STRENGTH AND DURABILITY CHARACTERISTICS OF GEOPOLYMER CONCRETE WITH GROUND NUT SHELL ASH

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ABSTRACT
Many developed and developing nations have shown progress in energy generation by means of biomass by introducing instrumented strategies and financial subsidies. So with this encouragement numerous organizations have started generating energy by utilizing biomass which indeed leads to the generation of biomass ash and create disposal problems. To overcome this problem, incorporation of these biomass ashes in construction provides a significant solution.
This paper explores the utilization of Ground Nut Shell Ash (GNSA) as the source material in producing Ground nut shell ash based geopolymer concrete (GNSAGC). This work presents the study on the development of various strengths for various Mix Proportions of GNSAGC for oven curing and ambient curing conditions. The concentrations of the sodium hydroxide solution were varied as 14 Molar, 16 Molar and 18 Molar. The alkaline solution used in the study is a combination of sodium silicate and sodium hydroxide solution with the ratio of 2. The ratio of liquid to ground nut shell ash is kept as 0.5. The effect of change in NaOH molarity and two different curing conditions on mechanical properties such as compressive strength, split tensile strength and flexural strength for GNSAGC are studied. This paper also presents the durability studies against acid attack on this concrete. The result also shows that as the molarity of NaOH solution increases the strength of this concrete also increases.

1. INTRODUCTION
Concrete is the copiously utilized structure material on the planet because of its high compressive quality, toughness and accessibility. Among the elements of the concrete, Ordinary Portland cement is the primary development material utilized in colossal amounts. As a recognizable measure of reducing environmental degradation, production of Ordinary Portland Cement (OPC) shall be decremented to bring about legitimate natural benefits regarding CO_2 outflow [1].

Biomass is a 'backhanded sunlight based fuel' source and is utilized in incalculable applications as a sustainable power source [2]. As this waste originates from vegetable natural issue, its ecological and financial potential have made it a focused option in contrast to customary strong fills [3]. Thus, biomass is a sustainable power source with gigantic potential. Utilized each day by an ever increasing number of individuals, it means to cover the popularity for vitality that society requests for quite a while introducing an answer for vitality issues, despite the fact that it likewise is badly arranged because of debris creation when thermo chemical forms are applied to deliver vitality.

This paper clarifies the trial stir taken up to look at the behavior of Ground nut shell ash based geopolymer concrete (GNSAGC) with 0% ,20% , 40% , 60% , 80% and 100% replacement of biomass ash by fly ash. The materials utilized for making GNSAGC, blend configuration, assembling and restoring of the test examples are clarified. The test procedures for considering the mechanical and durability properties of the GNSAGC were also explained. Every one of the procedures embraced for testing was as per the important codes of practice. There is the need to look for option in contrast to regular concrete and to truly consider the usage of modern and agrarian results as feedstock for the concrete business to create mixed concrete [9]. Usage of a portion of these products through incorporating them in the making of geopolymer concrete, leads to the sustainable building material [10]. The issue of transfer of these results is limited and the measure of green gases discharged into the air through concrete generation forms is likewise extraordinarily diminished [11]. Be that as it may, the expansion in prevalence of utilizing natural inviting, light weight construction materials in constructional industry has realized the need to explore how this can be accomplished by profiting condition just as keep up the materials prerequisites certified in the standards [12].

2. OBJECTIVE OF WORK

2.1. Objectives of present work

(a)To analyze the changes in mechanical properties of GNSAGC with change in curing conditions (Ambient curing and Heat curing) with partial replacement of flyash with ground nut shell ash.

(b) To study the durability of GNSAGC against acids attack such as H_2SO_4 and HCl.

(c) To analyze the mechanical and durability properties of this biomass ash based geopolymer concrete.

3. EXPERIMENTAL PROGRAM

Table1 shows the XRF chemical analysis of Ground Nut Shell Ash (GNSA) and fly ash (FA) which were used in making biomass ash based geopolymer concrete. The chemical analysis clearly depicts that GNSA is a potential material for replacing flyash in the production of geopolymer concrete

Table1. XRF Chemical analysis

S.No.	**Compound**	Percentage %	
		GNSA	**FA**
1	SiO_2	36.04	36.02
2	Al_2O_3	6.23	16.58
3	Fe_2O_3	1.88	10.91
4	CaO	8.53	14.75
5	MgO	6.51	2.4
6	Na_2O	8.95	0.45
7	K_2O	15.64	0.88
8	LOI	4.3	0.17

3.1Mixing

Making of Alkaline Liquids

Sodium Hydroxide

Sodium Hydroxide pellets (NaOH) taken and dissolved in water at the rate of 14, 16 and 18 molar concentrations. Davidovits (2002) has suggested that the preparation of sodium hydroxide solution must be done 24 hours prior to use and also if it exceeds 36 hours it terminates to semi- solid liquid state. So the prepared solution should be used within this time.

Molarity Calculation for Sodium Hydroxide solution

The Sodium Hydroxide pellets must be dissolved in water to make a solution with the required concentration. The concentration of Sodium hydroxide solution can vary in different Molar. The mass of Sodium Hydroxide pellets in a solution varies depending on the concentration of the solution. For example, Sodium Hydroxide (NaOH) solution with a concentration of 14 Molar consists of 14 x 40 = 560 grams of Sodium Hydroxide (NaOH) pellets per liter of water, were 40 is the molecular weight of NaOH.

Mixing procedure of all ingredients of ground nut shell ash based geopolymer concrete

Davidovits also recommended that the preference of a mixture of sodium silicate solution and sodium hydroxide solution together at least one day before adding the liquid to the solid constituents. The biomass ash and the aggregates are first dry mixed together in a mixing pan for about 3 to 5 minutes manually. After the dry mix is made, the alkaline solution which is prepared 24 hrs before is thoroughly mixed with the dry mix for another 3 to 5 minutes to make fresh biomass ash geopolymer concrete. The fresh biomass ash geopolymer concrete was filled in the mould. The specimens were compacted with three – layer filling and tamping using a stainless steel tamping rod. This was followed by an additional vibration of 10 seconds using a vibrating table. Specimens such as cubes, cylinders and beams were cast and tested. After casting the concrete mix was allowed to settle down in the moulds for 30 minutes. Different batches were adopted for variations in mix proportions as given below:

3.2Variations in mix proportions:

In order to obtain optimum mix proportion for the geopolymer concrete following variations were considered:

1. Ratio of sodium silicate solution-to-sodium hydroxide solution – 2.
2. Ratio of alkaline activator solution-to-biomass ash –0.5
3. Curing Method – Ambient curing and Hot air oven curing at 60^0C
4. Curing duration – Ambient curing for 28 days and Hot air oven curing for 24 hours
5. Sodium hydroxide solution concentration - 14 M, 16 M and 18 M

3.3Mix design for GNSAGC

As there is no standard mix design procedure is available for geopolymer concrete in any IS codes, the procedure suggested by Subhash.V.Patnakar in "Mix Design of Fly Ash Based Geopolymer Concrete" https://www.researchgate.net/publication/275340304 has been followed in the present work

The unit weight of concrete (mass) is considered as 2400 kg/m^3.

The Mass of combined aggregate is considered as 75 % of the mass of concrete.

Hence the mass of combined aggregate= 0.75 x 2400 = 1800 kg/m^3

Total mass of biomass ash and alkaline Liquid = 2400-1800 = 600 kg/m^3

Basing on above mix variations the percentage of ingredients was adopted as follows:

Ratio of Coarse aggregate to Fine aggregate = 1.5

Mass of coarse aggregate = 1080 kg/m^3

Mass of fine aggregate = 720 kg/m^3

Ratio of Alkaline liquid to ground nut shell ash = 0.5

Hence mass of ground nut shell ash = 400 kg/m^3

Mass of alkaline liquid = 200 kg/m^3

Ratio of Na_2SiO_3 to NaOH = 2

Hence mass of Na_2SiO_3 = 133.34 kg/m^3

Mass of NaOH = 66.7 kg/m^3 (14 molarity)

Extra water added = 12% of total mass of ground nut shell ash

Mass of water added = 48 kg/m^3

Super plasticizer = 1.5% of total ground nut shell ash

Mass of Super plasticizer = 6 kg/m^3

Table 2 shows the optimum mix proportions for ground nut shell ash based geopolymer concrete with partial replacement of ground nut shell ash with fly ash. The mix proportions were based on the above mix design.

Table2: Mix Proportions

Mix ID	% of Biomass Ash	% of Fly Ash	Molarity of NaOH	Ratio of Coarse aggregate to Fine aggregate	Ratio of Alkaline liquid to Biomass ash	Ratio of Na2SiO3 to NaOH	Added water %	Total volume of Aggregate %
GNSAGC100	100	0	18	1.5	0.3	2	12	75
GNSAGC80	80	20	18	1.5	0.3	2	12	75
GNSAGC60	60	40	18	1.5	0.3	2	12	75
GNSAGC40	40	60	18	1.5	0.3	2	12	75
GNSAGC20	20	80	18	1.5	0.3	2	12	75
GNSAGC0	0	100	18	1.5	0.3	2	12	75

4. RESULTS AND DISCUSSIONS

4.1. Mechanical properties of GNSAGC

4.1.1. Compressive strength

Table 3 shows the compressive strength results for Ground nut shell ash based geopolymer concrete in both curing conditions i.e., ambient and heat curing conditions.

Table3 Variations in compressive strength

S.No.	Mix ID	% of Biomass Ash	Compressive strength (MPa)	
			Ambient curing (28 days)	Heat curing (60^0, 24hrs.)
1	GNSAGC100	100	20.28	27.18
2	GNSAGC80	80	25.55	33.3
3	GNSAGC60	60	30.02	41.6
4	GNSAGC40	40	36.32	48.33
5	GNSAGC20	20	42.15	54.4
6	GNSAGC0	0	49.36	61.14

Figure 1 shows the variations in the compressive strength of GNSAGC in ambient curing and heat curing conditions.

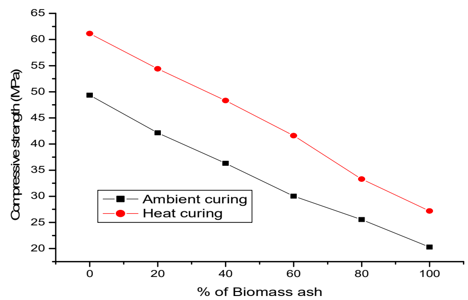

Fig.1: Compressive strength variations

The Fig.1 explains that the compressive strength of Ground nut shell ash based geopolymer concrete (GNSAGC) increases as the percentage of biomass ash decreases. Further it can also be concluded that the compressive strength of GNSAGC is higher in heat cured specimens. It is observed that the percentage increase in the compressive strength of GNSAGC was between 14% and 21% from GNSAGC100 to GNSAGC0 for ambient cured specimens. And also it was observed that the percentage increase in the compressive strength of GNSAGC was between 11% and 18% from GNSAGC100 to GNSAGC0 for heat cured specimens.

4.1.2. Split tensile strength

Table 4 shows split tensile strength results for Ground nut shell ash based geopolymer concrete in both curing conditions i.e., ambient and heat curing conditions.

Table4 Variations in split tensile strength

S.No.	Mix ID	% of Biomass Ash	Split tensile strength (MPa)	
			Ambient curing (28 days)	Heat curing (60^0, 24hrs.)
1	GNSAGC100	100	2.28	3.85
2	GNSAGC80	80	2.9	4.35
3	GNSAGC60	60	3.22	5
4	GNSAGC40	40	3.57	5.54
5	GNSAGC20	20	3.84	6.11
6	GNSAGC0	0	4.7	6.8

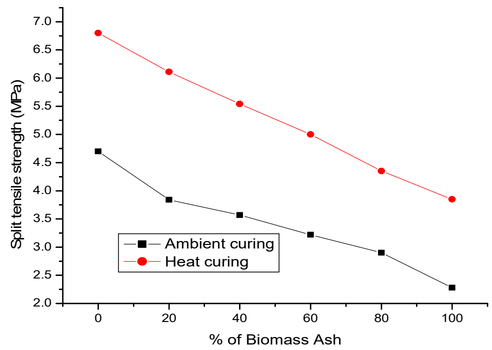

Fig.2: Split tensile strength variations

The Fig. 2 explains that the split tensile strength of Ground nut shell ash based geopolymer concrete (GNSAGC) increases as the percentage of biomass ash decreases. Further it can also be concluded that the split tensile strength of GNSAGC is higher in heat cured specimens. It is observed that the percentage increase in the split tensile strength of GNSAGC was between 18% and 21% from GNSAGC100 to GNSAGC0 for ambient cured specimens. And also it was observed that the percentage increase in the split tensile strength of GNSAGC was between 10% and 14% from GNSAGC100 to GNSAGC0 for heat cured specimens.

4.1.3. Flexural strength

Table5 shows Flexural strength results for Ground nut shell ash based geopolymer concrete in both curing conditions i.e., ambient and heat curing conditions.

Table5 Variations in split tensile strength

S.No.	Mix ID	% of Biomass Ash	Flexural strength (MPa)	
			Ambient curing (28 days)	Heat curing (60^0,24hrs.)
1	GNSAGC100	100	2.85	4.6
2	GNSAGC80	80	3.0	5.73
3	GNSAGC60	60	3.23	6.21
4	GNSAGC40	40	4.35	6.83
5	GNSAGC20	20	5.0	7.14
6	GNSAGC0	0	6.3	9.23

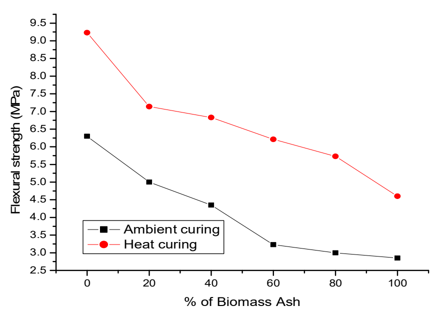

Fig. 3: Flexural strength variations

The Fig. 3 explains that the flexural strength of Ground nut shell ash based geopolymer concrete (GNSAGC) increases as the percentage of biomass ash decreases. Further it can also be concluded that the flexural strength of GNSAGC is higher in heat cured specimens. It is observed that the percentage increase in the flexural strength of GNSAGC was between 5% and 20% from GNSAGC100 to GNSAGC0 for ambient cured specimens. And also it was observed that the percentage increase in the flexural strength of GNSAGC was between 16% and 22% from GNSAGC100 to GNSAGC0 for heat cured specimens.

4.2. DURABILITY STUDIES OF GNSAGC

Research work was conducted to assess the performance of GNSAGC against acids attack such as 5%H_2SO_4 and 5%HCl). The performance against acid attack was analyzed by studying the visual appearance, change in mass, change in dimensions and change in compressive strength after soaking the specimen for 28 days in two different acid media.

4.2.1. Visual appearance:

It is observed that intensity of the harm was less under exposed to 5% HCl than exposed to 5% H_2SO_4.

4.2.2. Change in compressive strength (H_2SO_4 exposure)

Table 6 shows the change in compressive strength in GNSAGC with 5% H_2SO_4 exposure for 28 days when compared with that of GNSAGC not exposed 5% H_2SO_4 and with heat curing condition.

Table6 change in compressive strength

S.No.	Mix ID	% of Biomass Ash	Compressive strength (MPa)	
			No exposure to H_2SO_4 (heat cured)	Exposed to H_2SO_4 (28 days)
1	GNSAGC100	100	27.18	15.22
2	GNSAGC80	80	33.3	19.81
3	GNSAGC60	60	41.6	26.7
4	GNSAGC40	40	48.33	32.67
5	GNSAGC20	20	54.4	39.05
6	GNSAGC0	0	61.14	48.46

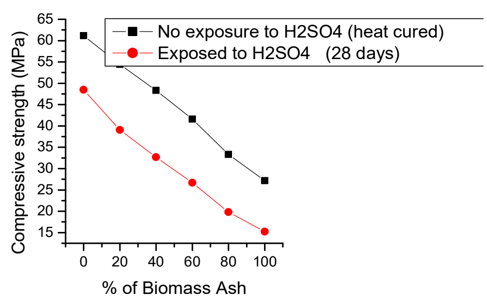

Fig4: Compressive strength variations

Fig.4 shows the results that the reduction in compressive strength was between 24% and 18% in the specimens exposed to H_2SO_4 for 28 days. It is also evident that there was decrease in the compressive strength of the specimens which exposed to acid media as the increase in the percentage of biomass ash.

4.2.3. Change in the mass (H_2SO_4 exposure)

Table7 shows the change in mass in GNSAGC with 5% H_2SO_4 exposure for 28 days when compared with that of GNSAGC not exposed and with heat curing condition.

Table7 Changes in mass

S.No.	Mix ID	% of Biomass Ash	Mass (Kg)	
			No exposure to H_2SO_4 (heat cured)	Exposed to H_2SO_4 (28 days)
1	GNSAGC100	100	8.02	6.9
2	GNSAGC80	80	8.25	7.1
3	GNSAGC60	60	8.44	7.5
4	GNSAGC40	40	8.60	7.8
5	GNSAGC20	20	8.56	8.0
6	GNSAGC0	0	8.68	8.3

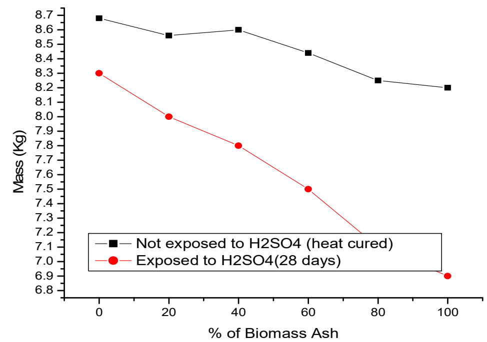

Fig5: Mass variations

Fig.5 shows the results that the reduction in mass was between 13% and 18% in the specimens exposed to H_2SO_4 and specimens not exposed H_2SO_4 for 28 days. It is also evident that there was decrease in the mass of the specimens which exposed to acid media as the increase in the percentage of biomass ash.

4.2.4. Change in diagonals (H_2SO_4 exposure)

Table 8 shows the change in diagonals in GNSAGC with 5% H_2SO_4 exposure for 28 days when compared with that of GNSAGC not exposed and with heat curing condition.

Table 8 change in diagonals

S.No.	Mix ID	% of Biomass Ash	Average length of four diagonals (mm)	
			No exposure to H_2SO_4 (heat cured)	Exposed to H_2SO_4(28 days)
1	GNSAGC100	100	256	248
2	GNSAGC80	80	254	248
3	GNSAGC60	60	256	251
4	GNSAGC40	40	254	251
5	GNSAGC20	20	256	252
6	GNSAGC0	0	257	255

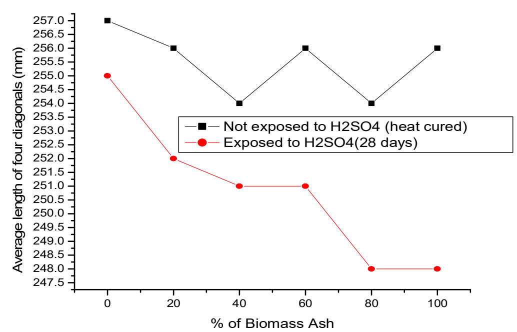

Fig.6.Variations in diagonals

Fig.6 shows the results that the reduction in average length of four diagonals was between 3% and 0.7% when compared to specimens not exposed to H_2SO_4 and the specimens exposed to H_2SO_4 for 28 days. It is also evident that there was decrease in average length of four diagonals of the specimens which exposed to acid media as the increase in the percentage of biomass ash.

4.2.5. Change in compressive strength (HCl exposure)

Table 9 shows the change in compressive strength in GNSAGC with 5%HCl exposure for 28 days when compared with that of GNSAGC not exposed and with heat curing condition.

Table 9 changes in compressive strength

S.No.	Mix ID	% of Biomass Ash	Compressive strength (MPa)	
			No exposure to HCl (heat cured)	Exposed to HCl (28 days)
1	GNSAGC100	100	27.18	26.22
2	GNSAGC80	80	33.3	32.3
3	GNSAGC60	60	41.6	40.56
4	GNSAGC40	40	48.33	47.31
5	GNSAGC20	20	54.4	53.53
6	GNSAGC0	0	61.14	60.4

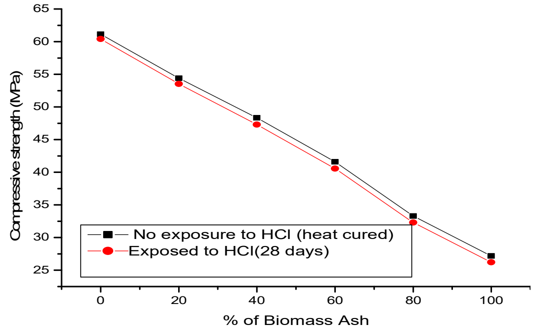

Fig7: Changes in compressive strength

Fig.7 shows the results that the reduction in compressive strength was between 13% and 19% in the specimens exposed to HCl for 28 days. It is also evident that there was decrease in the compressive strength of the specimens which exposed to acid media as the increase in the percentage of biomass ash.

4.2.6. Change in the mass (HCl exposure)

Table10 shows the Change in mass in GNSAGC with 5%HCl exposure for 28 days when compared with that of GNSAGC not exposed and with heat curing condition.

Table 10 Changes in mass

S.No.	Mix ID	% of Biomass Ash	Mass (Kg)	
			No exposure to HCl (heat cured)	Exposed to HCl(28 days)
1	GNSAGC100	100	8.15	7.8
2	GNSAGC80	80	8.2	8.04
3	GNSAGC60	60	8.28	8.15
4	GNSAGC40	40	8.36	8.25
5	GNSAGC20	20	8.4	8.3
6	GNSAGC0	0	8.56	8.5

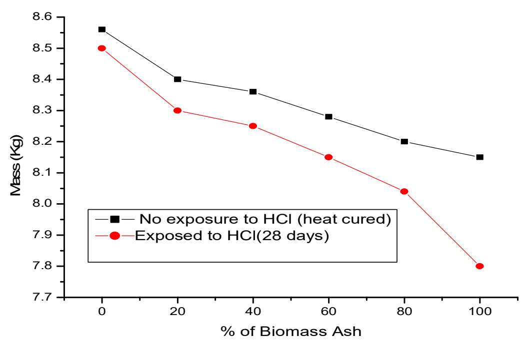

Fig. 8 Variations in mass

Fig.8 shows the results that the reduction in mass was between 4.5% and 0.7% in the specimens exposed to HCl and specimens not exposed HCl for 28 days. It is also evident that there was decrease in the mass of the specimens which exposed to acid media as the increase in the percentage of biomass ash.

4.2.7. Change in diagonals (HCl exposure)

Table 11 shows the change in diagonals in GNSAGC with 5%HCl exposure for 28 days when compared with that of GNSAGC not exposed and with heat curing condition.

Table 11changes in Average length of four diagonals (mm)

S.No.	Mix ID	% of Biomass Ash	Average length of four diagonals (mm)	
			No exposure to HCl (heat cured)	Exposed to HCl(28 days)
1	GNSAGC100	100	256	250
2	GNSAGC80	80	257	250
3	GNSAGC60	60	255	249
4	GNSAGC40	40	256	251
5	GNSAGC20	20	257	254
6	GNSAGC0	0	255	251

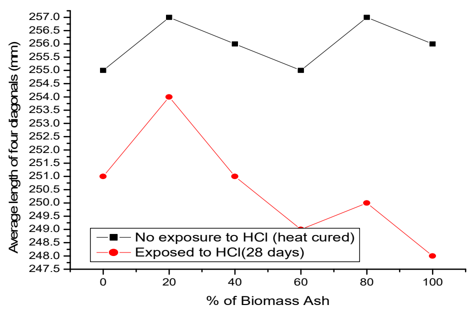

Fig9: Variations in Diagonals

Fig.9 shows the results that the reduction in average length of four diagonals was between 2.4% and 1.6% when compared to specimens not exposed to HCl and the specimens exposed to HCl for 28 days. It is also evident that there was decrease in average length of four diagonals of the specimens which exposed to acid media as the increase in the percentage of biomass ash.

5. CONCLUSIONS

The following conclusions are drawn based on the investigations made from the experimental work results in this paper.

1. From the experimental work conducted and by analyzing the results obtained from this study, it is concluded that GNSAGC20 Mix has the optimum proportion to achieve both strength and durability for both ambient and heat curing conditions.
2. The experimental work report states that the compressive strength of GNSAGC was 25%, more in GNSAGC100 exposed to heat curing than that of exposed to ambient curing.
3. In the durability studies of GNSAGC there was 20.74% to 44% of reduction in compressive strength from GNSAGC0 to GNSAGC100 when exposed to 5% H_2SO_4 acid for 28 days.
4. There was 4% to 15.85% reduction in mass for GNSAGC0 to GNSAGC100 respectively, when immersed in 5% H_2SO_4 acid for 28 days.
5. There was reduction in average length of diagonals of the specimens soaked in % H_2SO_4 acid for 28 days.
6. The above results show that there was not much change in compressive strength, mass and diagonals length for GNSAGC exposed to 5% HCl acid for 28 days.

References

1. Anil Kumara,n, Nitin Kumara, Prashant Baredara, Ashish Shuklab “A review on biomass energy resources, potential, conversion and policy in India”. Journal homepage: www.elsevier.com/locate/rser.
2. Francisco Agrela1, Manuel Cabrera1, Marı´a Martı´n Morales2, Montserrat Zamorano2 and Mazen Alshaaer
3.” Biomass fly ash and biomass bottom ash”. New Trends in Eco-efficient and Recycled Concrete. DOI: https://doi.org/10.1016/B978-0-08-102480-5.00002-6 © 2019 Elsevier Ltd. All rights reserved.
4. Ikumapayi, CM “Properties of Groundnut Shell (Arachis Hypogaea) Ash Blended Portland cement”. JASEM ISSN 1119-8362; J. Appl. Sci. Environ. Manage. Vol. 22 (10) 1553–1556 October 2018.
5. Buari T.A. **“**Characteristics Strength of groundnut shell ash (GSA) and Ordinary Portland cement (OPC) blended Concrete in Nigeria”. (buari4ever@yahoo.com)
6. T.C. Nwofor and S. Sule “Stability of groundnut shell ash (GSA)/ordinary Portland cement (OPC) concrete in Nigeria”. Pelagia Research Library
Advances in Applied Science Research, 2012, 3 (4):2283-2287
7. B.A. Alabadan, C. F. Njoku and M. O. Yusuf. “The Potentials of Groundnut Shell Ash as Concrete Admixture”. Agricultural Engineering International: the CIGR Ejournal. Manuscript BC 05 012, Vol. VIII. February, 2006.
8. B V Rangan” Engineering properties of geopolymer concrete”. https://www.researchgate.net/publication/279612420_Engineering_properties_of_geopolymer concrete.
9. J.C. Swanepoel, C.A. Strydom “Utilization of fly ash in a geopolymeric material”. https://www.journals.elsevier.com/applied-geochemistry.
10.Assessment report: Primary survey on household cooking fuel usage and willingness to convert to LPG. PrimarySurveyReportPPAC.pdf
11. “Compressive strength Characteristic of Cow dung ash blended cement Concrete”. By T. Omoniyi, S. Duna, A. Mohammed. International Journal of Scientific & Engineering Research, Volume 5, Issue 7, July-2014 ISSN 2229-5518.
12. “Microbial deterioration effect of cow dung ash modified concrete in freshwater environments”. by Vinita Vishwakarma https://www.researchgate.net/profile/Vinita_Vishwakarma.
13.”Performance of Cow Dung Powder on Compressive Strength of Blended Concrete”.by Jonathan Segun Adekanmi. https://www.researchgate.net/profile/Jonathan_Adekanmi
14. “Experimental studies on effect of cow dung ash (pozzolanic binder) and coconut fiber on strength properties of concrete”. by C Venkatasubramanian. IOP Conference Series: Earth and Environmental Science.
15. ”Effect of cattle manure ash’s particle size on compression strength of concrete”, by Shuguang Zhou. Journal www.elsevier.com/locate/cscm.
16. “A review on biomass energy resources, potential, conversion and policy in India”. by Anil Kumara. www.elsevier.com/locate/rser