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Experimental studies on water absorption and sorptivity of cashew nut shell ash in mortar

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Abstract
When excess water in mortar evaporates, it leaves voids inside the mortar element creating capillaries which are directly related to the mortar porosity and permeability. Proper selection of ingredients, adequate mix proportioning and following by good construction practices lead to almost impervious mortar. Due to incomplete compaction; mortar may consists of gel pores and capillary pores, which leads to low strength of mortar. Due to problems associated with the absorption test and permeability test; which are measuring the response of mortar to pressure which is rarely the driving force of fluids entering in to mortar; hence there is a need for another type of test. Such test should measure the rate of absorption of water by capillary suction;" Sorptivity "of unsaturated mortar. In this paper the study of sorptivity and water absorption properties of Cashew nut shell Ash mortar. The mix design was carried out for 1:3 proportion cement mortar on the basis of IS 269: 1970.

Keywords: sorptivity, capillary suction, water absorption, cashew nut shell ash, mortar

1. Introduction
Cement mortar is an intact combination of cement and sand mixed with ample amount of water to create synthetic paste. Its adhesive characteristics vary, depending on the amount of water added the mixture. the cement found in mortar provides strength and fills in air pockets present in sand on the other hand eliminate or reduces the cracks produced by the contraction of cement while it sets.

Mortar is a material having tiny spaces through which liquid or air may pass. The durability of mortar depends largely on the movement of water and gas enters and moves through it. The permeability is an indicator of mortar's ability to transport water more precisely with both mechanism that is controlling the uptake and transport of water and gaseous substances into cementations' material. While Sorptivity is materials ability to absorb and transmit water through it by capillary suction.

Uptake of water by unsaturated, hardened mortar may be characterized by the sorptivity. This is a simple parameter to determine and is increasingly being used as a measure of mortar resistance to exposure in aggressive environments. Sorptivity, or capillary suction, is the transport of liquids in porous solids due to surface tension acting in capillaries. It is a function of the viscosity, density and surface tension of the liquid and also the pore structure (radius, tortuosity and continuity of capillaries) of the porous solid. It is measured as the rate of uptake of water.

Transport mechanisms act at the level of the capillary pores and depend on the fluid and the solid characteristics. The porous structure of mortar is intimately related with its permeability. A low water/cement ratio results in mortar structures which are less permeable because they are characterized by having small pores which are not interconnected.

Table 1: Acceptance Limits for Durability Indexes

Acceptance criteria		OPI (log scale)	Sorptivity (mm/h)
Laboratory mortar		**>10**	**<6**
As-built Structures	Full acceptance	>9.4	<9
	Conditional acceptance	9,0 to 9,4	9 to 12
	Remedial measures	8,75 to 9	12 to 15
	Rejection	<8,75	>15

2. Design mix materials
2.1 Supplementary cementitious material: Cashew nut shell ash
Cashew nut shell ash is a high efficiency pozzolanic material obtained from cashew nut industries from Nagercoil, Tamil Nadu, India. It's subjected to strict quality control procedure. It conform IS: 3812.

Table 2: general properties of cashew nut shell ash

Property	Cashew nut shell ash
Presentation	Finely divided dry powder
Specific gravity	3.02
Colour	light yellow
Bulk weight (tonne per m^3)	0.852 tonne per m^3
Loss of ignition	0.71%
Particle size	90 micron sieve

Table 3: chemical composition of cashew nut shell ash

Constituents	% by weight
SiO_2	62.85
Fe_2O_3	4.20
Al_2O_3	2.01
Ca O	35.67
Mg O	1.85
Na_2O	0.80

2.2 Cement

The cement used is ordinary Portland 53grade cement. The ordinary Portland cement of 53 grade conforming to IS: 12269 is be used many test were conducted on cement; sum of them are specific gravity, consistency, Setting time test compressive strength, soundness test etc.

Table 4: properties of cement

Sl. no.	Properties	Result	Requirements as per IS:8112-1989
1	Specific gravity	3.05	3.10-3.15
2	Standard consistency (%)	27%	30-35
3	Initial setting time (hours, min)	45 min	30 minimum
4	Final setting time (hours, min)	420 min	600 maximum
5	Compressive strength	54 N/mm^2	53 N/mm^2 minimum

2.3 Fine aggregate

Local clean river sand those fraction from 4.75mm to 150 micron are termed as fine aggregate. The river sand is be used in combination in fine aggregate conforming to the require-ments of IS: 383-1970.The river sand is washed and screened, to eliminate deleterious materials and over size particles.

Table 5: Properties of sand

Property	Fine Aggregate (River sand)
Fineness modulus	3.7
Specific Gravity	2.62
Water absorption (%)	1.2
Bulk Density (gm/cc)	1.72

2.4 Water

Water is an important ingredient of mortar as it actually participates in the chemical reaction with cement. Since it helps to form the strength to giving cement gel, the quantity and quality of water is required to be looked into vary carefully.

3. Design mix methodology

3.1 Design mix

A cement mortar mix 1:3 was designed as per IS:269 methods and the same were used to prepare the test samples. The design mix proportion done in table 6, 7, 8.

Table 6: Mix Design Proportions

	Water	Cement	Fine aggregate
By Weight, [gms]	54	120	360
By Volume, [m^3]	0.45	1	3

Table 7: Cement Replacement by Cashew Nut Shell Ash

Sl.no	Type of mortar	Description of mortar
1	A0	River sand mortar…
2	A1	5% replacement by cashew nut shell ash
3	A2	10% replacement by cashew nut shell ash
4	A3	15% replacement by cashew nut shell ash
5	A4	20% replacement by cashew nut shell ash
6	A5	25% replacement by cashew nut shell ash
7	A6	30% replacement by cashew nut shell ash
8	A7	35% replacement by cashew nut shell ash
9	A8	40% replacement by cashew nut shell ash
10	A9	45% replacement by cashew nut shell ash
11	A10	50% replacement by cashew nut shell ash

Table 8: Mix Proportion for Mortar

Sl. No	Mortar type	W/C ratio	Design mix proportion		cashew nut shell ash
			Cement	Fine aggregate	
1	A0	0.45	1	3	-
2	A1	0.45	0.95	3	0.05
3	A2	0.45	0.90	3	0.10
4	A3	0.45	0.85	3	0.15
5	A4	0.45	0.80	3	0.20
6	A5	0.45	0.75	3	0.25
7	A6	0.45	0.70	3	0.30
8	A7	0.45	0.65	3	0.35
9	A8	0.45	0.60	3	0.40
10	A9	0.45	0.55	3	0.45
11	A10	0.45	0.50	3	0.50

3.2 Water absorption test

The 80mm diameter and 50mm thick cube after casting were immersed in water for 28days curing. These specimen were then oven dried 24hrs at the temperature 105 ºc ±5 ºc until the mass become constant and again weighed. This weight was noted as dry weight (W1) of the specimen. After that specimen was kept in water at 85ºc for 24hrs then this weight was noted as (W2) of the specimen

$$\% \text{ water absorption} = [(W2 - W1) / W1] \times 100$$

Where, W1 = Oven dry weight of cubes in grams
W2 = after 24 hours wet weight of cubes in grams

Fig 1: setup of weight

Fig 3: setup of sorpitivity

Fig 2: setup of oven

Fig 4: setup of hot water curing

Table 8: average% water absorption at 28 days

Mortar type	Dry Weight in grams (W1)	Wet Weight in grams (W2)	% Water Absorption
A0	562	572	2.0
A1	517	528	2.12
A2	544	556	2.22
A3	576	590	2.43
A4	570	585	2.65
A5	560	575	2.70
A6	554	564	2.75
A7	558	574	2.86
A8	528	544	3.03
A9	538	556	3.34
A10	528	550	4.16

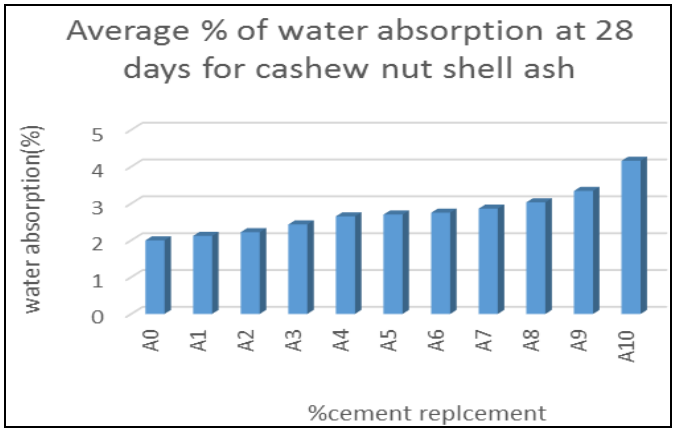

Fig 5:%Replacement of cement versus % water absorption

3.3 Sorptivity test

The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used of the test fluid. The cubes after casting were immersed in water for 28 days curing. The specimen size 80mm diameter x 50mm thick after drying in oven at temperature of 85 °C were drowned as shown in figure 3 with water level not more than 5 mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating. The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting up to 0.1 mg. surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds. Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t)

$$I=S.t^{½} \text{ therefore } S=I/ t^{½}$$

Where;
S= sorptivity in mm,
t= elapsed time in mint.

$$I=\Delta w/Ad$$

Δw= change in weight = W2-W1
W1 = Oven dry weight of cylinder in grams
W2 = Weight of cylinder after30 minutes capillary suction of water in grams.
A= surface area of the specimen through which water penetrated.
d= density of water

Table 9: Sorptivity at 28 days

Mortar Type	Dry Weight in grams (W1)	Wet Weight in grams (W2)	Sorptivity value in 10^{-4} mm/min0.5
A0	562	567	1.81
A1	514	517	1.08
A2	544	556	0.73
A3	588	591	1.08
A4	570	572	1.08
A5	588	590	0.73
A6	540	543	1.08
A7	528	532	1.45
A8	608	612	1.45
A9	498	502	1.45
A10	538	541	1.08

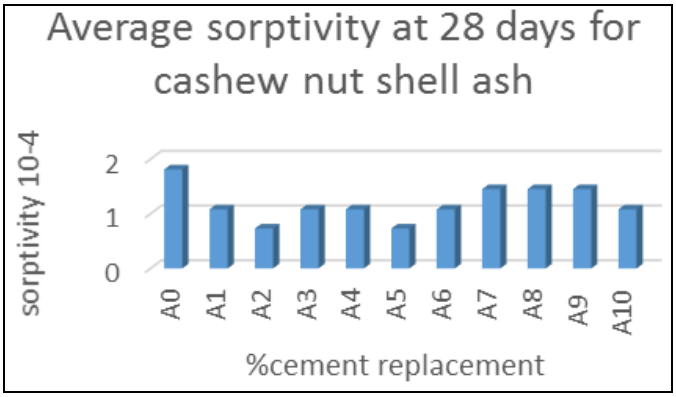

Fig 6:%Replacement of cement versus sorptivity

4. Experimental Results

Table-8 and 9gives the water absorption and Sorptivity test results of% replacement of fly ash in mortar for 28 days curing. The% replacement vs% water absorption and Sorptivity results are graphically shown in figure 5 and 6.

5. Conclusion

Based on limited experimental investigation concerning the water absorption and sorptivity of mortar, the following observations are made regarding the resistance of partially replaced cashew nut shell ash 1:3 proportion mortar:

1. The water absorption of cashew nut shell ash 1:3 mortar mix higher than traditional mortar.
2. Where percentage increase in water absorption is found to be 4.16% for A10 and sorptivity is found to be 0.73 mm/min$^{0.5}$ for A2&A5 respect to reference mix.
3. The water absorption and sorptivity of A1 to A10 cashew nut shell ash 1:3 proportion mortar shows higher water absorption and lesser sorptivity than traditional mortar.
4. The cashew nut shell ash can be innovative supplementary cementitious Construction Material but judicious decisions are to be taken by engineers.

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