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Experimental and FEA analysis on flexural behavior of a ferrocement slab using GGBS and Nano Silica

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ABSTRACT

The principal objective of this study is to investigate the flexural characteristics of ferrocement slabs incorporating geopolymer and to evaluate the most effective composition. Using Carbon Fiber Reinforced Polymer (CFRP) wounded wire mesh, characteristics of Nano silica based geopolymer incorporated ferrocement slab elements have been experimentally examined in detail at both room temperature curing and hot curing at 60 °C. Cement can be replaced in mortar by fly ash, saving on the need for expensive disposal land. GGBS is applied in addition to fly ash to increase strength in room temperature curing. Geopolymer mortar of 1:2 is used for the ferrocement slab. This binder is made up of 25% sodium silicate, 10% sodium hydroxide, and 65% fly ash. By changing the fly ash's weight with GGBS, the percentage was changed by 20%, 40%, 60%, 80%, and 100%. 80% percent GGBS addition is deemed ideal, even though the compressive test results show that the best strength was achieved with 100% GGBS. Nano silica added as 0.5%, 1%, 1.5%, and 2% by weight of binder further enhances the performance of the chosen blend. The strength of the geopolymer mortar increased by about 240% when 1.5% nano silica and 80% GGBS were added.

Keywords: Geopolymer; ferrocement; carbon fibre reinforced polymer; flyash; GGBS.

1. INTRODUCTION

According to studies, the manufacture and use of cement results in the release of roughly 7% of harmful gases into the atmosphere, with the manufacturing of cement accounting for about 5% of all worldwide CO_2 emissions. As a result, the most essential and crucial stage in protecting the environment is study in the field of building. Globally, geopolymers are given greater attention than Portland cement because of their significant reduction in carbon dioxide emissions, excellent chemical and thermal stability, and good adhesive, mechanical strength, and durability properties. Ferrocement is among the structural materials frequently employed for behaviours like impact strength and mechanical characteristics. For the establishment of mechanical behaviour under static and cyclic loading, ferrocement slabs have previously been the subject of extensive investigation. The setting time and mechanical characteristics of Geopolymer paste and mortar based on Ferrochrome slag. Ferrochrome Slag was employed as a raw component in this work for Geopolymer cement with silica modulus of 0.50, 0.60, and 0.70 and four different Na_2O concentrations of 4%, 7%, 10%, and 12% [1]. The setting and strength characteristics of Styrene-Butadiene (SB) latex geopolymer mortar and came to the conclusion that the setting times were achieved at a faster rate of 9 min and 70 min, or less than 30 min and 120 min, at the slag amount of 30 to 50% by the binder volume [2].

Alkali activated materials differ from OPC in terms of microstructure and reaction products, which means that they will have distinct evaluation processes and corrosion mechanisms. It may be made more carbonation resistant by increasing the MgO and activator content of the slag or lowering the calcium content of low calcium fly ash. From the review, it was suggested that CO_2 1% and RH 65 5% be used to obtain trustworthy and typical results. It was also suggested that raw material chemical and physical characteristics be taken into account, and that one should evaluate the longer-term durability properties rather than boosting test values with more concentrated CO_2 or salty solutions in the testing facility [3]. Increases in micro silica element generate a modest increase in initial and final setting time, while increased slag content accelerates setting times. Similar to how the early stages of the reaction were somewhat delayed and the final strength of the primary reaction was reduced owing to the presence of nano-silica. At 3, 7 and 28 days of usual cure ages, adding nano-silica up to

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2% had favourable outcomes, but doing so further revealed adverse effects. On materials with a greater slag/fly ash ratio, low porosity was observed [4, 5].

The mechanical properties of granulated blast furnaces filled with self-cured fly ash bio-geopolymer concrete containing natural sugars such as molasses/palm jaggery/honey, etc., the ambient environment, workability, compressive, spit tensile, and flexural strength were enhanced [6]. By assessing the mechanical and durability performances of alkali activated slag (AAS) mortar made with NH or PH and NS as the alkali activation mixes, 2% and 4% dosage of Nano silica, 5%, 7.5%, and 10% of Silica fume, and 2% and 4% dosage of Nano silica [7]. The ferrocement structural panels and RC beams exhibit greater capacity as compared to load-bearing RC beams and stone panels of the same thickness. Similar to this, brittle failure was only seen in sandstone roof slabs, but ductile failure was practised by the ferrocement roof slab system [8]. In the microstructural investigation, adding super-plasticizer admixture caused the overall consistency of the mixture to drop by around 29–70%. Flexural capacity, malleability index, and energy absorption all vary as the fractional mesh volume is increased. This results in a diversity of cracks, but the length and width of the cracks are reduced [9]. Based on the static and dynamic load behavior, it was possible to create a higher and lower reinforcement layer using varied rubber to metal ratios, RCMs of entirely variable thickness, and connective shears [10].

The flexural behaviour of ferrocement slab panels constructed of bamboo with fly ash. It was shown via experimentation that utilizing this sort of slab for unreachable roofing on affordable homes allowed for loads that were twice as much as the first fracture load and showed improved ductility before failure [11]. The study focuses on the flexural performance of ferrocement beams with lightweight cores and various types of mesh reinforcement. The cores are constructed from autoclaved aerated lightweight bricks, extruded foam, and lightweight concrete, and they are strengthened with expanded metal mesh [12]. To determine the optimal number of layers required for various composites, tensile tests were conducted initially on GFRP, CFRP, and ferrocement. The results revealed that, for the chosen composite constituents, one layer of CFRP was equivalent to three layers of GFRP and five layers of wire mesh reinforcement in ferrocement [13]. The research explored the influence of the reinforcement ratio and mortar strength, and an analytical model was developed to predict cracking and ultimate moment in reinforced stone slabs. In its natural state, the strengthened specimen exhibited sudden and brittle failure [14]. The study also considered the impact of fly ash content, micro silica addition, activator particle size, binder content, water-to-binder ratio, and curing conditions on the hardening and pore refinement of the mixtures. The adoption of a one-part synthesis method was identified as a potential enhancement in geopolymer production, promoting safety and efficiency [15]. Load-deflection behavior, failure modes, energy absorption capacity, displacement ductility, and curvature ductility were compared across various composites and at different levels of distress for each composite. The findings indicated that ferrocement outperformed other FRPs in terms of ductility, with GFRP displaying superior ductility compared to its CFRP counterpart within the FRP category [16]. The study incorporated fly ash with a total reactive content of approximately 68.80%, closely aligning with the amorphous content (66.28%) determined through quantitative XRD and XRF analysis [17]. Various ratios were examined, including water/solid, alkaline activator/fly ash, Na_2SiO_3/NaOH, and NaOH molarity, aiming to achieve targeted compressive strengths ranging from 30 MPa to 55 MPa at 28 days in laboratory experiments. This was achieved through the proposed MARS mix design methodology [18].

Geopolymers, despite their high alkali content, exhibited greater resistance to Alkali-Silica Reaction (ASR) compared to Ordinary Portland Cement (OPC). Furthermore, the geopolymer specimens showed no distinctive swelling or significant loss of rigidity [19]. Because of the IFA addition, gel formation was slowed, resulting in a loss in compression performance of the alkali activated GGBS-IFA binding material. On 60% substitution of GGBS by IFA, a moderate compressive strength of 17 MPa was produced; similarly, it efficiently restrains heavy metals [20]. microstructure study, the amount of chemically bound water rises with the addition of nano-silica, but the gel structure stays stable regardless of the nano-silica and slag/fly ash ratio. Based on workability tests, it was discovered that using nano silica reduces slump value and lowers slag and fly ash mixed ratios, demonstrating greater flow abilities [21]. Based on the literature survey and my preliminary research work I have found the optimum percentage for the flyash, GGBS, sodium silicate and sodium hydroxide. I have not incorporated those results in this article.

2. MATERIALS AND METHODS

The first step of the study started with a material characteristics examination, the design of the mortar mix, and a preliminary analysis of the strength properties of mortar made using silicates and sodium hydroxides [22–23]. This was done in order to choose the ideal mixture needed to achieve the performance objectives and be economical. Finely aggregated materials, sodium silicates, ground granulated blast furnace slag (GGBS), sodium hydroxide, CFRP (carbon fibre reinforced polymer), nano silica, cement, super plasticizer, wire mesh, and fly ash are only a few of the components used in the research. In the context of environmental conditions and their influence on various aspects of daily life, a significant detail is highlighted: the typical room temperature in the local area is approximately 27 °C with a permissible range of variation of ±2 °C. This information holds notable significance as it provides insight into the climatic conditions that people experience regularly within that specific region.

2.1. Sodium silicate

The chemical formula for sodium silicate is Na_2O (SiO_2). It's colourless, and its appearance is a gel-like formation. Sodium silicate has a specific gravity of 1.39 at 20 °C. The major constituent in sodium silicate is H_2O which is 57%; SiO_2 30%; and Na_2O 16%.

2.2. GGBS

The waste material created when producing iron in a blast furnace is known as granulated blast furnace slag. Later, it was turned into a fine powder and used in place of cement to create concrete. To alter the properties of the fly ash-based Geo polymer mortar in this case, GGBS took part as a participant on behalf of the fly ash. The specific gravity of GGBS is 2.89, the bulk density is 1998 kg/m^3 and the fineness is 349 m^2/kg [24–26]

2.3. Sodium hydroxide

The colour of sodium hydroxide is white and has the appearance of pellets; the boiling point is 102 °C for a 40% aqueous solution, the molecular weight is 39.996 g/mol; and the specific gravity is 1.51.

2.4. Carbon Fiber Reinforced Polymer (CFRP)

With a matrix made of polymer resin and reinforcement made of carbon fibre, CFRP is a strong, lightweight polymer and composite material. The composition of CFRP is Pultruded Carbon Fibre laminate with epoxy resin matrix black; the colour is black; the Vf is 70% fibre content; the TGM is 100–125 °C; and the size of CFRP is 150m × 1000 mm × 1.2 mm. The mechanical properties are: ultimate tensile strength is 1860 MPa, Ultimate Elongation is 1.6%, and elastic modulus is 165 GPa [27, 28].

2.5. Nano silica (SiO_2)

They are superior to pozzolanic substances due to the abundance of amorphous silica and the reduction in size of the spherical nanosilica particles of order 5–10 nm. Nanosilica was purchased for this experiment from Astrra Chemicals in Chennai, India. Due to its fineness, the material is readily blown away by the breeze. The colour of nanosilica is white, the form is amorphous, it has an apparent density of 0.3695 g/cm^3, the size of the particle varies from 10 to 20 nm, the silica content is 99.75% on a dry basis, the dispersity (CCl_4) is 98.5%, and it has a free water content of less than or equal to 3%. The selection of a particle size range of 10 to 20 nm signifies a meticulous approach to material synthesis and experimentation. Nanoparticles possess unique properties due to their small size and high surface area-to-volume ratio. By utilizing particles within this specific range, the researchers aim to explore phenomena that arise due to quantum effects and surface interactions, which become increasingly prominent at the nanoscale [29].

2.6. Master Glenium 51

Superplasticizers are chemical additives that are used in this study to lower the water content of concrete mixes. It was produced by BASF Chemicals and is a naphthalene-based superplasticizer called Master Glenium 51. It was produced by BASF Chemicals and is a naphthalene-based superplasticizer called Master Glenium 51. An admixture of a new generation known as Master Glenium 51 is present in modified polycarboxylic ether. The creation of this substance will allow for the excellent performance and longevity of high-performance concrete applications. Master Glenium 51 has low alkali but no chloride; the structure of the material is Polycarboxylic ether-based; the colour of the superplasticizer is amber; a density of 1.080–1.140 kg/litre; a chlorine content of less than 0.1%; and an alkaline content of less than 3%. The choice of polycarboxylicether-based water reducers remains the preferred option for achieving optimal concrete performance. The introduction of Master Glenium 51, a super plasticizer based on modified polycarboxylic ether, marks a significant advancement in construction chemistry, offering a promising solution for enhancing the properties of concrete mixes and contributing to more efficient and eco-friendly construction practices.

2.7. Wire mesh

Welded wire mesh measuring 25 mm × 25 mm is purchased from a nearby steel supplier. Wire mesh was discovered to be 5 mm thick [30].

2.8. Fly ash

The manufacture of the geopolymer mortar uses fly ash, one of the waste products derived from coal-based thermal power plants. The properties for the investigation provided by the corporation that was bought from Mettur thermal power plant have a specific gravity of 1.9 for sub-bituminous ash to 2.95 for bituminous ash, which is rich in iron, the shape and size range between 10 and 100 microns; and the colour is dark grey to black [22, 23].

2.9. Analysing the properties

Studying the properties of materials such as Sodium Silicate, GGBS, Fly Ash, Sodium Hydroxide, Nano Silica, M-Sand, Wire Mesh, and Master Glenium 51. Codal provisions allow for the study and confirmation of both physical and chemical characteristics.

2.10. Mix proposition

This trial mix esign was created with the density of mortar fixed at 2200 kg/m^3. According to ACI standards, the binder to fine aggregate ratio was set at 1:2. Binder material accounted for 737 kg/m^3 of the mortar's total density, whereas M-sand sand made up 1463 kg/m^3. The material geo polymer is selected as the binder. Table 1 provide the components needed for mortar per cubic metre.

3. METHODOLOGY

3.1. Optimization of geopolymer mortar mix

This study employed fly ash as the primary material for geopolymer mortar, entirely replacing traditional cement mortar. For the purpose of modifying the strength and durability attributes, GGBS has been used in place of fly ash in amounts of 20%, 40%, 60%, 80%, and 100% by weight when combined with an alkaline solution. The 50 mm × 50 mm × 50 mm cube specimen was cast with 2% superplasticizer using several binder compositions. Each combination's compression strength for 3, 7, and 28 days was evaluated, and an ideal blend was discovered.

3.2. Casting of ferrocement slab with wire mesh

Nano silica added to a powdered, optimised mixture of GGBS and fly ash in the binder produces cubes and slabs. Nano silica was added as powder in weights of 0.5, 1, 1.5, and 2%. The slabs and cubes undergo ambient curing as well as heat curing. For 24 hours, a hot oven at 60 °C was used for heat curing. On universal testing equipment, the slab's flexural behaviour was evaluated on the 28th day. The article takes a deliberate step in presenting the effective cover of 12mm in the ferrocement slab. This decision not only emphasizes the article's commitment to conveying accurate information but also assists in shedding light on the meticulous planning and engineering that goes into designing structures that are safe, resilient, and capable of withstanding various challenges over their lifespan. This particular. The specific measurement of 30mm serves as a reference point for other researchers, engineers, and professionals who might be interested in replicating or expanding upon the study's findings

3.3. Casting of ferrocement slab with CFRP wound wire mesh

After that, a slab of cement was poured over the wire mesh with CFRP coiled over it in layers of up to four. On the 28th day, universal testing equipment was used to evaluate the cast ferrocement slabs. The deflection and load displayed by the machine were both recorded, and a plot was created. Durability is another key factor that

Table 1: Optimized geo polymer binder with nano silica.

MIX NO	FLY ASH (kg/m^3)	GGBS (kg/m^3)	SODIUM SILICATE (kg/m^3)	SODIUM HYDROXIDE (kg/m^3)	FINE AGGRE-GATE (kg/m^3)	SUPER PLASTI-CIZER (%)	MORTAR RATIO	LIQUID TO POWDER	Na_2SiO_3/NaOH	MOLAR-ITY OF NaOH SOLUTION	% ADDI-TION OF NANO SILICA
GFG 4	92.12	368.49	197.41	78.96	1463	0.4	1:2	0.6	2.5	10 M	0
GFGS1	92.12	368.49	197.41	78.96	1463	0.4	1:2	0.6	2.5	10 M	0.5
GFGS2	92.12	368.49	197.41	78.96	1463	0.4	1:2	0.6	2.5	10 M	1.0
GFGS3	92.12	368.49	197.41	78.96	1463	0.4	1:2	0.6	2.5	10 M	1.5
GFGS4	92.12	368.49	197.41	78.96	1463	0.4	1:2	0.6	2.5	10 M	2.0

propels the use of CFRP. The corrosion-resistant nature of carbon fibers ensures that the composite remains resilient even in harsh environments or when exposed to aggressive chemicals. This longevity contributes to the material's extended service life, reducing maintenance and replacement costs over time.

3.4. Specimen details of ferro cement slabs

To evaluate the deflection parameter in a normal and hot air environment, a total of 40 slabs were cast. Figure 1(a) shows slab mould and 1(b) depicts casting of ferrocement slab, Figure 2 shows after casting of ferrocement slab and followed by reinforcing configurations and slab casting. The size of the specimens is 750 mm × 300 mm × 30 mm, and reinforcement with weld mesh is 25 mm × 25 mm, which has an effective span of 700 mm.

3.5. Curing of ferro cement slabs

The cast specimens are heated to roughly 60 °C and then allowed to cool before being finished curing. Examining and comparing the specimens that were cured under the two environmental conditions The normal room temperature was around 27 °C. From the day of de-moulding until the day of testing, the specimens were subjected to a 24-hour hot air curing period and stored at room temperature. Figure 3 shows the curing of slabs.

Figure 1: Ferrocement slab mould (a) and casting (b).

Figure 2: After casting of ferrocement slabs.

Figure 3: Curing of slabs.

4. RESULTS AND DISCUSSION

The axial strength results for the selected trial mixtures are presented and analysed. Results for cast ferro cement slabs under flexure are also achieved. The axial strength data are presented using graphs, and the readings are displayed in tabular form. Similarly, the load versus deflection curvature is produced to show the flexural behaviour of slabs under external loading.

4.1. Compressive strength test result

The compressive strength of ferro cement mortar for various arriving trial mixes is shown in Figures 4 and 5 under open air curing conditions. Similar to Figures 6 and 7, these show the experimental mixtures under high curing conditions, heated to 60 °C. The chart representations in Figures 4, 5, 6 and 7 are used to make certain judgements. As a result, the specimen with 100% fly ash achieves its ultimate setting time after only 2 days at both regular and hot curing temperatures. However, the use of GGBS reduces the setting time of cement mortar. The strength is improved by replacing 20% of the fly ash with GGBS. After 100% removal of fly ash by GGBS, the maximal strength level is obtained. Under room temperature curing, strength is raised by almost 436% compared to the control specimen, while hot curing increases strength by nearly 118%. Even though 100% of GGBS achieved optimality, some minor fractures may be seen on the cube specimens' surfaces, making them unsuitable for slabs. In comparison to the control specimen, the strength rose to 329% for room temperature curing and 143% for hot curing in the combination containing 80% GGBS and 20% fly ash. The optimised specimen has nano silica added at 0.5, 1, 1.5, and 2% by weight powder concentrations. By adding the weights of GGBS and fly ash, one may calculate the weight of the powder.

4.2. Flexural strength of ferrocement slabs

On the 28th day following the casting process, the ferrocement slabs are subjected to testing. A 400 kN universal testing machine is used for this purpose. The testing procedure entails supporting the slabs with a 25 mm overhang on each end, resulting in an effective span of 700 mm. To apply a single-point load to the slabs, an iron rod is inserted between the loading plate and the slab. By maintaining the LVDT (linear variable differential

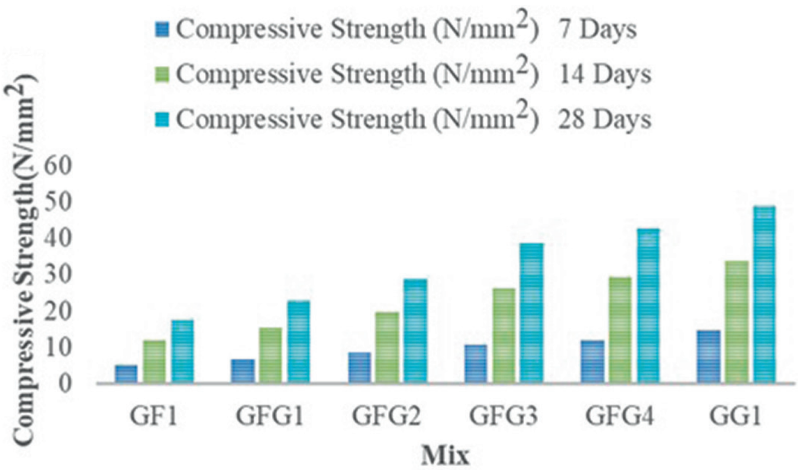

Figure 4: Geo polymer binder-based trial mix with varying fly ash and GGBS content under room temperature.

transformer) below the slabs at mid-span, the deflection is brought down. Along with the deflection, the load shown on the machine is measured and plotted. The flexural performance of the concrete slab was tested by static and cyclic load tests on a slab of size 750 mm by 300 mm by 30 mm. This test is aimed at measuring the load and deflection of the first and ultimate cracks in the slab.

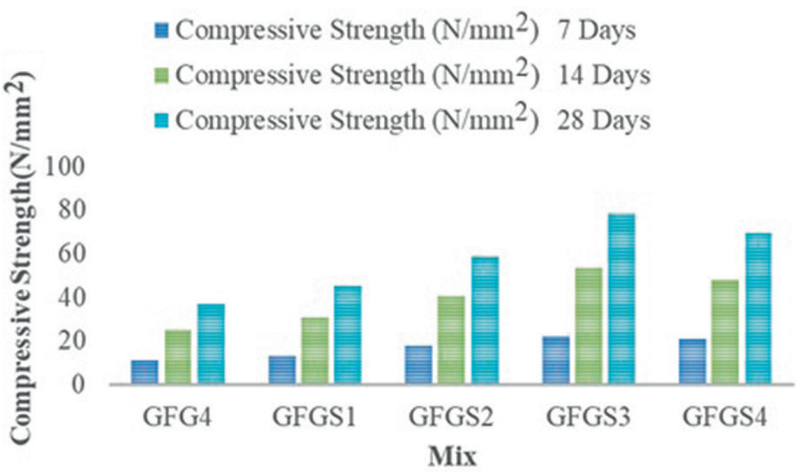

Figure 5: Optimized geo polymer binder with nano silica under room temperature.

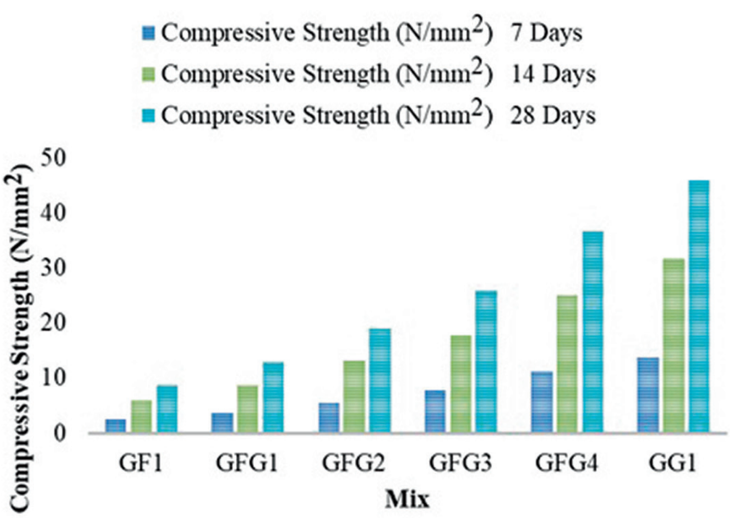

Figure 6: Geo polymer binder-based trial mix with varying fly ash and GGBS content (hot curing).

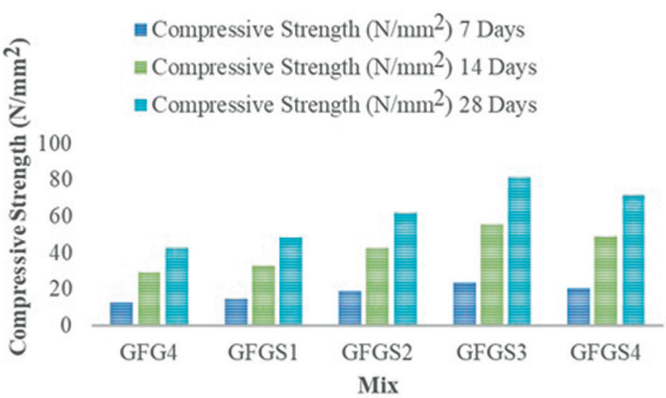

Figure 7: Optimized geo polymer binder with nano silica (hot curing).

4.2.1. Static load test

Loading was applied through a hydraulic jack to reach 0.25 kN, and measurements such as deflections and strains were observed at loading points and the midpoint of the slab. Measurements were recorded at every 0.25 kN load increment. Load deflections were recorded for the initial crack and the ultimate load. The vertical deformation at mid-span and two load points at different load levels were recorded using the deflectometers fixed at the bottom of the slab. Crack patterns were also marked for all loading intervals. This decision is bolstered by the strain gauge's least count of 0.001 mm, highlighting the dedication to accurate and reliable data collection. Such attention to detail showcases the article's commitment to providing valuable insights into the behavior of materials and structures under different load scenarios, enhancing the understanding of their mechanical properties and performance characteristics. Besides, the number of cracks developed, crack spacing, and crack propagation height from the bottom of the beam were also recorded at each load interval. Figures 8 and 9 show the ultimate load and deflection of geoplymer slabs containing flyash and GGBS content curing at room temperature and 600 °C under static load conditions. The choice of placing the static loading at the center is often deliberate, as it allows for a simplified analysis and calculation process. Moreover, this arrangement helps in simulating worst-case scenarios, aiding engineers in designing structures that can safely withstand a range of loading conditions. By thoroughly studying the response of the slab to the central static loading, engineers can make informed decisions about material choices, reinforcement requirements, and overall structural adequacy.

4.2.2. Cyclic load test

Loading was applied through a hydraulic jack in a cyclic pattern, and measurements such as deflections were observed at loading points and the midpoint of the slab. Load deflections were recorded for the ultimate load. The vertical deformation at mid-span and two load points at different load levels were recorded using the deflectometers

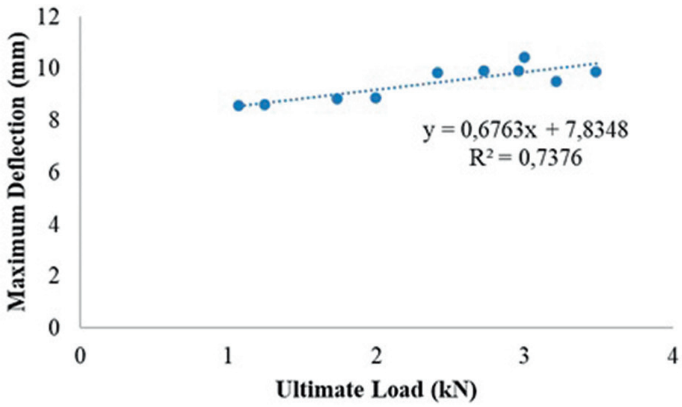

Figure 8: Deflection of ferro cement slab cured in room temperature.

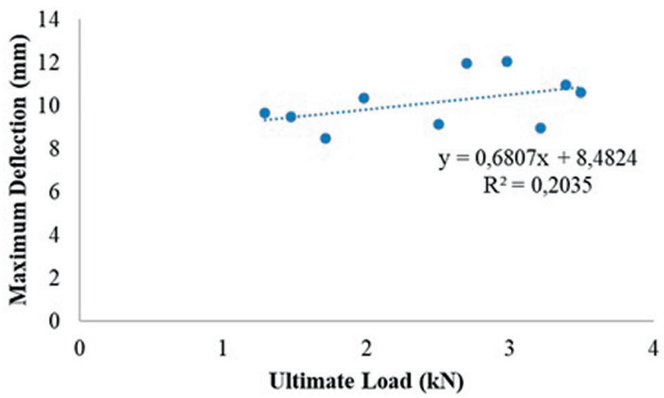

Figure 9: Deflection of ferro cement slab cured at 60°c temperature.

fixed at the bottom of the slab. The strain measurements at different load levels were recorded by a demountable mechanical strain (DEMEC) gauge with the lowest count of 0.001 mm. Crack patterns were also marked for all loading intervals. Besides, the number of cracks developed, crack spacing, and crack propagation height from the bottom of the slab were also recorded at each load interval. Figures 10 and 11 show the ultimate load and deflection of geoplymer slabs containing flyash and GGBS content curing at room temperature and at 60 °C under cyclic load conditions. The decision to employ a load increment of 0.25 kN is likely a well-thought-out strategy aimed at precisely capturing the structural response of the specimen under cyclic loading conditions. Load increments serve to mimic the real-world scenario where external forces are gradually applied and increased, allowing for the observation of the material's behavior, deformation, and potential failure modes at each incremental step. A smaller load increment, such as 0.25 kN, provides a more detailed view of how the material or structure reacts to changing loads, revealing valuable insights that might not be apparent with larger increments.

4.2.3. Ansys

The behaviour of reinforced concrete components in structures subjected to different loading conditions is very important in order to design a safe and functional structure. There are several methods to analyse the behaviour of reinforced concrete structures. Experimentally testing the behaviour is one of the methods, but it consumes much time and involves huge costs. The use of the finite element method has become more popular for its less time-consuming nature and accuracy. The results of the FE analysis must be verified with experimental observations. Numerical research is performed to analyse the geopolymer ferrocement slab element using logical reasoning. The numerical approach for geopolymer ferrocement slabs with static load tests created a great impact in the research field. Static load test and cyclic load test for analysing the behaviour of geopolymer ferrocement slabs with high accuracy from the results, the GFGS3 slab gives superior results compared with other

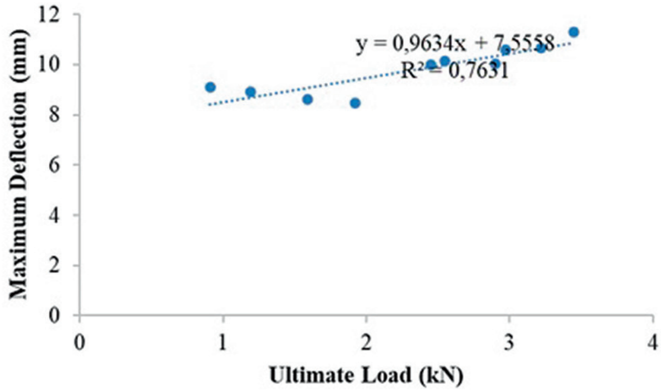

Figure 10: Deflection of ferro cement slab cured in room temperature.

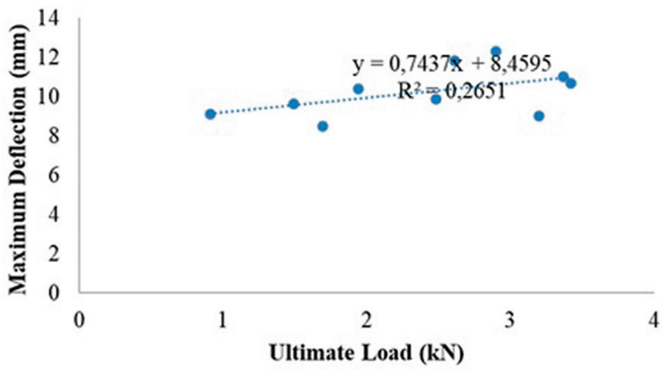

Figure 11: Deflection of ferro cement slab cured at 60 °C temperature.

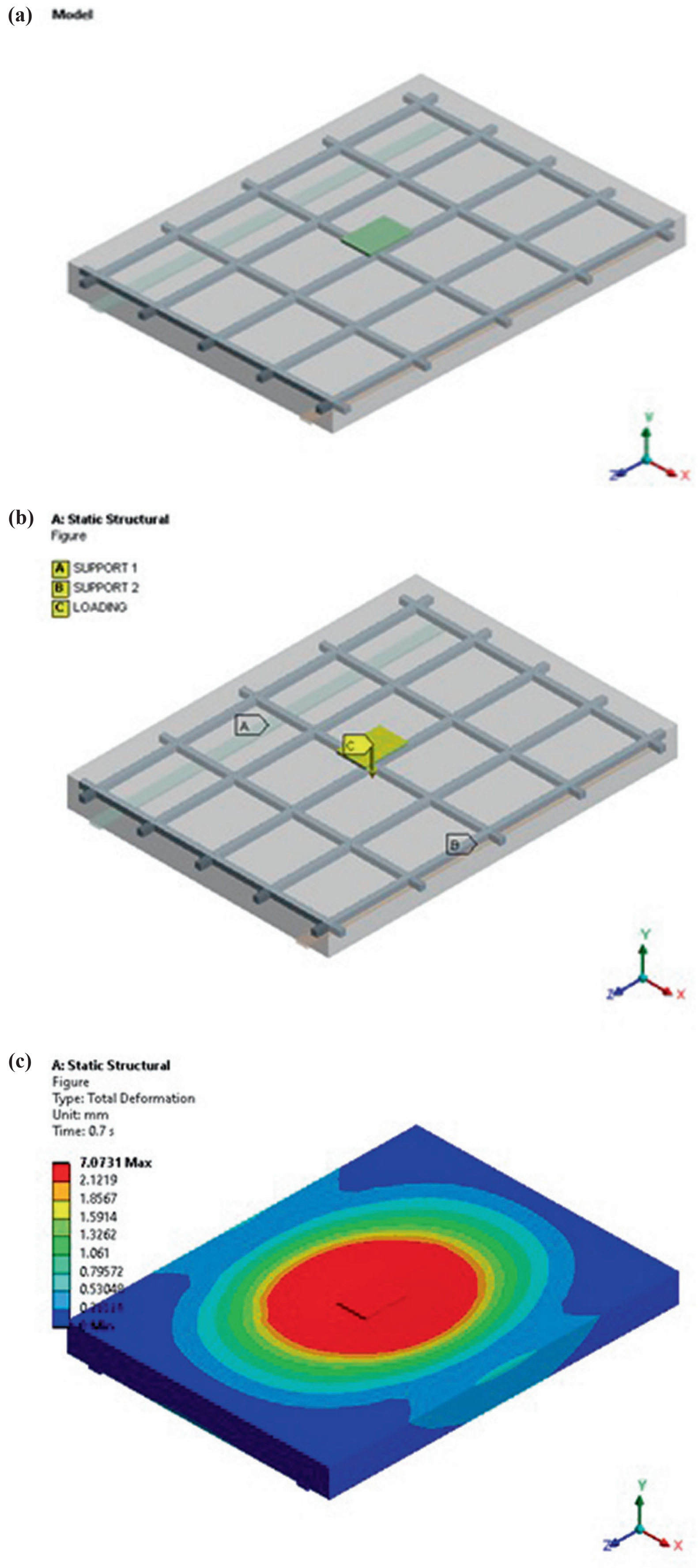

Figure 12: (a) Geometry of the reinforcements, (b) boundary conditions, (c) FEA model for static loading.

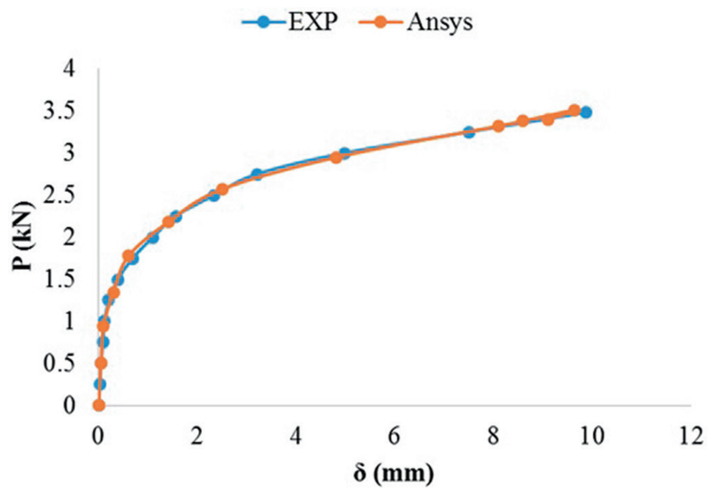

Figure 13: Load vs deflection behavior of GFGS3 – experimentally and ANSYS approach.

mixes. The GFGS3 slab is analysed using ANSYS software to compare the maximum deformation under static loading. The geometry of the reinforcement, the boundary conditions, and the FEA model for static loading are shown in Figures 12(a), (b), and (c). The Comparison of Experimental results with ANSYS-GGFGS3 is shown in Figure 13.

5. CONCLUSIONS

The study's conclusions are detailed as follows:

1) The mix consisting of 80% GGBS and 20% fly ash is identified as the optimized blend, even though 100% GGBS achieved the highest strength. The optimized mix exhibited a strength increase of 329% in open air curing conditions and 143% in hot curing conditions compared to the control specimens. The use of 100% GGBS resulted in some minor surface cracks on the cube specimens, which is not recommended for slabs.
2) The introduction of nanosilica into the mix was observed to effectively reduce the porosity of the mortar specimens. This led to a strength increase of 114% under open curing conditions and 91% under hot curing conditions, compared to the optimized mix with 1.5% nanosilica.
3) Flexural tests have been conducted in static and cyclic methods for both curing at room temperature and hot curing (60 °C). In both static and cyclic tests, room temperature curing is superior to hot curing.
4) By adding nanosilica and GGBS, the curing time has been reduced to a greater extent. The strength of ferrocement geopolymer reaches maximum strength with room temperature curing, which neglects the problem of hot curing.
5) In the static load test, the deflection is lower compared with the cyclic load test. The first crack and the ultimate crack are also less visible in static loading conditions.
6) The flexural result of the GFGS3 comparison with static and ansys is 95% similar, giving the best results at room temperature curing.

6. BIBLIOGRAPHY

[1] KARAKOÇ, M.B., TÜRKMEN, I., MARAŞ, M.M., *et al.*, "Mechanical properties and setting time of ferrochrome slag based geopolymer paste and mortar", *Construction & Building Materials*, v. 72, n. 1, pp. 283–292, 2014. doi: http://dx.doi.org/10.1016/j.conbuildmat.2014.09.021

[2] LEE, N.K., KIM, E.M., LEE, H.K., "Mechanical properties and setting characteristics of geopolymer mortar using styrene-butadiene (SB) latex", *Construction & Building Materials*, v. 113, n. 1, pp. 264–272, 2016. doi: http://dx.doi.org/10.1016/j.conbuildmat.2016.03.055

[3] ZHANG, J., SHI, C., ZHANG, Z., *et al.*, "Durability of alkali-activated materials in aggressive environments: a review on recent studies", *Construction & Building Materials*, v. 152, n. 1, pp. 598–613, 2017. doi: http://dx.doi.org/10.1016/j.conbuildmat.2017.07.027

[4] GAO, X., YU, Q.L., BROUWERS, H.J.H., "Characterization of alkali activated slag-fly ash blends containing nano-silica.", *Construction & Building Materials*, v. 98, n. 1, pp. 397–406, 2015. doi: http://dx.doi.org/10.1016/j.conbuildmat.2015.08.086

[5] NAVEEN ARASU, A., NATARAJAN, M., BALASUNDARAM, N., *et al*., "Utilizing recycled nanomaterials as a partial replacement for cement to create high performance concrete", *Global NEST Journal*, v. 6, n. 25, pp. 89–92, 2023.

[6] KARTHIK, A., SUDALAIMANI, K., KUMAR, C.V., "Investigation on mechanical properties of fly ash-ground granulated blast furnace slag based self-curing biogeopolymer concrete", *Construction & Building Materials*, v. 149, n. 1, pp. 338–349, 2017. doi: http://dx.doi.org/10.1016/j.conbuildmat.2017.05.139

[7] RAMEZANIANPOUR, A.A., MOHAMMAD, A.M., "Mechanical and durability properties of alkali activated slag coating mortars containing nanosilica and silica fume", *Construction & Building Materials*, v. 163, n. 1, pp. 611–621, 2018. doi: http://dx.doi.org/10.1016/j.conbuildmat.2017.12.062

[8] AHMAD, T., ARIF, M., MASOOD, A., "Experimental investigations on ferrocement roof slab system for low-cost housing", *Journal of The Institution of Engineers Series A*, v. 95, n. 1, pp. 9–18, 2014. doi: http://dx.doi.org/10.1007/s40030-014-0066-y

[9] MADADI, A., ESKANDARI-NADDAF, H., SHADNIA, R., *et al*., "Characterization of ferrocement slab panels containing lightweight expanded clay aggregate using digital image correlation technique", *Construction & Building Materials*, v. 180, n. 1, pp. 464–476, 2018. doi: http://dx.doi.org/10.1016/j.conbuildmat.2018.06.024

[10] ABDULLA, A.I., KHATAB, H.R., "Behavior of multilayer composite ferrocement slabs with intermediate rubberized cement mortar layer", *Arabian Journal for Science and Engineering*, v. 39, n. 8, pp. 5929–5941, 2014. doi: http://dx.doi.org/10.1007/s13369-014-1171-y

[11] PASSOS, L., MORENO JUNIOR, A.L., GOMES, C.E.M., "Durability of concrete produced with coarse aggregate from red ceramic waste.", *Matter*, v. 25, n. 2, pp. 1–12, 2020.

[12] JEEVA, C.S., KUMAR, S., "Flexural behaviour of bamboo based ferrocement slab panels with flyash", *Construction & Building Materials*, v. 134, n. 1, pp. 641–648, 2017.

[13] IBRAHIM, G.S., YOUSRY, B.S., ESSAM, L.E., *et al*., "Flexural characteristics of lightweight ferrocement beams with various types of core materials and mesh reinforcement", *Construction & Building Materials*, v. 171, pp. 802–816, 2018. doi: http://dx.doi.org/10.1016/j.conbuildmat.2018.03.167

[14] GANESAN, N., BINDURANI, P., INDIRA, P.V., "Flexural strengthening of RCC beams using FRPs and ferrocement - A comparative study", *Advances in Concrete Construction*, v. 2020, pp. 35–48, 2020.

[15] GUO, Z.X., WANG, L., CHAI, Z.L., *et al*., "Flexural behavior of stone slabs strengthened with reinforced mortar.", *Construction & Building Materials*, v. 144, pp. 158–167, 2017. doi: http://dx.doi.org/10.1016/j.conbuildmat.2017.03.177

[16] ABREU, F.D.S., RIBEIRO, C.C., PINTO, J.D.S., *et al*., "Analysis of epoxy based paint efficiency in expanded clay lightweight concrete protection of sulfuric acid attack.", *Matéria (Rio de Janeiro)*, v. 25, pp. e-12834, 2020. doi: http://dx.doi.org/10.1590/s1517-707620200003.1134

[17] MEERT, R., HASTENPFLUG, D., ANDRADE, J.J.D.O., "Contribution to the use of wet sludge water treatment plant fine aggregate in portland cement concretes: evaluation of consistency, density, porosity, absorption, strength and tensile strength.", *Matéria (Rio de Janeiro)*, v. 26, n. 3, pp. e13025, 2021. doi: http://dx.doi.org/10.1590/s1517-707620210003.13025

[18] DONG, M., ELCHALAKANI, M., KARRECH, A., "Development of high strength one-part geopolymer mortar using sodium metasilicate", *Construction & Building Materials*, v. 236, pp. 117611, 2020. doi: http://dx.doi.org/10.1016/j.conbuildmat.2019.117611

[19] GANESAN, N., BINDURANI, P., INDIRA, P.V., "Flexural strengthening of RCC beams using FRPs and ferrocement - A comparative study", *Advances in Concrete Construction*, v. 2020, pp. 35–48, 2020.

[20] KRISHNAN, U., AMBIKAKUMARI, S., MUKUND, L., *et al*., "Investigating the potential reactivity of fly ash for geopolymerization", *Construction & Building Materials*, v. 225, pp. 283–291, 2019. doi: http://dx.doi.org/10.1016/j.conbuildmat.2019.07.140

[21] LOKUGE, W., WILSON, A., GUNASEKARA, C., *et al*., "Design of fly ash geopolymer concrete mix proportions using Multivariate Adaptive Regression Spline model.", *Construction & Building Materials*, v. 166, pp. 472–481, 2018. doi: http://dx.doi.org/10.1016/j.conbuildmat.2018.01.175

[22] MAHMOOD, N.M., MAJEED, S.A., "Flexural behavior of flat and folded ferrocement panels", *Al-Rafidain Engineering*, v. 17, n. 4, pp. 1–11, 2009.

[23] LIU, Y., ZHU, W., YANG, E.-H., "Alkali-activated ground granulated blast-furnace slag incorporating incinerator fly ash as a potential binder.", *Construction & Building Materials*, v. 112, n. 1, pp. 1005–1012, 2016. doi: http://dx.doi.org/10.1016/j.conbuildmat.2016.02.153

[24] HADI, M.N., FARHAN, N.A., SHEIKH, M.N., "Design of geopolymer concrete with GGBFS at ambient curing condition using Taguchi method.", *Construction & Building Materials*, v. 140, pp. 424–431, 2017. doi: http://dx.doi.org/10.1016/j.conbuildmat.2017.02.131

[25] NAVEEN ARASU, A., NATARAJAN, M., BALASUNDARAM, N., *et al*., "Optimization of jigh performance concrete composites b using nano materials", *Research on Engineering Structures and Materials*, 2023.

[26] ARASU, N., ROBINSON, J., "Experimental analysis of waste foundry sand in partial replacement of fine aggregate in concrete.", *International Journal of Chemtech Research*, v. 10, n. 8, pp. 605–622, 2017.

[27] THIRUKUMARAN, T., KRISHNAPRIYA, S., PRIYA, V., *et al*., "Utilizing rice husk ash as a bio-waste material in geopolymer composites with aluminium oxide.", *Global NEST Journal*, v. 25, n. 6, pp. 119–129, 2023. doi: http://dx.doi.org/10.30955/gnj.004694

[28] VERAPATHRAN, M., VIVEK, S., ARUNKUMAR, G.E., "Flexural behaviour of HPC beams with steel slag aggregate", *Journal of Ceramic Processing Research*, v. 24, n. 1, pp. 89–97, 2023.

[29] SURESHBABU, Y., GANESHAN, P., RAJA, K., *et al*., "Performance and emissions parameters optimization of thermal barrier coated engine tested with Tamanu blended diesel fuel: a novel emission pollution-preventive approach.", *Global NEST Journal*, v. 25, n. 3, pp. 78–86, 2023.

[30] PUFAL, K.M., SAVARIS, G., BALESTRA, C.E.T., *et al*., "Evaluation of direct shear strength of self-consolidating and conventional concretes.", *Matéria (Rio de Janeiro)*, v. 26, n. 3, pp. 26, 2021. doi: http://dx.doi.org/10.1590/s1517-707620210003.13036