STM JOURNALS

Journal of
Structural Engineering and Management

ISSN: 2393-8773
Volume 11, Issue 3, 2024
September—December
DOI (Journal): 10.37591/JoSEM

https://journals.stmjournals.com/josem

Research JoSEM

Performance Evaluation of Geopolymer Coconut Shell Concrete: A Comparative Study with Conventional Concrete

Veerendra Vishwakarma[1,*], Harsh Rathore[2]

Abstract

The increasing demand for sustainable construction materials has driven the exploration of alternative aggregates such as coconut shells in geopolymer concrete. This study investigates the characteristics and performance of Geopolymer Coconut Shell Concrete (GPCSC) and compares it with traditional Geopolymer Conventional Concrete (GPCC). Both mixes were evaluated for workability, density, and compressive strength at 3, 7, and 28 days. The slump values for GPCSC and GPCC were 10 mm and 15 mm, respectively, indicating low workability due to the high viscosity of the geopolymer mix. The fresh and hardened densities of GPCSC were measured at 2010 kg/m³ and 1980 kg/m³, while GPCC exhibited densities of 2480 kg/m³ and 2440 kg/m³. The reduced density of GPCSC offers a significant advantage in terms of reduced self-weight, leading to lower reinforcement requirements and cost savings in structural applications. The compressive strength of GPCSC at 28 days reached 32.6 N/mm², while GPCC achieved 35.2 N/mm². Although GPCC demonstrated higher compressive strength, GPCSC reached 93% of its 28-day strength in just 7 days, demonstrating excellent early-age strength development under ambient curing conditions. This study highlights the potential of GPCSC as a viable, sustainable alternative to conventional concrete, offering both environmental and economic benefits, especially in regions where coconut shells are abundant.

Keywords: Geopolymer concrete, coconut shell aggregate, compressive strength, workability, density, sustainable construction, ambient curing

INTRODUCTION

The construction industry is increasingly focusing on sustainable alternatives to conventional materials due to the growing environmental concerns and depletion of natural resources. Coconut shells, a waste by-product from the coconut industry, offer a promising solution as a lightweight aggregate in geopolymer concrete. Geopolymer concrete, which uses alkaline activators such as sodium silicate and sodium hydroxide, has emerged as an eco-friendly alternative to traditional Portland cement concrete. By incorporating coconut shells into the mix, the resulting geopolymer concrete not only reduces waste but also lowers the overall environmental footprint of concrete production [1-11].

Objectives

The objective of this study is to evaluate the performance of Geopolymer Coconut Shell

***Author for Correspondence**
Veerendra Vishwakarma
E-mail: veerendra92civileng@gmail.com

[1]Research Scholar, Department of Civil Engineering, Sanjeev Agarwal Global Educational University, Bhopal, Madhya Pradesh, India
[2]Associate Professor, Department of Civil Engineering, Sanjeev Agarwal Global Educational University, Bhopal, Madhya Pradesh, India

Received Date: November 22, 2024
Accepted Date: December 18, 2024
Published Date: December 21, 2024

Citation: Veerendra Vishwakarma, Harsh Rathore. Performance Evaluation of Geopolymer Coconut Shell Concrete: A Comparative Study with Conventional Concrete. Journal of Structural Engineering and Management. 2024; 11(3): 63–68p.

Concrete (GPCSC) in comparison with conventional geopolymer concrete (GPCC). The specific goals include determining the workability, fresh and hardened densities, and compressive strength of both types of concrete at various curing ages. This research aims to assess the feasibility of using coconut shells as an effective aggregate in geopolymer concrete, focusing on the potential benefits in terms of weight reduction, strength development, and sustainability [12-16].

Material

This study utilized several materials: Ground Granulated Blast Furnace Slag (GGBS) as the binder, manufactured sand (M-sand) as the fine aggregate, and Coconut Shell (CS) and Crushed Granite (CG) as the coarse aggregates to create Ground-Powered Concrete with Shell Concrete (GPCSC) and Ground-Powered Concrete with Crushed Granite (GPCC). Sodium silicate and sodium hydroxide solutions were employed as alkaline activators for the binder. For reinforcement, both mild steel bars and high-yield deformed steel bars were used. Detailed descriptions of these materials and their properties are provided in the subsequent sections [17-20].

Ground Granulated Blast Furnace Slag (GGBS)

The Ground Granulated Blast Furnace Slag (GGBS) used in this study is a by-product from the iron industry, commercially available and utilized as a binder in the concrete mix.

Manufactured Sand (M-sand)

Manufactured sand, sourced from granite and conforming to Grading Zone II as per IS 383: 2016, was used as the fine aggregate throughout the study.

Coconut Shell (CS)

Coconut shells were procured from a local market, then crushed into fragments using a crushing machine. The average thickness of the shell fragments ranged from 3-9 mm, with sizes up to 12.5 mm [21-25].

Crushed Granite (CG)

Crushed granite stones, sized less than 12.5 mm, were used in the concrete. The granite was air-dried and sifted to eliminate any impurities before incorporation into the mix.

Water

Potable water was employed throughout the study. The water was clean and devoid of contaminants such as grease, oil, silt, and organic matter, ensuring it did not interfere with the concreting and curing processes.

Alkaline Activator

The alkaline activator was created by mixing sodium silicate (composed of 13% Na_2O, 30% SiO_2, and 57% water by mass) with a sodium hydroxide (NaOH) solution of 10 Molarity. The sodium hydroxide solution was prepared in the laboratory 24 hours prior to casting. The ratio of sodium hydroxide to sodium silicate used was 1:2.5 by weight [26-29]

Mixing, Casting, and Curing Procedures for Specimens

Initially, coarse and fine aggregates were blended in a mixer for approximately 5 minutes. GGBS binder was then added, and the mixture was combined for an additional 5 minutes. Subsequently, alkaline activators were introduced and mixing continued for another 4 minutes. The freshly prepared concrete mix was poured into molds and compacted using a table vibrator. After casting, the specimens were covered with plastic sheets to prevent water evaporation, following ASTM C171-16 standards. The molds were removed after 24 hours, and the specimens were kept covered with a polythene wrap (conceal curing) until the time of testing [30].

Results

Workability (Slump Test)

According to IS 1199: 1959, the workability of both GPCSC (Figure 1) and GPCC (Figure 2) was evaluated using the slump test. The slump measurements recorded were 10 mm for GPCSC and 15 mm for GPCC. These low slump values are attributed to the high viscosity of the geopolymer mixture, which prevents segregation and bleeding during the mixing, placing, and compacting processes, unlike traditional concrete. The viscosity and cohesiveness of the mix were maintained primarily through the use of sodium silicate and sodium hydroxide solutions. Key factors influencing the properties of geopolymer concrete include the chemistry of the alkaline activators, the binder, and the liquid-to-solid ratio, similar to observations made in oil palm shell concrete by Alamgir Kabir et al. (2017).

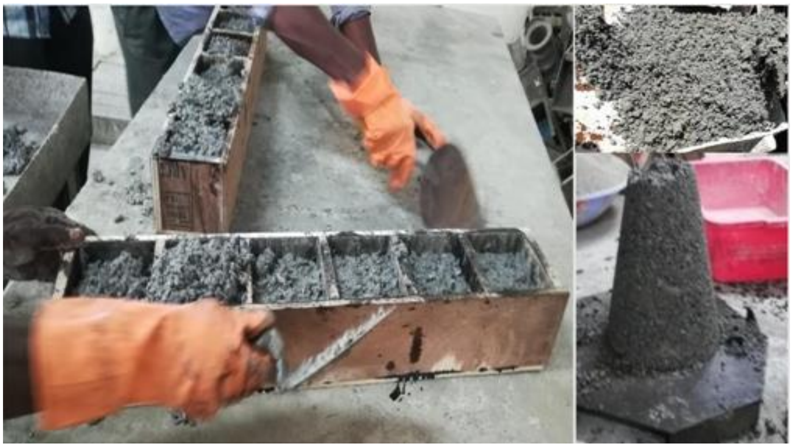

Figure 1. GPCSC during the slump test and casting of cubes using a table vibrator.

Figure 2. GPCC during the slump test and casting of cubes using a table vibrator.

Fresh and Hardened Density

The fresh and hardened densities of GPCSC were measured at 2010 kg/m³ and 1980 kg/m³, respectively, while GPCC had densities of 2480 kg/m³ and 2440 kg/m³. The reduced density of GPCSC compared to GPCC is due to the lower weight of coconut shells compared to crushed granite. The 28-day hardened density of GPCSC, which is below 2000 kg/m³, falls within the range for structural grade lightweight concrete (LWC), as reported by Gunasekaran et al. (2010, 2011a, 2011b, 2012, 2013a, 2013b, 2013c, 2014, 2015). GPCSC's hardened density was approximately 24% less than that of GPCC, offering a benefit of reduced self-weight. This reduction lowers the overall load moment, which can decrease the area of reinforcement required, leading to cost savings.

Compressive Strength of Geopolymer Concrete

Table 1 presents the compressive strength of GPCSC and GPCC at 3 days, 7 days, and 28 days. GPCC exhibited approximately 7% higher compressive strength compared to GPCSC. According to Davidovits (2011), GGBS-based geopolymer mortar, when cured under ambient conditions without heat, develops substantial strength by 28 days. In this study, GPCSC reached 93% of its 28-day compressive strength in just 7 days, and 80% in 3 days, under ambient curing. Similarly, GPCC achieved 81% of its 28-day strength in 7 days and 69% in 3 days under the same curing conditions.

Table 1. Characteristics of Concrete Mixtures

Mix	**Slump (mm)**	**Fresh Density (kg/m^3)**	**3 – Day**		**7 - Day**		**28 - Day**	
			Density (kg/m^3)	***Compressive Strength (N/mm^2)***	***Density (kg/m^3)***	***Compressive Strength (N/mm^2)***	***Density (kg/m^3)***	***Compressive Strength (N/mm^2)***
Geopolymer Coconut Shell Concrete (GPCSC)	10	2010	1995	26.20	1985	30.25	1980	32.60
Geopolymer Conventional Concrete (GPCC)	15	2480	2465	24.20	2450	28.45	2440	35.20

This indicates that the key factors influencing concrete strength are the GGBS binder and alkaline activator, regardless of the type of aggregate used. Since outdoor curing is the only feasible method for in-situ construction, the typical heat curing process was omitted due to the glassy nature of the GGBS binder. This approach aligns with findings from the compressive strength tests on geopolymer oil palm shell concrete (LWGPOPS) by Azizul Islam et al. (2015), which were conducted under ambient curing conditions at 3, 7, and 28 days.

Gunasekaran et al. (2011) reported a compressive strength of 26.7 MPa with a cement binder, which might be attributed to the specific properties and size of the coconut shell used. In contrast, steam-cured coconut shell concrete exhibited lower compressive strength compared to water-cured samples, likely due to the organic nature of coconut shell that may inhibit hardening under steam. Similar observations were noted by Shafigh et al. (2013) for palm shell concrete cured with hot water versus normal water.

Jayaprithika et al. (2016b) achieved a maximum compressive strength of 29.2 MPa with concealed curing. In this study, a higher compressive strength of 32.6 MPa was achieved with an increased proportion of coconut shell (1:2.53:1.05) compared to previous studies by Gunasekaran et al. (2013a, 2013b) with ratios of (1:1.47:0.65), Jayaprithika et al. (2016a, 2016b) with (1:1.77:0.49), and Alamgir Kabir et al. (2017) with (1:2.5:0.6). This enhanced strength is primarily attributed to the optimized binder and alkaline activator used in the mix.

CONCLUSIONS

The results indicate that Geopolymer Coconut Shell Concrete (GPCSC) offers promising characteristics as an alternative to conventional concrete. Despite slightly lower compressive strength compared to GPCC, GPCSC demonstrated significant advantages in terms of reduced density, which can lead to cost savings in structural reinforcement. The rapid strength development of GPCSC, especially under ambient curing conditions, positions it as a sustainable and viable material for future construction applications. This research contributes to the growing body of knowledge on the use of agricultural waste materials in sustainable concrete production, offering a feasible solution for both environmental and economic challenges in the construction industry.

REFERENCES

1. AASHTO (T 259 -80), Standard method of test for resistance of concreteto chloride ion penetration, West Conshohocken, PA: American Association of State Highway and Transportation Officials.
2. ACI 544.IR-96, 2002, Report on Fibre Reinforced Concrete, America Concrete Institute, Farmington Hills, MI, USA.
3. ACI 211.2-98, 1998, Standard practice for selecting proportions for structural lightweight concrete

(reapproved 2004), American Concrete Institute, Farmington hills, Michigan, USA.
4. ACI 213R-14, 2014, Guide for structural lightweight-aggregate concrete, American Concrete Institute, Farmington hills, Michigan,USA.
5. ACI 318-14, 2014, Building code requirements for structural concrete and commentary, American Concrete Institute, Farmington hills, Michigan, USA.
6. Ahlawat, D & Kalurkar, LG 2014, 'Coconut shell as partial replacementof coarse aggregate in concrete', IOSR Journal of Mechanical and CivilEngineering, pp. 61–44.
7. Alengaram, UJ, Jumaat, MZ, Mahmud, H & Fayyadh, MM, 2011, 'Shear behaviour of reinforced palm kernel shell concrete beams',Construction and building materials, vol.25, no.6, pp. 2918-2927.
8. Azizul Islam, Alengaram, UJ, Mohd Zamin Junaat, Iftekhair Bashar &Alamgir Kabir, SM 2015, 'Engineering properties and carbon footprintof ground granulated blast –furnance slag – palm oil fuel ash – based structural geopolymer concrete', Materials and Construction, vol. 101, pp. 503–523.
9. Azizul Islam, Alengaram, UJ, Jumaat, MZ & Bashar, 2014, 'The development of
10. Bougara, A, Lynsdale, C & Ezziane, K 2009, 'Activation of Algerian slag in mortars', Construction and Building Materials, vol. 23, no. 1, pp.542-547.
11. BS 8110-1, 1997, Structural use of concrete, code of practice for designand construction, British Standards Institution, London, UK.
12. BS EN 12390-3, 2009,Testing Hardened Concrete Part 3, CompressiveStrength of Test Specimens, British Standard Institution BSI, London, UK.
13. Chandra, KP, Natrajan, M & Meiaraj, C 2017, 'Eco friendly light weightgeo polymer concrete for sustainable development', International Journal of Civil Engineering and Technology, vol. 8, issue 8, pp. 572 - 580.
14. Chang, JJ 2003, 'A study on the setting characteristics of sodium silicateactivated slag pastes', Cement and Concrete Research, vol. 33, no. 7, pp.1005-1011.
15. Douglas, E & Brandstetr, J 1990, 'A preliminary study on the alkali activation of ground granulated blast-furnace slag', Cement and Concrete Research, vol. 20, no. 5, pp. 746-756.
16. Dewanshu Ahlawat & Kalurkar, LG, 2014, 'Coconut shell as partial replacement of coarse aggregate in concrete', International conference on advances in engineering and technology(ICAET – 2014), pp. 61-64.
17. EuroLightCon 2000, 'Properties of LWC Containing Lytag and Liapor, European Union—BriteEuRamIII', Document BE 963942/ R8. www.sintef.no/static/BM/projects/EuroLight Con/BE3942R08.pdf.Accessed 25 Jan 2013.
18. Gonçalves, JP, Tavares, LM, Filho, RDT, Fairbairn, EMR & Cunha, ER2007, 'Comparison of natural and manufactured fine aggregates incement mortars', Cement and Concrete Research, vol. 37, no. 6, pp. 924–932.
19. Goretta, KC, Chen, N, Gutierrez-Mora, F, Routbort, JL, Lukey, GC & Van Deventer, JSJ 2004, 'Solid-particle erosion of a geopolymer containing flyash and blast-furnace slag', Wear, vol. 256, no. 7-8, pp. 714–719.
20. Gong, C & Yang, N 2000, 'Effect of phosphate on the hydration of alkaliactivated red mud-slag cementitious material', Cement and Concrete Research, vol. 30, no. 7, pp. 1013-1016.
21. Gunasekaran, K, Kumar, PS & Lakshmipathy, M 2010, 'Compatibility studies on the coconut shell cement composites', Indian Journal of Indian Concrete Institute, vol. 11, no. 1, pp. 27–31.
22. Gunasekaran, K, Annadurai, R & Kumar, PS 2013b, 'Study on reinforced lightweight coconut shell concrete beam behaviour under shear', Materials and Design, vol. 46, pp. 293 -301.
23. IS 1199: 1959, Indian Standard Method of Sampling and Analysis of Concrete, Reaffirmed 2004, Bureau of Indian Standard, New Delhi, India.
24. IS 516: 1959, Indian Standard code of practice for method of tests forstrength of concrete, Bureau of Indian Standard, New Delhi, India.
25. IS 13311 (Part 1) : 1992, Indian Standard for Non-Destructive Testingof Concrete, Bureau of Indian Standard, New Delhi, India.
26. IS 1237 - 2012 BIS (2012), Cement concrete flooring tiles, 2nd revision,BIS, New Delhi, India.
27. IS 456:2000, Indian Standard Plain and Reinforced Concrete—Code ofPractice; Bureau of Indian

Standards. New Delhi, India.
28. IS 2386: Part 1: 1963, Indian standard methods of test for aggregate forconcrete Part III, specific gravity, density, voids, absorption and bulking(reaffirmed 2016). Bureau of Indian Standards, New Delhi, India.
29. IS 2386: Part 4: 1963, Indian standard methods of test for aggregate for concrete, Part IV, mechanical properties (reaffirmed 2016), Bureau of Indian Standards, New Delhi, India.
30. IS 383: 2016, Indian Standard for Specification for Coarse and Fine Aggregates from Natural Sources for Concrete; Bureau of Indian Standard: New Delhi, India.

