International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Optimization of a Rice Husk-Derived Hybrid Activator to Improve Performance of Hybrid Geopolymer Concrete

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Abstract
The increasing need for environmentally friendly construction materials has prompted more rapid study into geopolymer concrete as a viable alternative to conventional Portland cement. This research explores the creation and optimisation of a hybrid activator produced from rice husk for the purpose of boosting the performance of hybrid geopolymer concrete (HGPC). Rice husk, which is a plentiful by-product of agriculture, was treated in order to extract silica. This silica was then mixed with alkaline solutions to create a hybrid activator. The mechanical strength, durability, and microstructural features of HGPC were comprehensively examined with regard to the effects of activator content, molarity, and curing conditions. The findings showed that the hybrid activator that was generated from rice husk substantially increased compressive strength, decreased permeability, and increased resistance to acid and sulphate attacks in comparison to traditional activators. The production of a thick geopolymer matrix with well-developed aluminosilicate gel phases was verified by microstructural characterisation utilising XRD, FTIR, and SEM. The optimised hybrid activator not only valorises agricultural waste but also eliminates the need on activators from industrial chemicals. This offers a cost-effective and sustainable avenue for large-scale geopolymer concrete applications. The findings of this study demonstrate the possibility of using rice husk-derived activators in the development of environmentally friendly building technologies and the implementation of circular economy practices.

Keywords: Husk-Derived, Hybrid, Improve, Performance, Hybrid, Geopolymer

Introduction

The building sector has been expanding at a rapid rate, which has put a large amount of strain on natural resources and contributed substantially to the overall carbon emissions of the world. The primary ingredient in modern concrete manufacture is ordinary Portland cement (OPC), which accounts for around 7–8% of the carbon dioxide emissions produced worldwide. This is due mainly to the calcination of limestone and the significant amount of energy required for the manufacturing process. Researchers and industry practitioners are continually investigating environmentally friendly alternatives that have the potential to reduce negative impacts on the environment while maintaining or improving performance. One interesting option that is being considered is geopolymer concrete (GPC), a material that is produced by means of the alkaline activation of aluminosilicate precursors such as fly ash, ground granulated blast furnace slag (GGBFS), or agricultural by-products. There are various advantages to using geopolymer concrete, including superior chemical resistance, decreased shrinkage, strong early compressive strength, and a less carbon footprint. However, there are several obstacles that must be overcome before it can be used on a big scale. One of the most significant of these is the fact that it requires industrial-grade alkaline activators, such as sodium hydroxide and sodium silicate. These activators are expensive to manufacture, require a significant amount of energy, and may present health and safety hazards while handling. In an effort to overcome these restrictions, researchers have started to concentrate on the development of alternative and hybrid activators that are generated from renewable or waste resources. These activators have the potential to lower both the environmental burden and manufacturing costs that are connected with geopolymer concrete. Rice husk, which is an agricultural byproduct that is produced in vast numbers in rice-producing nations such as India, China, and Southeast Asia, has drawn a great deal of attention in this area. Rice husk ash (RHA), which is extremely rich in amorphous silica, is produced by the controlled burning of rice husk. It is possible to extract this silica by chemical means and then use it as a precursor for the production of alternatives to sodium silicate or as an ingredient in a hybrid activator system. The process of converting rice husk into a functional activator not only successfully manages agricultural waste, but also reduces the environmental imprint of geopolymer concrete. This contributes to the advancement of the concepts of the circular economy and sustainable development.

Hybrid geopolymer concrete (HGPC) is a type of concrete that is created by combining bio-derived activators with industrial by-products including fly ash and ground granulated blast furnace slag (GGBFS). It is a new frontier in green building technology. Superior performance in terms of strength, durability, and microstructural refinement may be achieved by the use of several aluminosilicate sources that are activated by hybrid activator systems. The effectiveness of this method, however, is contingent upon the optimisation of activator composition and processing conditions. The reactivity of precursors and the quality of the geopolymer matrix that is produced are heavily influenced by a number of factors. These factors include the mixing proportions, the curing regime, the molarity of the alkaline solution, and the silica-to-sodium ratio. It has been proven via previous research that solutions based on rice hull ash (RHA) and silica may be used in place of standard sodium silicate in whole or in part. Nevertheless, a considerable information gap still exists about the way in which hybrid activators produced from rice husk interact with various precursors in order to form geopolymer binders that have good performance. In addition, there are only a few systematic optimisation methodologies that maximise both mechanical and durability features while maintaining cost-effectiveness and scalability. The purpose of this work is to fill up these gaps by creating and optimising a hybrid activator made from rice husk for the manufacturing of geopolymer concrete. The purpose of the research is to determine how differences in activator content and curing circumstances impact compressive strength, microstructural properties, and durability in hostile situations. In order to assess the changes in the mineralogy and microstructure of the geopolymer matrix, advanced characterisation methods such as X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM) are utilised. This study not only suggests a sustainable alternative to chemical activators by combining waste valorisation with performance optimisation, but it also enhances the practical use of geopolymer concrete. The findings are anticipated to make a contribution to the ever-expanding collection of information on eco-efficient building materials. They will provide insights into the ways in which agricultural leftovers, such as rice husk, might be put to use in the development of next-generation binders for infrastructure applications.

For nations in which rice farming is a significant source of income, the use of agricultural leftovers like rice husk represents not only an ecologically acceptable practice but also an economically strategic one.

Every year, millions of tonnes of rice husk are produced across the world; a significant portion of this material is either thrown away or burnt inefficiently, which results in contamination of the environment. The conversion of this trash into a high-value resource for the building sector provides two advantages: minimisation of waste and increased efficiency of resources. Silica that is obtained from rice husk has a high degree of pozzolanic activity when it is handled in the proper manner. This allows it to successfully engage in geopolymerization processes, which makes it an excellent option for use in the synthesis of activators. The production of hybrid activators from rice husk is a major improvement over methods that are more traditional. Although sodium hydroxide and commercially available sodium silicate are good activators, they make a significant contribution to the overall cost and embodied energy of geopolymer concrete. A rice husk-derived hybrid activator, on the other hand, not only cuts material prices but also lessens the need on industrial chemicals. This change might make geopolymer technology more accessible in underdeveloped nations, where the availability of raw materials and pricing are important considerations.

Aside from the advantages of increased sustainability, another essential characteristic of hybrid activator systems is the enhancement of performance. When rice husk ash (RHA) is utilised as a source of silica, it interacts with precursors that are high in alumina, such as fly ash and slag, in order to generate additional calcium–alumino–silicate–hydrate (C–A–S–H) and sodium–alumino–silicate–hydrate (N–A–S–H) gel phases. It is the role of these gels to increase the densification of the geopolymer matrix, which in turn improves the compressive strength, durability, and resistance to harsh conditions, such as exposure to acid and sulphate. As a result, hybrid geopolymer systems have the potential to outperform traditional systems that are based on ordinary Portland cement (OPC) in terms of long-term durability, which is an essential need for infrastructure that is exposed to extreme environmental conditions.

In spite of these potential benefits, there are still a number of scientific hurdles that have yet to be overcome. The diversity in the quality of rice husk ash, which is dependent on combustion settings, the effectiveness of silica extraction, and the reactivity of bio-derived activators, presents obstacles to standardisation and widespread use. Additionally, because to the complicated interaction that exists between hybrid activators and various precursors, a systematic analysis is necessary in order to optimise the curing parameters, molarity, and activator composition. Inconsistencies in the mechanical and durability performance of this material may prevent its practical acceptability in mainstream construction, particularly if optimisation is not applied.

Historical background and foundational concepts

Ultrasonic velocity was shown to be a feasible and instructive probe for studies of the liquid state during the course of early investigations. Pioneering research have elucidated the relationship between the compressibility and density of a medium and the velocity of ultrasonic waves, as well as the manner in which experimental data reveal the presence of deviations from perfect mixing behaviour in the form of excess parameters. In the field of ultrasonic research, the ideas of intermolecular free length and adiabatic compressibility were formalised and established as standard derived values. These fundamental principles provided the groundwork for further theoretical and empirical research endeavours that were focused on determining the connection between interactions at the molecular level and acoustic data.

Key derived parameters and their interpretations

Adiabatic compressibility (βa): determined using the relationship βa = 1/(u^2ρ), where u represents the ul trasonic velocity and ρ represents the density. A change in the value of βa with composition is suggestive of a change in elastic characteristics that is related to molecular interactions; a reduction in the value of βa is often an indication of greater attractive contacts and stiffer local environments.

Intermolecular free length (Lf): Related to βa and frequently interpreted using models that connect free length to molecule packing and interaction strength. In general, shorter free lengths indicate that the packing is tighter or that there are greater affinities between species.

Acoustic impedance (Z): Z = uρ; it is helpful in identifying rapid changes in mixture characteristics and is frequently employed in applications other than purely academic ones (for example, material characterisation).

Internal pressure and energy of activation for viscous flow: derived from measurements of viscosity, density, and ultrasonic velocity that were taken in conjunction with one another. The cohesion of forces as well as the ease with which molecules can move are both elucidated by these factors.

Excess functions (e.g., excess molar volume VE, excess compressibility βE, excess acoustic parameters): When excess parameters are taken into account, the divergence from ideal mixing is quantified. The sign and magnitude of these parameters are indicative of whether interactions are diluting or associative in nature.

Theoretical and semi-empirical models

A number of different models have been utilised by researchers to analyse ultrasonic and associated thermodynamic data:

Nomoto's relation: A semi-empirical method that makes the assumption of optimal mixing of elastic characteristics in order to forecast the ultrasonic velocity of mixtures When it comes to non-ideal interactions, variations from the forecasts made by Nomoto are taken as proof.

Jukes/Junjie/Tanaka-style mixing rules: In order to take into account the molar contributions to compressibility and velocity, there are a number of different mixing rules, some of which are named after authors in particular domains. It is common practice to compare them to values that have been observed in order to find non-ideal behaviour.

Free volume and hole theory approaches: These notions are related to free volume (or free length) and give a mechanical description of how changes in ultrasonic parameters are associated with variations in composition and temperature. They also explain the relationship between molecular mobility and viscosity.

Statistical thermodynamic formalisms: In the cases where it is applicable, more stringent methods that are based on perturbation theories or lattice models have been applied in order to establish a link between microscopic interaction potentials and macroscopic thermodynamic and acoustic observables.

Representative experimental studies and systems

Ultrasonic methods have been utilised to investigate a diverse range of systems that are made up of two components. Important topics to address include:

Alcohol + hydrocarbon mixtures: A large number of classical investigations looked into the combination of alkanes or aromatic hydrocarbons with short-chain alcohols. Negative surplus volumes and variations in ultrasonic velocity are frequently seen in these systems; these deviations can be attributed to the presence of hydrogen bonding and particular solute–solvent structure.

Polar–polar mixtures: It is common for combinations such as alcohols with ketones, esters, nitriles, or aprotic polar solvents to exhibit complicated behaviour. Trends in velocity and the metrics that are derived from it demonstrate a lack of linearity due to the presence of hydrogen-bond acceptor/donor roles and dipolar interactions. These factors are depending on the composition.

Ionic or ion-dipole systems: It is common for mixtures that include ionic species or strong dipoles to exhibit significant variations in compressibility and internal pressure, which are often indicative of strong solvation shells or ion pairing.

Polymer solutions and associating liquids: In order to investigate the interactions between polymers and solvents, as well as the association and dissociation equilibria in complicated fluids, ultrasonic techniques have been developed. Acoustic characteristics continue to give valuable information, despite the fact that interpretation might be more challenging as a result of polydispersity and chain dynamics.

Typical findings and interpretive patterns

Across numerous studies, certain consistent patterns emerge:

Sign of excess parameters: In many cases, negative excess molar volumes and compressibilities are related with strong associative contacts (for example, hydrogen bonding), which lead to tighter packing. On the other hand, positive values may suggest structural disruption or volume expansion caused by inadequate packing or a steric mismatch.

Temperature dependence: In general, an increase in temperature decreases associative contacts, such as hydrogen bonds. This results in changes in ultrasonic velocity that are indicative of an increased free length, higher compressibility, and lower acoustic impedance.

Composition dependence: Composition that is not linear The characteristic that defines non-ideal behaviour is the dependency between the functions of the velocity and the excess. The stoichiometry of association or preferred solvation can be deduced from the position and amplitude of the extrema in excess functions.

Correlations with viscosity and density: The interpretative power is improved when measurements of viscosity and density are combined with ultrasonic data. An increase in viscosity in combination with a reduction in compressibility, for example, frequently indicates higher intermolecular interaction and a smaller free volume.

Materials used

Fly ash

Thermal power plants utilise coal as a fuel in order to generate energy. After it has been used, the substance that remains is referred to as fly ash (F.A). Calcium oxide (CaO) concentration of less than ten percent is employed in this study. The calcium oxide content of Class F-F.A. is low. The location from where the material was gathered was the thermal power plant in Rajpura, Punjab. The physical and chemical parameters of the F.A are presented in Tables 1 and 2, respectively. Figure 1 displays the picture of the sample in question.

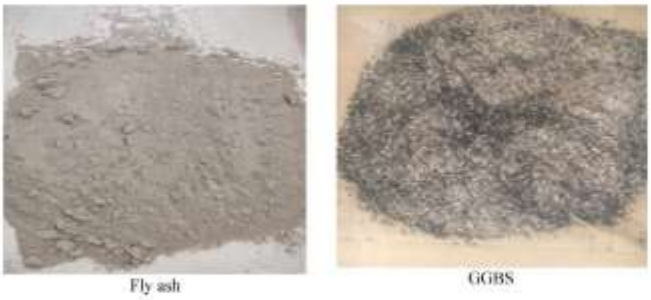

Fig. 1. Sample images of fly ash and GGBS.

Ground granulated blast furnace slag

The iron production business produces a by-product called ground granulated blast furnace slag (GGBFS). Iron ore, coke and limestone are combined in a furnace and heated to a temperature of 1500 degrees Celsius in order to produce molten iron. The molten slag, which is abundant in silica, alumina, and calcium oxide, floats on the surface of the liquid iron. This phenomenon occurs because the molten slag is lighter in weight than the molten iron. The slag is cooled by high-pressure water jets, and the quick cooling process results in the formation of granular particles of slag. Additionally, the slag is subjected to a process of drying and subsequently pulverised into a fine powder. The addition of GGBFS to geopolymer concrete results in a fast setting time and an increased strength accomplishment, generating concrete that is appropriate for curing in ambient conditions. The highest strength is attained when geopolymer concrete contains 40–50 percent ground granulated blast furnace slag (GGBFS) [16,17]. This study employed 40 percent granulated ground granulated blast furnace slag (GGBFS), which was obtained from Nanopar Tech, Chandigarh. The physical attributes and chemical composition of GGBFS are shown in Tables 3 and 4, respectively. Figure 1 displays the sample's picture.

Rice husk ash

Rice husk ash (RHA) is a by-product of paddy, which is produced around the world as a staple diet, as rice is a food that is consumed globally. When growing rice in fields, it is necessary to provide the rice with the appropriate amount of water and temperature. After harvesting, the rice paddy is subjected to a process in which the outer husk, which comprises around 25% of the rice paddy, is removed. This husk is likewise composed of cellulose and is most often burned at either a local power plant or on the field itself. When burned, around twenty percent of these husks generate ash. Consequently, approximately 45 to 50 kilogrammes of rice husk ash (RHA) will be produced as a result of the processing of one tonne of rice. Silica makes up more than 90 percent of rice husk ash, which has pozzolanic characteristics and an effective surface area. The temperature at which the husk is burned during the process of producing rice husk ash determines the amount of rice husk ash that is generated and whether the ash is amorphous or crystalline. If the temperature is high, RHA will be crystalline, but if the temperature is low, there will be an increase in carbon content.

Table 1 Physical properties of F.A

Colour Specif	Moisture	Lossofignition	Sulphuricanhydride	ChlorideIon	Chemical	Relativewater	Strengthindex

ic							
gravity	(%)	(%)	(%)	(%)	composition (%)	requirement (%)	(%)
grey 2.2	<0.1	1.10	0.1	0.00	91.30	94.00	102.0

Table 2 Chemical composition of F.A.

SiO_2 (%)	CaO (%)	Al_2O_3(%)	Fe_2O_3(%)	SO_3 (%)	MgO (%)	Na_2O (%)	K_2O (%)	SrO (%)	TiO_2 (%)	P_2O_5 (%)	Mn_2O_3(%)	TotalAlkali
51.20	3.50	32.10	9.40	0.10	1.10	0.30	0.50	<0.1	1.80	0.45	0.15	0.60

Table 3 Physical properties of GGBFS.

Specific Gravity	Relative water Requirement(%)	Loss on Ignition(%)	Relative Strength (%)	Temperature Rise	Fineness(passing45mm)(%)
2.78	103.00	0.20	100.00	18.8°	98.00

Table 4 Chemical composition of GGBFS.

CaO(%)	SiO_2(%)	S(%)	SO_3(%)	MgO(%)	Al_2O_3(%)	FeO(%)	MnO(%)	Cl(%)	In soluble residue content(%)
41	31	0.35	2.30	5.40	12.60	0.70	0.10	0.01	0.20

Table 5 Physical properties of RHA.

color	Specific Gravity	Fineness(passing45 mm)
Dark grey	2.13	97.00

RHA used in this study was manufactured in college campus by burning the rice husk. Tables 5 and 6, shows the physical parameters and chemical composition of the RHA respectively. The image of sample is shown in Fig. 2.

Chemical activators

In the current work, mixture NaOH and NA_2SiO_3 as a chemical 0r alkaline activator is used. When NaOH' molarity is increased, it has been revealed that strength and modulus of elasticity have been increased [20] and setting time has been decreased due to rise in pH of geopolymer concrete [21–25]. 200 kg/m3 of alkaline activator solution was used in the study to carry out the analyses. In which 80 kg/m3 of NaOH is used, and 120 kg/m3 of Na_2SiO_3 is used as an alkaline activator. The proportion of Na_2SiO_3 to NaOH was kept as 1.5, and the molarity of NaOH was kept as 16 M. the density of NaOH was 1.451 g/cc, and the density of Na_2SiO_3 was 1.34 g/cc. Mass of water in NaOH was 43.6 kg/m3 , and the mass of water in Na_2SiO_3 was 78.6 kg/m3 , then the total mass of water was 122.2 kg/m3 .

Table 6 Chemical composition of RHA.

SiO2(%)	Al2O3(%)	Fe2O3(%)	SO3(%)	CaO(%)	Na2O(%)	LOI(%)	Others(%)
91.5	0.15	0.06	1.29	0.48	0.27	3.1	3.15

Table 7 Physical properties of fine aggregate.

Water absorption	Specific gravity of fine aggregate	Free moisture content	Fineness modulus
0.166	2.59	2%	3.102

Table 8 Physical properties of coarse aggregate.

Water absorption	Specific gravity	Free moisture content	Fineness modulus
1	2.66	0.0%	2.67

Fine aggregates

Locally available sand confirming to zone III was used in this study. The fine aggregate used was organic material free, silt free, and debris free. There was not any kind of bulking of sand as moisture content was less than 5%. Table 7 shows the physical properties of the fine aggregates.

Coarse aggregates

Coarse aggregates are said to be inert materials. Crushed stones or gravels having a size greater than 4.75 mm are classified as coarse aggregates. In this study, 20 mm aggregates were used. Table 8 shows the physical properties of aggregates.

Fig. 2. Sample images of RHA.

Fig. 3. Sample image of coconut fibres.

Super plasticizer

New geopolymer concrete can benefit from the use of high-quality, water-reducing naphthalene-based super plasticisers to improve its workability. Strengthening the material is another benefit of using a superplasticizer. The use of a super plasticiser lowers the geopolymer concrete's risk of segregation. A standard set is the outcome of an overdose. It leaves a smooth finish and won't harm fibre reinforcement because it doesn't include chloride. You could also employ other kinds of super plasticisers. One percent of the binder material, or four kilogrammes per cubic metre, was Super Plasticiser A, also known as Naphthalene Formaldehyde Condensate, in this study.

Coconut fibre

Natural fibres, which are readily accessible, can be utilised as concrete fibre reinforcement. These fibres are inexpensive, have low density, and are resistant and ductile when compared to other natural fibres. These fibres are highly effective in the production of insulating walls and concrete constructions that weigh relatively little. Figure 3 displays the photograph of the specimen in question.

Source material

The blend of fly ash, GGBFS, and RHA that is employed as the source material in this case is in different proportions, such as 30, 40, and 30 percent, respectively. The chemical makeup of the raw material is displayed in Table 9.

Specimen preparation

To begin, a mixture of NaOH and Na2SiO3 was created and then dissolved in distilled water. After that, measured amounts of raw materials—namely, fly ash (F.A), rice husk ash (RHA), ground granulated blast furnace slag (GGBFS), and coconut fibers—are combined into the NaOH and Na2-SiO3 solution and stirred until the mixes have a consistent appearance. The mixes were cast into moulds and cured for a period of 48 hours in sunshine. Following this, they were demolded and cured under ambient curing conditions with regular supply water. Prior to the testing phase, the specimens underwent a continuous curing process. After an interval of seven days and twenty-eight days, testing was performed. Tables 10 and 11 provide the mix design and mix IDs, respectively. In this context, the letter "M" represents the hybrid geopolymer mix HG, while the numbers 0, 1, 2, 3, 4, 5, and 6 indicate the proportion of coconut fibre as a percentage (by weight) of the binder material.

Results and discussion

Compressive strength

The universal testing equipment located in the concrete technology lab at DCRUST, Murthal, was used to carry out the compressive strength test on the moulds, which measured 150 by 150 by 150 millimetres. The ultimate loads were recorded, and the compressive strength of each mould was determined by the load per unit area of the specimen, following the guidelines of IS 516: 1959. For regular concrete, the compressive strength is tested after seven and twenty-eight days, since 65 and 100 percent of the strength is created after this time, respectively. since a result, the strength of the concrete after seven and twenty-eight days has been examined. Figure 4 displays a depiction of the Universal Transverse Mercator (UTM) projection. As can be seen in Fig. 5, the compressive strength of the sample after seven days of incubation ranges from 19.87 to 22.12 megapascals (Mpa), whereas the compressive strength of the sample after twenty-eight days of incubation ranges from 29.91 to 36.89 megapascals (Mpa). The highest compressive strength is 24.11 Mpa for seven days and 39.33 Mpa for twenty-eight days, and it is achieved with mix MHG2. The fluctuation in compressive strength that is seen might be attributed to the quantity of coconut fibre that is present in the

Table 9 Chemical composition of source material.

CaO(%)	SiO2(%)	Al2O3(%)	Fe2O3(%)	SO3(%)	MgO(%)	Na2O(%)	MnO(%)
17.594	55.21	14.445	2.838	1.526	2.49	0.09	0.121

Table 10 Mix Ids of hybrid concrete.

Mix Id	MHG0	MHG1	MHG2	MHG3	MHG4	MHG5	MHG6
Coconut fibres(%)	0	0.1	0.2	0.3	0.4	0.5	0.6

Table 11 Mix design of geopolymer concrete with coconut fibre.

Mix	AAS(kg/m3)	F.A(kg/m3)	RHA(kg/m3)	GGBS(kg/m)	NaOH(kg/m)	Na2SiO3 (kg/m3)	Coconut fiber(kg/m3)	Fine agg.	Coarseagg.	S.P(kg/m)
MHG0	200	120	120	160	80	120	0.00	432.20	1331.66	4
MHG1	200	119.88	119.88	159.84	80	120	0.4	432.20	1331.66	4
MHG2	200	119.76	119.76	159.68	80	120	0.8	432.20	1331.66	4
MHG3	200	119.64	119.64	159.52	80	120	1.2	432.20	1331.66	4
MHG4	200	119.52	119.52	159.36	80	120	1.6	432.20	1331.66	4

MHG5	200	119.40	119.40	159.2	80	120	2.0	432.20	1331.66	4
MHG6	200	119.28	119.28	159.04	80	120	2.4	432.20	1331.66	4

Fig. 4. Image of UTM.

Mingle or blend together. The amount of coconut fibre in mix MHG2 is equal to 0.2% of the binder material content in the mix, or 0.8 kilogrammes per cubic metre of concrete. The mixes MHG5 and MHG6, which were each supplied with 2 kilogrammes of coconut fibre per cubic metre and 2.4 kilogrammes of coconut fibre per cubic metre, respectively, exhibited a significant reduction in compressive strength. Mix M30 s compressive strength was found to be higher than that of mix MHG0, which is a control mix. The compressive strength of mix MHG0 was 22.0 Mpa after seven days and 36.81 Mpa after twenty-eight days. The mix MHG3 was given with a coconut fibre concentration of 1.2 kilogrammes per cubic metre. When the fibre content of geopolymer concrete was 1.6 kg/m3, the compressive strength of mix MHG4 exhibited a little reduction compared to the control mix at seven days, with a compressive strength of 29.04 Mpa, and at twenty-eight days, with a compressive strength of 35.82 Mpa.

Flexural strength

The flexural strength test was carried out at the concrete technology lab at DCRUST Murthal using a universal testing equipment on the moulds, which measured 150 by 150 by 700 millimetres. The testing was carried out in accordance with the guidelines outlined in IS 516:1964. Flexural strength at seven days is shown in Fig. 6 to range from 3.21 to 2.71 Mpa, while flexural strength after twenty-eight days is shown to range from 5.31 to 4.67 Mpa. The highest flexural strength is seen in mix M2, which is 3.21 megapascals after seven days and 5.31 megapascals after twenty-eight days. The fluctuation that is observed in the flexural strength can be attributed to the amount of coconut fibre that is present in the mixture. The amount of coconut fibre in mix M2 is equal to 0.8 kilogrammes per cubic metre of concrete, or 0.2 percent of the total amount of binder material in the mix. For mix M5 and M6, the flexural strength is shown to have undergone a significant reduction.

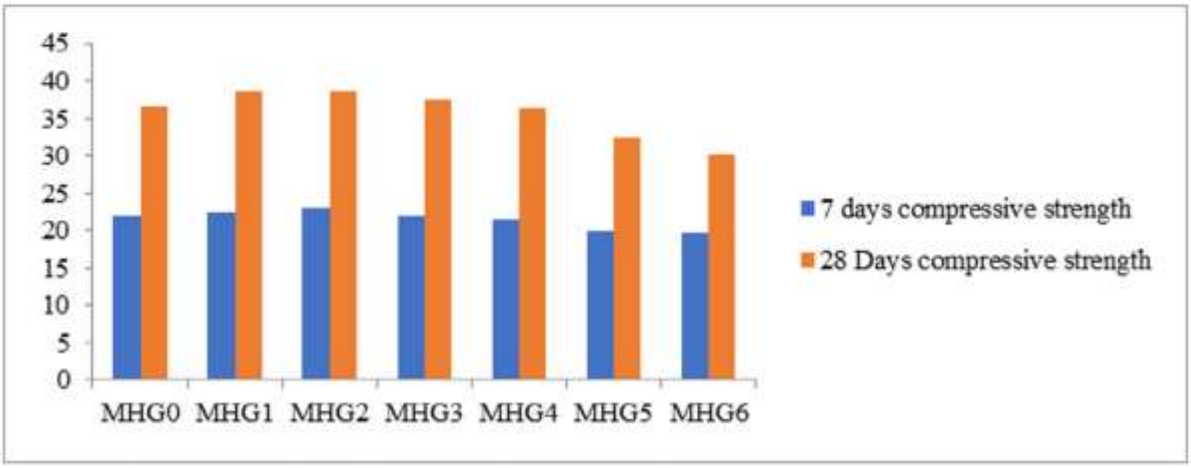

Fig. 5. Compressive strength of concrete made using a hybrid geopolymer.

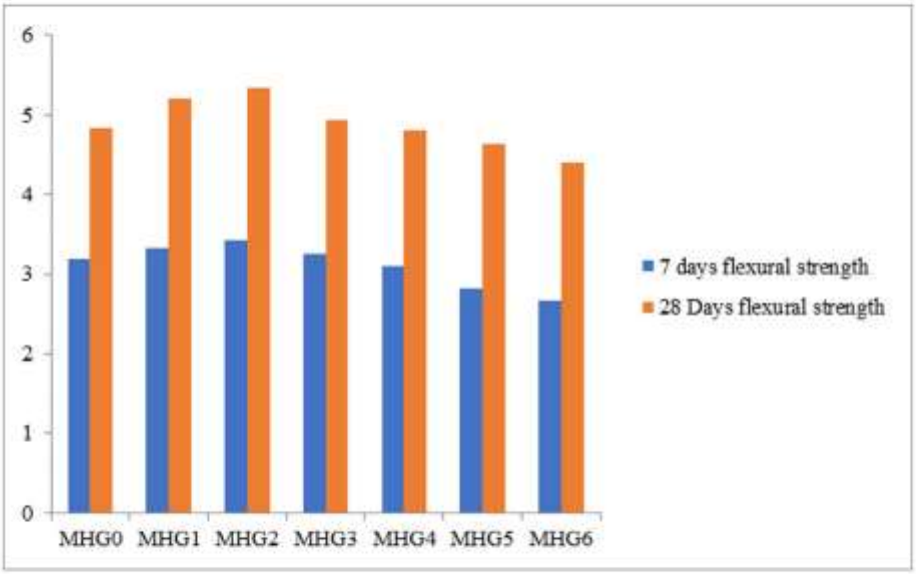

Fig. 6. The flexural strength of hybrid geopolymer concrete.

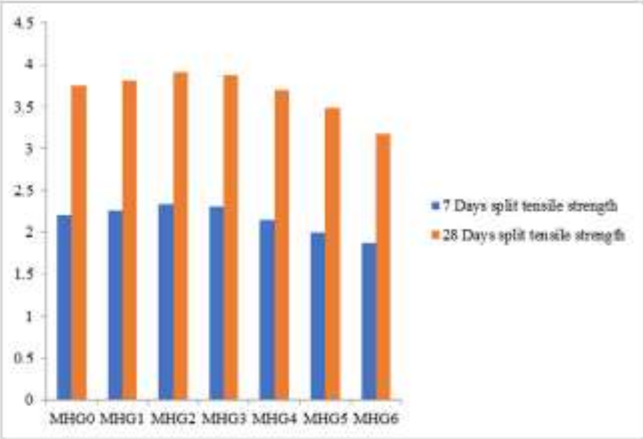

Fig. 7. Hybrid geopolymer concrete's splitting tensile strength.

The coconut fibre had densities of 2 kilogrammes per cubic metre and 2.4 kilogrammes per cubic metre, respectively. When compared to mix M0, which was the control mix, mix M3 had a higher flexural strength. The flexural strength of mix M0 was 3.15 Mpa after seven days and 4.97 Mpa after twenty-eight days. The mixture labelled M3 was found to contain 1.2 kilogrammes of coconut fibre per cubic metre. For mix M4, the flexural strength exhibited a little drop compared to the control mix. The flexural strength was 3.01 MPa for seven days and 4.93 MPa for twenty-eight days, with a fibre content of 1.6 kg/m3 of geopolymer concrete.

Split tensile strength

The split tensile strength test was carried out according to the specifications of IS 516: 1964 using a universal testing equipment. The moulds used for the test were 150 by 300 millimetres in size. The split tensile strength at seven days is shown in Figure 7 to range from 2.41 to 1.96 megapascals, while the split tensile strength after twenty-eight days ranges from 3.98 to 3.32 megapascals. Mix M2 had the greatest split tensile strength of the mixes, with a strength of 2.41 MPa after seven days and a strength of 3.96 MPa after twenty-eight days. The fluctuation in split strength that is seen in this mixture can be attributed to the amount of coconut fibre that is included in the mixture. The amount of coconut fibre in mix M2 is equal to 0.8 kilogrammes per cubic metre of concrete, or 0.2 percent of the total amount of binder material in the mix. Mixes M5 and M6, which were made with coconut fibre at a concentration of 2 kg/m3 and 2.4 kg/m3, respectively, exhibited a significant reduction in split tensile strength. The split tensile strength of mix M3 was found to be larger than that of mix M0, which served as the control mix, with a split tensile strength of 2.39 Mpa after seven days and 3.94 Mpa after twenty-eight days. The mixture labelled M3 was found to contain 1.2 kilogrammes of coconut fibre per cubic metre. The split tensile strength of mix M4 exhibited a minor reduction compared to control mix 2.05 Mpa for seven days and 3.60 Mpa for twenty-eight days with a fibre content of 1.6 kg/m3 of geopolymer concrete. In the past, the increase in split tensile strength was a result of the ductile character of coconut fibre, but the decline is a consequence of the increased number of voids and the low density of coconut fibre. The high strength qualities of geopolymer concrete can be attributed to the source material's high concentrations of silica, alumina, and calcium oxide, which aided in the formation of aluminosilicate hydrates and C-S-H gel. Pores that were created with the inclusion of coconut fibres were then filled with C-S-H gel, resulting in the production of geopolymer concrete that was more compact. The addition of coconut fibres to geopolymer concrete led to an increase in strength, which was caused by the superior bonding between the fibres and the geopolymer concrete.

Conclusion

As an effective and non-destructive method of inquiry, ultrasonic analysis of binary liquid mixes offers valuable information into the nature of molecular interactions. It does this by providing a means of examining the thermodynamic and acoustical features of the mixtures. By examining ultrasonic velocity in conjunction with density and viscosity, it is possible to analyse critical derived characteristics such as adiabatic compressibility, free length, acoustic impedance, internal pressure, and excess functions with a high degree of sensitivity. It is the presence of composition and temperature changes that underscores the non-ideal behaviour of liquid mixtures, which is controlled by interactions that are complex in nature, including hydrogen bonding, dipole–dipole associations, and dispersive forces. The research examined shows that ultrasonic methods are quite accurate when it comes to establishing correlations between microscopic interactions and macroscopic thermodynamic parameters. The basic tendencies, which include reductions in compressibility indicating greater molecular attractions or positive excess parameters suggesting structural breakdown, serve to substantiate the diagnostic efficacy of acoustical research. Furthermore, the usefulness of these insights is not limited to fundamental chemistry; they also contribute to improvements in chemical engineering, medicines, polymer research, and industrial formulations. In conclusion, ultrasonic velocity measurements are a very useful experimental instrument that may be used to connect theory and practice in the field of solution chemistry. They not only give evidence for interaction processes in binary systems, but they also open up routes for the development of novel materials, the improvement of solvent formulations, and the advancement of multidisciplinary applications where mixtures of liquids play a vital role.

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