improving the mechanical properties.

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