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Research paper

Experimental Investigation on the Mechanical and Microstructural Properties of Concrete with Agro-Waste

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Abstract

Due to ever-increasing disposal problems of agricultural wastes in developing countries have created opportunities for use of agricultural wastes in the construction industries. An attempt has been carried out by partial replacement of cement with areca-nut shell, fine aggregate with coconut shell powder by pulverizing it into ashes and coarse aggregate with oil palm shell[9]. Concrete specimens were cast and cured for 28 days, a detailed comparison is made with conventional concrete and concrete with agrowaste by testing the specimens to finding the mechanical and durability properties like compressive, tensile flexural and rapid chloride penetration test. From the experimental results, it is found that the combination comprising of 10% of areca nut ash (ASA), 5% of coconut shell charcoal powder (CSCP) and 5% of oil palm shell (OPS) shows desirable results in enhancing the properties of agro waste concrete. The detailedmicrostructural investigation has been done to find the reason for enhancing the mechanical properties of concrete with agro waste by using the Scanning Electron Microscope(SEM), Energy-dispersive X-ray spectroscopy(EDAX) and X-ray diffraction(XRD) methods.Due to the presence of CSH gel and $Ca(OH)_2$in concrete with agro waste specimens which attributes the strength and other properties.

Keywords: *Agro waste, Microstructural, Durability, Strength, Properties*

1. Introduction

In India, more than 600 MT wastes have been generated from agricultural waste per year leading to a disposal problem.Studies have been going on how agricultural waste materials can be used in concrete as replacement alternatives for cement,fine aggregate, coarseaggregate. Reuse of such agro-waste as sustainable construction materials take care of the issue of contamination and the expense of building materials[6].Mostly these agro-waste comprises of the areca-nut shell,coconut shell, and oil palm shell of 24%,19%, and 13% respectively[7].The partial replacement of these materials will enhance the physical and chemical properties of freshening and harden concrete.In this paper,an attempt has been carried out by partial replacement of cement with areca-nut shell,fine aggregate with coconut shell powder,bypulverizing it into ashes and coarse aggregate with oil palm shell[4].The main objective of this study is to investigate the basic property of fresh concrete with agro-waste and to study their mechanical properties of the hardened concrete with agro-waste. And it also aims at the behavior of RCC beams with agro-wastes as lightweight aggregate.

2. Experimental Investigation

1. Cement

Ordinary Portland cement 53 grade conforming to IS 12269-1987 was used.

2. Aggregates

Normal weight graded natural sand having a maximum particle size of 4.75 mm and specific gravity 2.64 was used as fine aggregate[3].The coarse aggregate used was crushed gravel with a maximum size of 20mm and have a specific gravity of 2.7.

3. Areca nut husk ash(AHA)

Areca nut husk was collected from areca nut gardens of Thondamuthur, Coimbatore, India. The husk was cleaned with water, dried in sunlight and burned into ashes.After the burning process is completed, the ash was left to cool down to room temperature.In order to achieve fineness comparable to OPC,the burned AHA was grounded for 30 minutes and screened through 90mm micron sieve[1]. The sieved ash was stored immediately in airtight containers to avoid pre-hydration[1].

4. Coconut shell charcoal powder(CSCP)

The coconut palm is one of the most useful plants in the world. Coconut is grown in 92 countries in the world[2]. Global production of coconut is 51 billion nuts from an area of 12 million[2].The coconut shell charcoal was collected from the factory outlet of Sirumugai,Tamilnadu.These are similar to sand particles as it is of small granular particles[7].

5. Oil palm shell(OPS)

The OPS is a waste product derived from palm oil mills. Waste disposal is growing and contributing to environmental pollution if no control measures were organized in the regions involved[6]. The waste of shell indicates the quantity of waste 4,506 k tonnes. The OPS is a one of the huge waste producing from palm oil extraction process[10]. As a result, OPS which are light and naturally sized was ideal for substituting aggregates in OPS concrete construction and water absorption from OPS is high compared to normal weight aggregates (NWA)[8]. These shells were collected from oil palm India limited,Kollam district Kerala, India. The chemical properties of materials used are shown in Table 1. The basic physical properties of materials used like specific gravity and Bulk density are shown in Table 2.

Table 1: Chemical Properties of Materials used

Elements	OPC	ASA	CSCP	OPS
Sio_2	60.5	28.44	50.41	64.8
Al_2O_3	5.72	3.64	30.66	6.3
Fe_2O_3	0.52	1.91	3.34	2
MgO	2.94	3.87	0.93	3.55
SO_3	2	7.80	1.71	10.1
Na_2O	0.65	0.24	3.07	0.6
K_2O	0.39	26.52	0.78	3.5

Table 2: Physical Properties of Materials used

Properties	OPC	ASA	CSCP	OPS
Specific gravity	3.15	1.39	1.15	1.20
Bulk density (kg/m^3)	3150	1390	1150	1200

6. Concrete mix proportion

The water-cement ratio adopted for casting is 0.50.In order to find the compressive strength,tensile strength, andflexural strength, the cube,cylinder,andprism were castrespectively[3].Thus a detailed comparison is made with conventional concrete and concrete with agrowaste[5]. Table 3 shows the detailed mix proportion of the agrowaste concrete specimens.

Table 3. Detailed Mix Proportion of Agrowaste Concrete Specimens

Type of Specimen	Percentage of Materials (%)			Mix Proportion of Concrete with agro waste (kg/m^3)					
	ASA	CSCP	OPS	Cement	FA	CA	ASA	CSCP	OPS
C1	2.5	5	5	362.7	700.23	1173.	9.3	16.05	25.12
C2	2.5	5	10	362.7	700.23	1111.9	9.3	16.05	50.25
C3	5	5	5	353.4	691.20	1158.5	18.6	15.84	24.80
C4	5	5	10	353.4	691.20	1097.5	18.6	15.84	49.60
C5	7.5	5	5	344.1	687.19	1151.8	27.9	15.75	24.66
C6	7.5	5	10	344.1	687.19	1091.2	27.9	15.75	49.32
C7	10	5	5	334.8	684.18	1146.8	37.2	15.68	24.55
C8	10	5	10	334.8	684.18	1087.4	37.2	15.68	40.10

FA – Fine aggregate, CA – Coarse Aggregate

7. Casting

Concrete specimens were cast and tested comprising the cube of size 150*150*150mm to find the compressive strength, cylinder of size 150mm diameter and 300mm height to find the splitting tensile strength and the prism of size 500*100*100mm to find the flexural strength based on M20 mix proportion. For each combination, three specimens were casted accordingly[5].Compacting of concrete was done by vibration as per IS:516-2000[5]. After casting, all the casted specimens were stored in laboratory condition for 24h and then de-molding and placed into a water-curing tank with a temperature of 25°C – 30°C until the time of testing[5].

3. Result and Conclusion

A. Compressive Strength

The specimen C7 comprising 10% of areca nut ash as a partial replacement of cement,5% of coconut shell charcoal powder as a partial replacement of fine aggregate and 5% of partial replacement of coarse aggregate shows an approximate strength as that of normal concrete[8].C8 comprising of 10% of areca nut ash.5% of coconut shell charcoal powder and 10% of oil palm shell shows less compressive strength compared to rest of the specimen containing agro-wastes[8]. Figure 1 shows the variations in compressive strength, here we can see a gradual hike in strength by constantly keeping 5% of oil palm shell coconut shell and charcoal powder increased to 10%.

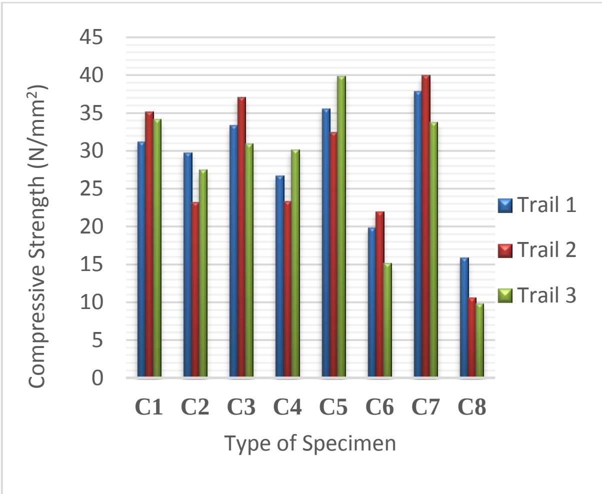


Fig. 1: Compressive Strength of Concrete with Agro waste

Graph 1 shows the variations in compressive strength. Here we can see a gradual hike in the strength of specimens by constantly keeping 5% of oil palmshell,coconut shell charcoal powder and gradually increasing the percentage of areca nut ash as a partial replacement of cement from 2.5%-10%[1].On another side, we can see a depletion in the strength of concrete where the Oil palm shell and coconut shell charcoal powder increased to 10%.[2]

B. Split Tensile Strength

After 28 days of curing the cylinders are tested using the compressive testing machine. As mentioned above the concrete specimen C7 shows an approximate strength compared to normal concrete strength and compared to rest. The C8 specimen(10%AHA,5%CSCP,10%OPS) shows less strength compared to the other specimens.

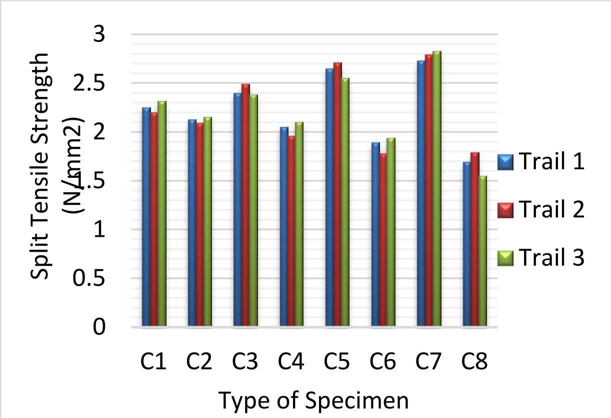


Fig. 2: Split Tensile Strength of Concrete with Agro waste

The where the peak load is found out from the compressive testing machine. Figure 2 shows variation in split tensile strengths. As mention above Here we can see a gradual hike in the strength of specimens by constantly keeping 5% of oil palm shell, coconut shell charcoal powder and gradually increasing the percentage of areca nut ash as a partial replacement of cement from 2.5% to 10%.On another side, we can see a depletion in the strength of concrete where the Oil palm shell and coconut shell charcoal powder increased to 10%.

C. Flexural Strength

The flexural strength of concrete at 28 days is presented in Figure 3.Specimen C7 shows approximate strength when compared to normal concrete. The peak load is found out by testing in the computerized universal testing machine. The beams are properly marked inorder to test and the cracks were noted during the testing of the beam.

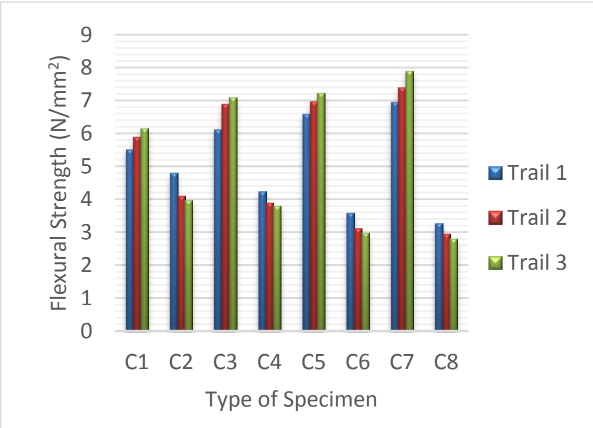


Fig. 3: Flexural Strength of Concrete with Agro waste

Figure 3 shows the variations of flexural strength. As mentioned above the same aspect we can see in the flexural strength of the beam. When the percentage of oilpalm shell and coconut shell charcoal powder is kept constant at a percentage of 5% and by gradually increasing the percentage of arecanut ash from 2.5%-10 %,the strength gets increased. Whereas the percentage of oil palm shell and coconut shell charcoal powder increased to 10 % we can see a decrease in the strength of the concrete.

D. Density

The density of the concrete specimenswas noted down by estimating the weight of the concrete specimens with agro waste as well as conventional concrete. Table 4 shows the density of concrete with agro waste and for conventional concrete. From the results, C8 comprising of 10% of areca nut ash.5% of coconut shell charcoal powder and 10% of oil palm shell shows less density compared to rest of the specimen containing agro-wastes.Thus the amount of agro wastes increases, the density decreases, so it is considered as lightweightaggregates in concrete specimens.

Table 4: Density of Concrete Specimens

Type of Specimen	Weight(Kg)	Density(Kg/m3)
C1	8.3	2460.71
C2	8.26	2448.8
C3	8.24	2442.92
C4	8.2	2431.07
C5	8.17	2422.17
C6	8.12	2407.35
C7	8.09	2398.45
C8	8.04	2383.634
CC	8.5	2520.011

CC- Conventional Concrete

E. Rapid Chloride Penetration Test

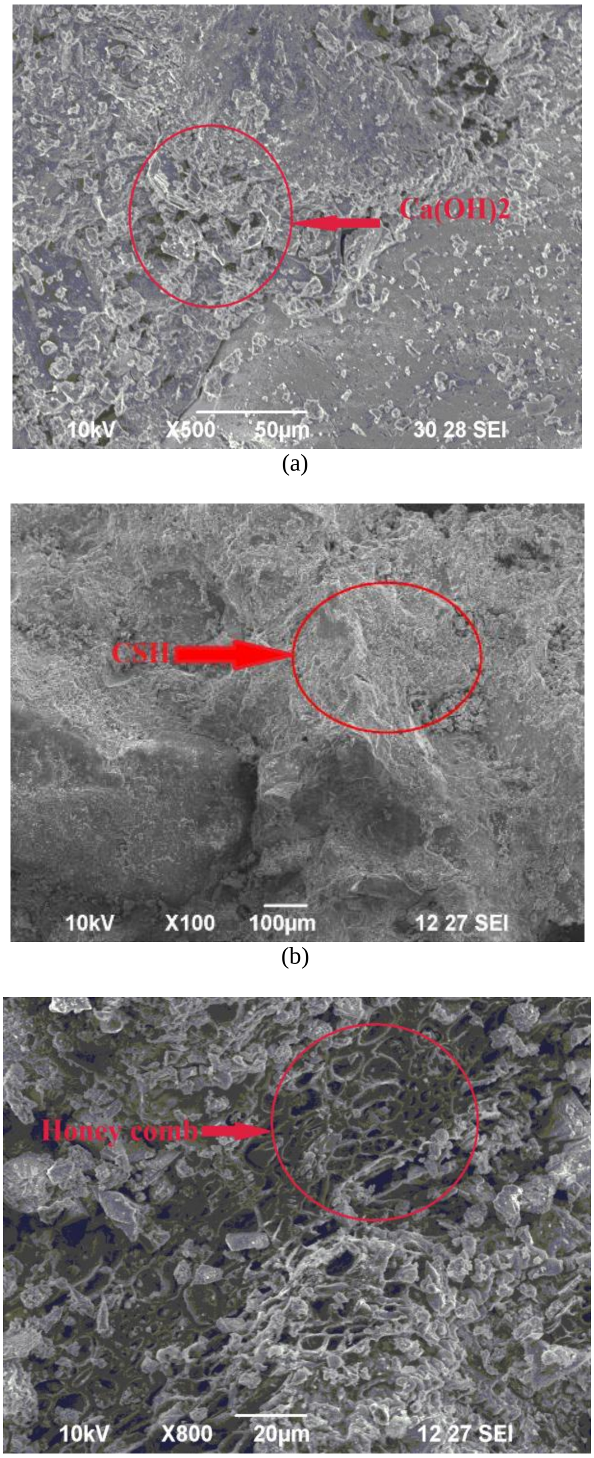
This test gives an indirect measure of permeability and internal pore structure of concrete. The result of this is used to access the durability of concrete[4]. From the experimental study table, 5 states as the chloride ion penetration increasewhen an increasein the percentage of agro-wastes. It is clear that the penetration values range in between 1000-2000 and is referred as low based on the ASTMC 1202:97.

Table 5: Quality of Concrete with agro waste

Type of Specimen	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
Chloride Ion Penetration (coulombs)	900	1000	980	1200	1126	1344	1282	1426
Quality of Concrete as per ASTMC 1202:97	Low	Low	Low	Low	Low	Low	Low	Low

F. Scanning Electron Microscopy (SEM)

After testing the concrete specimens to find out the mechanical properties of concrete with agro waste, the C7specimens shows the better performance in strength wise when compared to the other mix concrete specimens[1].
Due to that C7 concrete sample were collected in powder form and given to microstructural investigation[4].
From the results of the SEM analysis, the figure 4 explains the plates like structure formation indicates the presence of $Ca(OH)_2$ which inhibits strength to the concrete[6].
The smoke or gas form like structure indicates the presence of CSH gel (Calcium Silicate Hydrate) which also helps in increasing the strength with the addition to calcium hydroxide[1].Here we can see a huge formation of honeycomb structures which helps in reducing the structural weight and hence make lightweight concrete[7].



(a)

(b)

(c)

Fig. 4: SEM analysis Image for C7 Sample (a) $Ca(OH)_2$ (b) CSH gel (C) Honey Comb

G. Energy Dispersive X-ray spectroscopy (EDAX)

The chemical constituents which help in increasing the strength and other parameters areanalyzed through EDAX[6]. As the atomic weight % of CaCO3 increases, the strength and an increase in the element of SiO_2 is more. Table 6shows the chemical constituents present in the concrete sample.

Table 6: EDAX Test Results for C7 Sample

Element	SiO_2	MgO	CaCO3	FeS2	Ca	Fe
Atomic %	77.93	0.36	9.93	0.10	11.29	0.39

H. X-ray diffraction (XRD)

The graph is shown between 20 and 70 for the concrete specimens[6]. From the XRD results some of the major chemical compounds were found such as SiO_2, $CaCO_3$, $Ca(OH)_2$ and CSH. Thus attributes and enhance the performance of the concrete when compared with other concrete specimens[6].

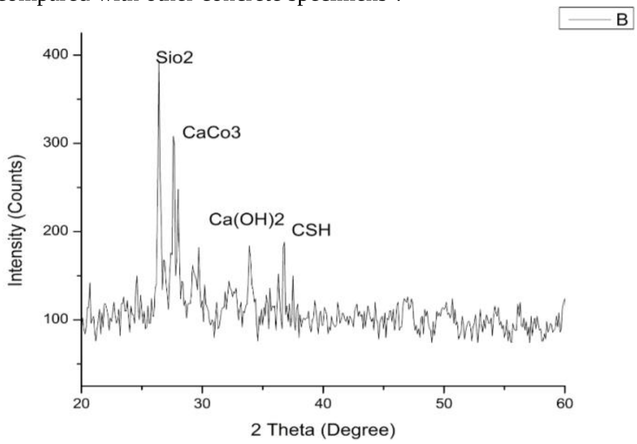


Fig. 5: X-ray diffraction pattern for C7 Sample

4. Conclusion

- Comparing to normal concrete the strength of the concrete with agro wasteshows the approximate value of strength to that of normal concrete.
- The concrete comprising of 10% areca nut ash 5 %of coconut shell charcoal powder and 5% of oil palm shell shows the higher value of strength compared to other combination of the mix.
- The strength gradually increases when the oil palm shell and coconut shell powder is kept constant at a proportion of 5% and by gradually increasing the percentage of areca nut ash from 2.5%-10%.
- It is clear when the percentage of oil palm shell and coconut shell charcoal powder increased to 10% the strength of the concrete gradually decreases.
- Comparing the weight of concrete,the concrete with agro wastes shows less weight compared to normal concrete.
- The concrete is agro wastes is more economical and friendly to the environment.
- From the microstructure investigation, the more amount of SiO_2, $CaCO_3$, $Ca(OH)_2$ and CSH increase the performance and strength of the concrete.
- The rice husk can be used asapartial replacement for lightweight concrete and same like it we can use agrowaste.

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