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Study on partial replacement of groundnut shell ash with cement

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ABSTRACT

Concrete plays a prominent role in the construction industry. In the present scenario, there is a shortage of this material so there is a need to find alternatives to replace it in the concrete. In order to overcome this situation; many waste products which are available freely like a paper waste, red mud, rice husk and plastic waste can be used. Among all of these, Ground nut shell ash is one of the good waste materials available from the oil industry. It can be used widely for the replacement of cement. The ground net shell contains CaO, SiO_2, Al_2O_3, and Fe_2O_3. This experimental investigation was carried out to evaluate the strength of concrete, in which cement was replaced with ground nut shell ash for cubes, cylinders, and Prisms with different percentages which vary from 0% to 30% at an interval of 5% were performed. Concrete was batched by weight on adopting a ratio of 1:2:4 with water–cement ratio of 0.6. Concrete cubes of 150*150*150 mm in dimensions, cylinders of 150*300 mm in dimensions and 100*150 mm prisms are used. These Cubes, cylinders, and prisms were tested for 7, 14 and 28 days for compression, flexural and split tensile strengths. It is observed that 10% replacement of ground nut shell ash shown the highest strength values when compared with other percentages and for 15% replacement of ground nut shell ash the compressive and split tensile strength obtained the highest strength rather than other flexural strength.

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1. Introduction

The explicitly in use of concrete, and its adaptability to environmental conditions make concrete suitable for applications in almost all civil engineering and building structures (Mtallib and Ibrahim, 2009). To save energy and to earn carbon credit is very much essential for the improvement of mankind. To produce tons of cement we use earth resources like limestone, clay, and chalk etc. During manufacturing of Cement, an equal amount of carbon-dioxide is released into the atmosphere which is harmful for both environment and human. Energy plays an important role in the period of developing countries like India, China, Cuba, and Egypt etc. By earning carbon credit by using agriculture waste (ground nut) for Building Materials like cement, both the energy & environment can be saved. Concrete consists of cement, aggregates (generally coarse aggregates made of gravel, crushed stone, and limestone, plus fine aggregates such as sand from the river), water, and/or admixtures. Concrete is made by mixing of Cement, water, coarse and fine aggregates and admixtures (if required). By mixing; this objective concrete gives strength and durability. Concrete is presently one of the most popular materials used in construction and civil engineering works. When reinforced with steel, concrete has a higher capacity for carrying loads. Most of the cement used in construction work is ordinary Portland cement. Portland cement is manufactured by mixing naturally occurring substances containing chemical composition.

Therefore the utilization of groundnut shell ash reduces the environmental problem. In recent days, the natural pozzolanas materials use as partial replacement for cement has increased strength and durability. Literature and various research papers are available which have mentioned about the various advantages in the use of pozzolans in concrete production. At present, issues related to environmental conservation have gained

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importance; hence the utilization of these waste materials that are available in our environment is now necessary. Apart from these materials, for replacement, many fresh materials are also been used as replacement materials in the recent construction works. Some of the replacement materials are red mud, paper waste, hypo sludge, industrial waste etc. These replacement materials are been used in case of high strength concrete too. In this study, Groundnut shell Ash (GNSA) is used as a partial replacement of cement. Groundnut shell is the form of fuel used in sweet manufacturing units and the oil mills. The groundnut shell after being used as fuel generates ash which can be used as a replacement material for cement, the disposal of which is the major hassle. Thereby results in the decrease in waste to be disposed of and also there is the effective usage of the waste that is generated.

With the use of groundnut shell ash in concrete the cost will decrease and also it reduces the environmental pollution and saves the energy. GNSA has better pozzolanic property. It contains some chemical composition also. The pozzolanic activity of ash increases with an increase of time. The addition of GNSA in cement concrete may reduce drying shrinkage, water absorption, but increases the setting time. Increases of setting time are due to slow reactivity of GNSA.

The presence of GNSA may block the existing pore structure of concrete and thereby increase its strength and impermeability. The main object is to find a solution to reduce the environmental pollution due to cement manufacturing by using GNSA.

2. Mix Proportioning

Concrete mix design for M15 grade in this experiment was designed as per the guidelines specified in I.S. 10262-1982. Design stipulations are shown below.

2.1. Design stipulations

- Characteristic compressive strength =15 N/mm^2 (Required in the field at 28 days)
- Maximum size of aggregate = 20 mm (angular)
- Degree of workability = 0.80
- Degree of quality control = Good
- Type of exposure = Mild
- Type of vibration = Vibration

2.2. Test data for materials

- Type of cement or grade of cement- OPC 53 grade
- Specific gravity of cement = 3.12
- Specific gravity of coarse aggregates = 2.527
- Specific gravity of fine aggregates = 2.62

2.3. Design of concrete mix

- Target mean strength (f_c') = F_{ck}+1.65(s)= 15+1.65(3.5)=20.775N/mm^2
- Water cement ratio = 0.6
- Water content =186 litres
- Cement content per m^3 of concrete = 310 kg
- Percentage of entrapped air =2%
- Fine aggregates required = 620 kg/m^3
- Coarse aggregate required =1240 kg/m^3

Table 1 shows the mix proportions of plain concrete mix.

Table 1. Mix ratio for plain cement concrete.

Cement	Fine aggregates	Coarse aggregates	W/C ratio
310	620	1240	186
1	2	4	0.6

3. Materials

The materials used in this study were ground nut shell ash (GNSA), ordinary Portland cement (OPC 53 grade), sand as fine aggregates, chippings as coarse aggregates (20 mm size), and water. Wooden moulds were used for cubes, cylinders and for the prism. The ground nut shells were taken from a farm in Srikakulam in India state.

3.1. Cement

Ordinary Portland cement available in the market of grade 53 was used in the project. Care has been taken to see that the procumbent made from a single batch is stored in airtight containers to prevent it from being affected by the atmospheric moisture and humidity. Cement was subjected to some physical tests in accordance with BS 4550 (1978) such as compressive strength, specific gravity, setting time etc. the details of tests are given in Table 2.

3.2. Fine aggregates

Fine aggregates is an available river sand. Sand is used as fine aggregates in this project. The sand is free from clay, silt, and organic impurities. Sand was tested for various properties like specific gravity, bulk density, fineness modulus, partial size etc. and in according with IS 2386-1963. These test results are given in the Table 3.

3.3. Coarse aggregates

Machine crushed angular granite metal of 20 mm nominal size from the local source was used as coarse aggregates. It is free from impurities such as dust, clay, and organic matter etc., it was tested with different properties as shown below in Table 4.

3.4. Groundnut shell ash

The shells were sun dried and then ground using rice milling machine to reduce its size to a size conforming to coarse aggregates as specified in BS 882 (1992). The ash was obtained by burning of ground nut shells on an iron sheet or iron tin in an open air under normal temperature

(650^0C). After burning of ground nut shell, ash will generate. This ash was cooled and after used to sieve through British standard sieve of 75 microns. GNSA consists some chemical properties as shown in Table 5.

Table 2. Properties of cement.

S. no.	Properties	Test results	Requirement as per IS:12269-1987
1.	Fineness, m^2/kg	245	225 minimum
2.	Setting time		
	Initial (minutes)	50	Not less than 30
	Final (minutes)	180	Not more than 600
3.	Specific gravity	3.15	----------
4.	Soundness, mm	7	10 maximum
5.	Compressive strength, MPa		
	3 days	30	27
	7 days	39	37
	28 days	55	53

Table 3. Properties of fine aggregates.

S. no.	Property	Test result
1.	Specific gravity	2.52
2.	Fineness modulus	6.104
3.	Mean particle size	0.1-0.2μm
4.	Partial size	Spherical

Table 4. Properties of coarse aggregates.

S. no.	Property	Test result
1.	Specific gravity	2.56
2.	Fineness modulus	2.385
3.	Mean particle size	0.1-0.2μm
4.	Particle size	Angular

Table 5. Chemical composition of GNSA.

Constituent	Percentage composition GNSA (%)
Silica (SiO_2)	16.3
Ferrous Oxide (Fe_2O_3)	1.7
Calcium Oxide (CaO)	8.69
Aluminium Oxide (Al_2O_3)	6
Magnesium Oxide (MgO)	7
Sodium Oxide (Na_2O_3)	10
Potassium Oxide (K_2O)	16
Sulphite (SO_3^{2-})	6.3

3.5. Water

The locally available portable water accepted for local construction was used in the experimental investigation after testing. The pH value should not be less than 6. The water is portable; it therefore satisfies the specification requirement for water according to BS 3148 (1980).

3.6. Concrete cubes productions

The mix proportion used for this work was 1:2:4 (M15 grade). The proportions of cement to ash in the concrete were 100:0%, 95:5%, 90:10%,85:15%,80:20%,75:25% and 70:30%, respectively. The concrete materials cement, sand, chippings, and ground nut shell ash were mixed by hand with a water/cement ratio of 0.6 by weight. The materials were mixed together thoroughly by string to form a uniform mass.

The moulds were cleaned with engine oil or grease to prevent the development of the bond between the mould and concrete. The freshly prepared mixed concrete was taken into mould. Each mould was filled with three layers of concrete and each layer was rammed 25 times with tamping rod. Then the concrete cubes and cylinders in the moulds were left in the open air 24 hours. For each of the cement: ash proportion, 3 cubes, 3 cylinders and 3 prisms were cast. Therefore a total 72 cubes, 72 cylinders and 72 prisms were produced for testing. Removing of the concrete cubes and cylinders from the moulds was carefully done after 24 hours of the concrete setting. Curing of the concrete cubes was done by complete immersion in a pond or tank filled with tap water only for periods of 7, 14 and 28 days respectively.

3.7. Batching information for cubes and cylinders cast

Table 6 shows the mix proportions of different mix used in this study.

4. Testing of Specimens

4.1. Compressive strength test

Before crushing, cubes were brought out of the water and kept it for about 1-2 hours for water to dry off. They were brought and then then taken to the crushing machine in according with BS 1881 (1983). Cubes get cracks due to failure in their strength as a result of the load applied to the cubes by the crushing machine; the

load on the cubes was applied at a constant rate of stress equal to 0.2 N/mm^2 per second .The strength was recorded to the nearest 0.2 N/mm^2. The compressive strength is calculated as $F_{ck}=P/A$; where, F_{ck} is compressive strength, P is ultimate load (N) and A is the loaded area (mm^2).

Table 6. Percentage replacement with different proportions of materials.

Percentage of GNSA	GNSA (kg)	Cement (kg)	Sand (kg)	Granite (kg)	Water (litre)	Water/Cement ratio
0%	0	39.177	78.399	156.798	23.506	0.6
5%	1.953	36.918	78.399	156.798	22.321	0.6
10%	3.915	35.254	78.399	156.798	21.153	0.6
15%	5.557	33.232	78.399	156.798	19.935	0.6
20%	7.835	31.34	78.399	156.798	18.798	0.6
25%	9.72	29.358	78.399	156.798	17.61	0.6
30%	11.708	27.328	78.399	156.798	16.426	0.6
35%	13.775	25.39	78.399	156.798	15.26	0.6

4.2. Spilt tensile strength test

After the specimen had been cured for 7, 14 and 28 days in the water tank, the specimens were taken out from water and allowed dry for 1-2 hours. This test was carried out by placing the specimens horizontally between the loading surface of a testing machine and the load is applied until the cylinder gets failure.

Split tensile strength test was calculated as $=2P/\pi DL$.

4.3. Flexural strength test

Flexural strength is also called bend strength. Flexural strength specimen is in rectangular shape. After the specimen had been cured for 7, 14 and 28 days in the water tank, the specimens were taken out from water and allowed dry for 1-2 hours. This test is carried out by placing the specimens under a load in a three point bending or four-point bending. Flexural strength test was calculated as:

For three point bending is = $\sigma = 3FL/2bd^2$;

For four point bending strength= $\sigma = 3FL/4bd^2$;

where, F is the load, L is the length of the support spam, B is width, D is the thickness.

4.4. Slump test

Slump test was carried out to determine the workability of the concrete mix prepared in the lab during the progress of the work. This test was carried out in different percentages to check the uniform quality of concrete during mixing. Generally, this test used to find the workability which indicates water- cement ratio but there are various factors including properties of materials, mixing, methods, admixtures etc. also affect the slump value. The slump cone was placed on a flat non-porous surface and held down by foot. The mould was then filled in three layers. Each layer was compacted. After the third layer had been tamped, the slump cone was immediately removed by raising it vertically. The height of the slump cone was determined by taking measurement from the top of the slump cone to the top of the concrete. The slump was measured as the difference between the height of the cone and the height of the slump concrete.

5. Results and Discussions

5.1. Compressive strength

The results of the compressive strength test carried out are shown in the Fig. 1 below. It shows that compressive strength increases with the increase of cubes curing and decreases when the percentage of ground nut shells ash increases. At 0% ash and 100% cement that served as the control, compressive strength increases from 13.65 N/mm^2 at 7 days to 17.35 N/mm^2 at 28 days.

Compressive strength of 90:10% cement /ash increases from 15.6 N/mm^2 at 7 days to 23.15 N/mm^2 at 28 days. The compressive strength for 35% ash replacement were 5.9 N/mm^2, 7.52 N/mm^2 and 8.92 N/mm^2 for 7, 14, and 28 days, respectively

According to BS 8110, a grade 15 concrete of 1:2:4 without any mixing with cement should have acquired strength of 13.65 N/mm^2 within 7 days of wet curing; 17.35 N/mm^2 within 28 days. Based on the result obtained from this reported work, OPC/GASH of 90:10% would be suitable for concrete. The results shows that their strength improves with time since pozzolanas react more slowly than cement due to variation in their constituent's composition.

The pattern of this study was similar to Alabadan et al. (2006), Sideris and Sarva (2001), Sengul et al. (2005); they reported that cement blended with pozzolanas would produce 65 to 95 % strength of OPC concrete in 28 days. As previously described by Bengtsson and Whilken (1986), Nwofor and Sule (2012); a percentage replacement of 10% with GSA will be adequate for good concrete work.

5.2. Split tensile strength

The result below shows that split tensile strength for the 100:0% cement/ground nut shell ash is 1.8 N/mm², 2.1 N/mm² and 2.7 N/mm² for 7, 14 and 28 days, respectively while it was for 90:10% cement/ground nut shell ash is 2 N/mm², 2.6N/mm² and 3 N/mm² for 7, 14 and 28 days. The result shows that 10% of ground nut ash replacement gives the better result when compared to other replacement. The split tensile strength increase as the age of the concrete increase as shown in Fig. 2.

5.3. Flexural strength

The result below shows that flexural strength for the 100:0% cement/ground nut shell ash is 6.00 N/mm², 6.5 N/mm² and 7.5N/mm² for 7, 14 and 28 days, respectively while it was for 85:15% cement/ground nut shell ash is 6.2N/mm², 6.9N/mm² and 7.5 N/mm² for 7, 14 and 28 days.

The result in Fig. 3 show that 15% of ground nut ash replacement gives the better result when compared to other replacement.

5.4. Slump Test

Slump test is used to find the improper mixed batch. It measures the consistency of fresh concrete before its set.

The inner portion of the mould and its base should be moistened at the beginning of every test. The slump value is indicated in Fig. 4.

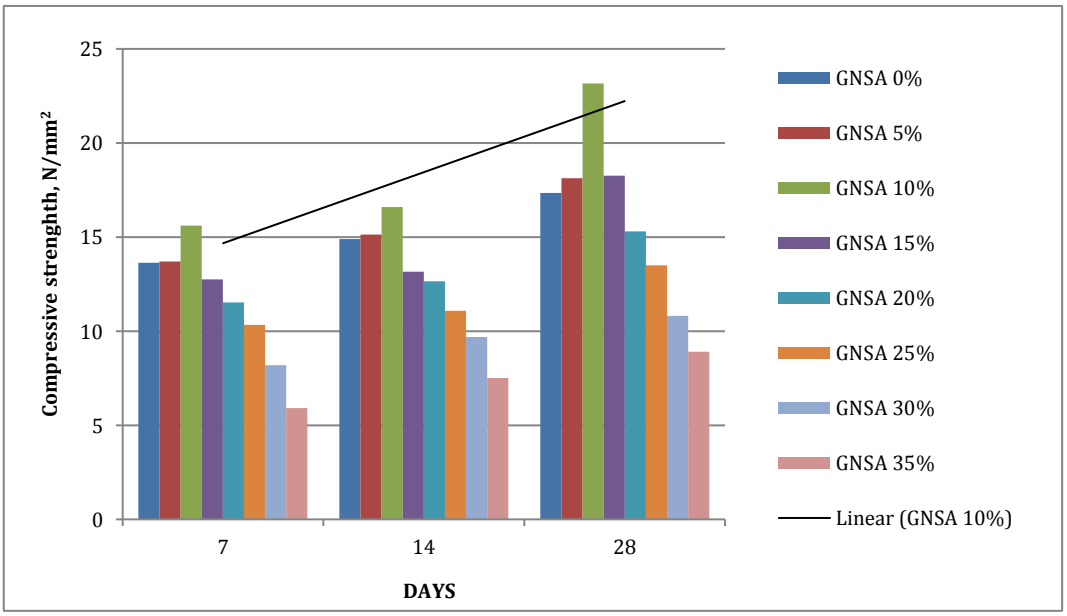

Fig. 1. Compressive strength for all percentages.

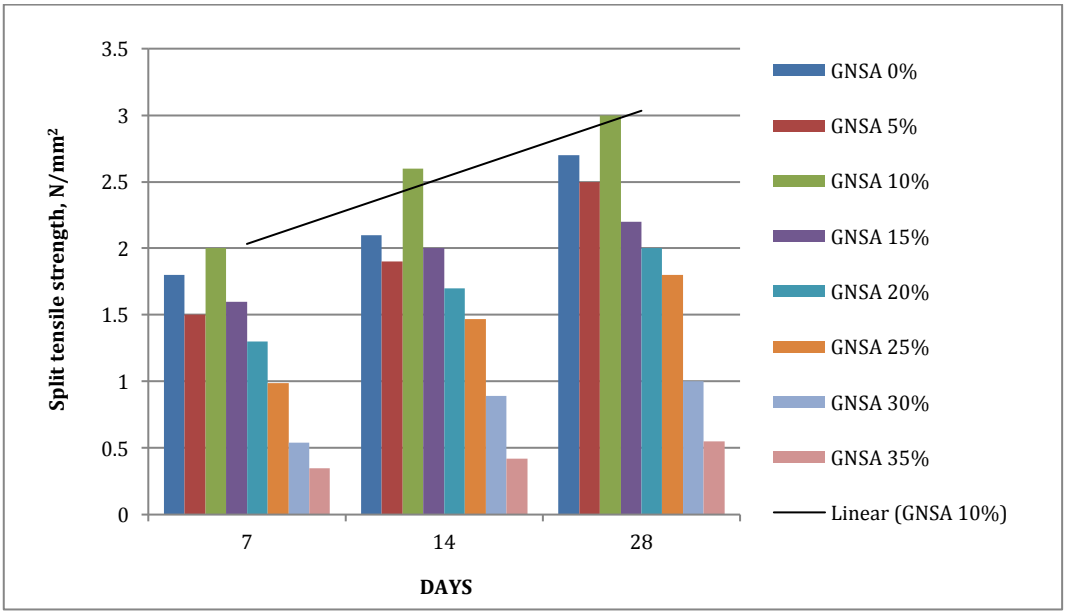

Fig. 2. Split tensile strength for all percentage replacement.

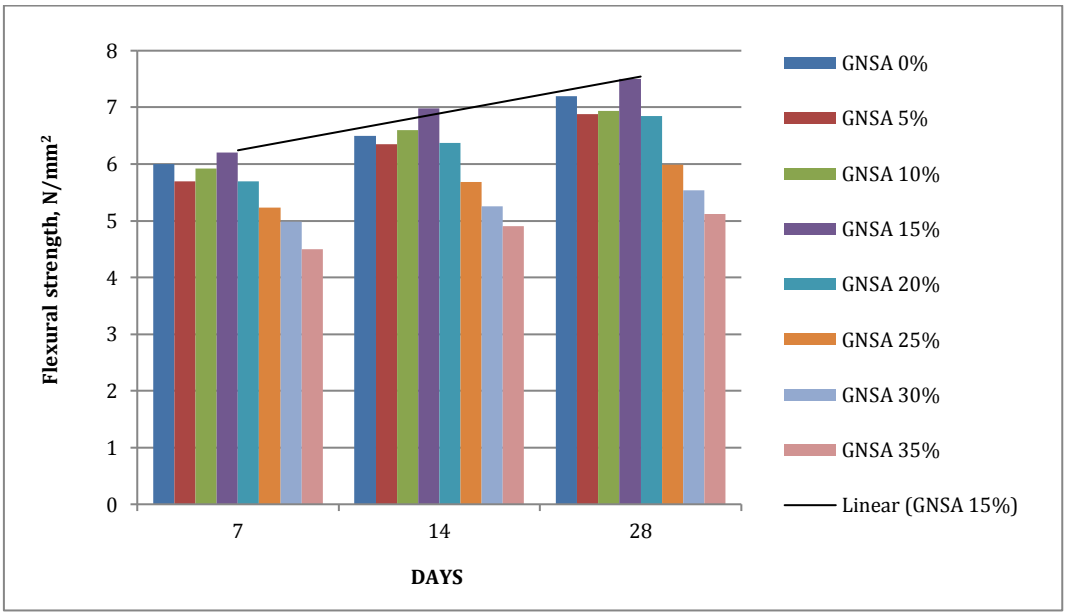

Fig. 3. Flexural strength for all percentages.

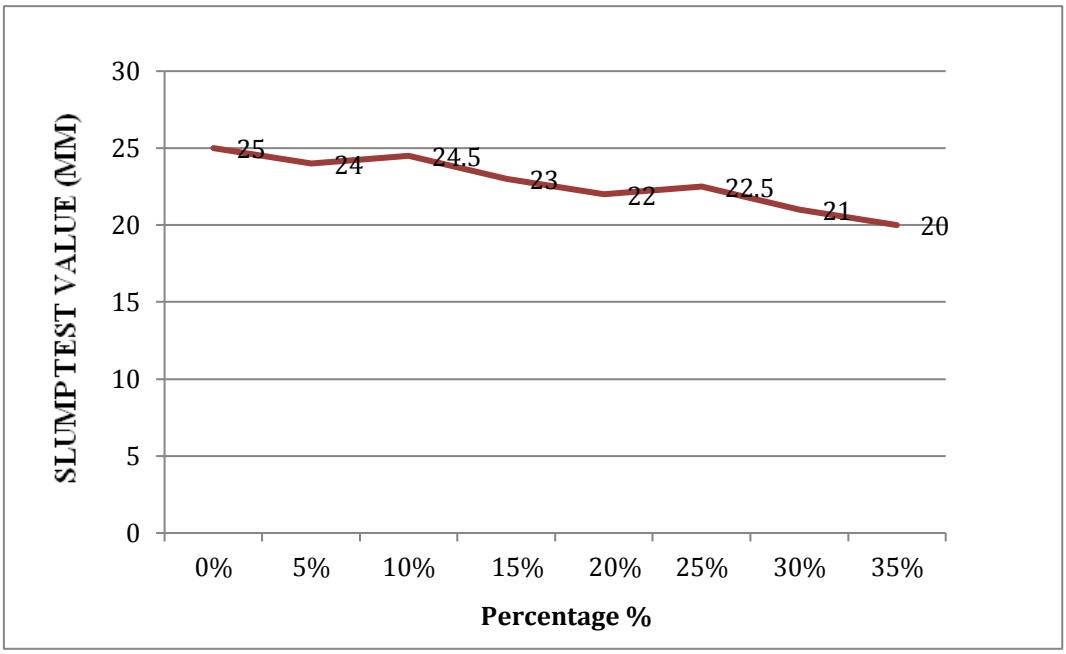

Fig. 4. Slump test values for different percentages.

6. Conclusions

Based on experimental investigations by considering the compressive strength, split tensile strength and flexural strength of concrete, the following observations are made:

- The compressive strength of concrete is increases when the replacement of Cement with groundnut shell ash up to 10% replaces by weight of Cement.
- The split tensile strength of concrete is increases when the replacement of Cement with groundnut shell ash up to 10% replaces by weight of Cement
- The flexural strength of concrete is increases when the replacement of Cement with groundnut shell ash up to 15% replaces by weight of Cement.
- When W/C ratio is increased respectively, compressive strength, spilt tensile strength and flexural strength of concrete is increased.
- Groundnut shell ash is a better innovative supplementary cementations' construction material which is used in concrete, so it can save the agriculture waste disposal costs and produce a greener concrete for construction.
- This research concludes that groundnut shell ash can be innovative supplementary cementations' Construction Material in Concrete but judicious decisions are to be taken by engineers.

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