PREDICTION OF COMPRESSIVE STRENGTH OF GEOPOLYMER CONCRETE USING DEEP LEARNING TECHNIQUES

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ABSTRACT

The prediction of compressive strength in geopolymer concrete is a critical aspect of optimizing construction materials for sustainable and durable infrastructure. In present study artificial neural networks is employed to forecast the compressive strength of geopolymer concrete. Geopolymer concrete, an ecofriendly alternative to traditional Portland cement-based concrete, poses challenges in predicting its compressive strength due to its complex composition. ANNs are employed as a powerful tool to model the intricate relationships between various input parameters such as mix design, curing conditions, and curing time, and the resulting compressive strength. The study involves collecting a comprehensive data set of geopolymer concrete mixtures and their corresponding compressive strengths, followed by training the ANN model. The model's performance is evaluated and finetuned to ensure accurate predictions. This research aims to enhance our understanding of geopolymer concrete behaviour and provide a practical tool for engineers and construction professionals to optimize mix designs, and enhance sustainability by mixing over-engineering. The utilization of ANNs demonstrates their potential as a valuable predictive tool for optimizing geopolymer concrete formulations, ultimately contributing to more sustainable and resilient infrastructure.

Keywords: Geopolymer, ANNs (Artificial Neural Network), Compressive strength.

1. Introduction

Cement stands as the prevailing binder in the construction sector recognizing for its widespread use. However, it falls into the category of high energy intensive product emitting carbon dioxide ($CO2$) into the atmosphere throughout its manufacturing process. On the production of your polymer concrete, employing fly ash as exclusive binder and incorporating $NaOH$ and $NA2SIO3$ in the alkaline activator solutions. The primary objective is to comprehend the influence of diverse total aggregate content percentage and varying molar concentration of NaOH solution on the compressive strength of geopolymer concrete derived from fly ash through systematic experimentations, the research seeks to establish correlations between these key variables and the resulting material strength. Moreover, to explore the impact of different curing temperatures with within a range of 60°C to 100°C degrees Celsius with intervals of 10°C, accompanied by a critical resting period of 24 hours.[1]. According to Rai [2], Prolonging the curing duration exhibits a positive correlation with comprehensive strength, yet the incremental gain plateau after 48 hours. geopolymer concrete is a new kind of material that doesn't need regular cement (like OPC), presents promising prospects for applications in marine structures, recast items, and repair materials the research recognize the impact of curing temperature, molarity, activated to fly as ratio and delay time on the comprehensive strength of geo polymer concrete shedding light on crucial factors influencing its structural performance. The amount of super plasticizer and the strength of the alkaline solution affects how easy it is to work with the concrete, how strong it becomes, and its microscopic structure. The researchers looked into the workability, strength, and durability of self-compacting concrete when the replace regular cement will fly ash, testing variation of up to 35% and 80% respectively. The finding indicates that self-compacting concrete containing fly ash not only improved how easy it was to work with but also enhanced its strength and durability once it set.[3]. Superplasticizers are used to enhance the workability of geopolymer concrete. Proper compaction of freshly poured concrete is crucial for achieving through consolidation, consistent properties, highlighted quality, and long-lasting durability it establishes a robust connection with reinforcement and enhances the interaction between the aggregate and the solidified paste contributing to overall structural integrity and performance. [8]. The paper explores petrographic observation and chemical composition analysis of geopolymer concrete (GPC) samples. Varied dissolution was employed in petrographic observation to scrutinize the detailed impact of sodium silicate (Na2SiO3) and fly ash (FA) the analysis of GPC sample utilized equipment and specific sample preparation methods for a comprehensive understanding of their structural and chemical characteristics. Concrete is widely employed as a structural material due to its malleability and the abundance of raw materials. However, the sustainable emission of greenhouse gasses, particularly carbon dioxide (CO2), stemming from limestone decarbonisation and fossil fuel consumption in cement production poses significant environmental concerns. The manufacturing process, notably for ordinary Portland cement stands as one of the most energy intensive process, ranking closely with steel and aluminium production. The immense energy requirement contributes to a pronounced negative environmental impact highlighting a critical issue for both society and the cement industry. Addressing these challenges, the adaptation of modern environmentally friendly material in construction is deemed essential. Recently ecofriendly alternatives like geopolymer concrete have immersed as variable substitute for ordinary Portland cement (OPC) offering a promising solution to mitigate the environmental footprint associated with traditional concrete production. [36] [,38]. Concrete structures constructed with Portland cement often experiences accelerated deterioration due to chemical interaction with environment. Geopolymers are emerging as promising alternative binders for environmentally friendly and sustainable concretes, contributing to reduce greenhouse gas emissions and the utilization of industrial byproducts geopolymer concrete demonstrates notable advantages, including high early strength and resistance to chemical attacks positioning it as a valuable substitute for conventional Portland cement concrete. Despite these merits, the durability of geopolymer concrete remains a subject of debate with opinions divided on its readiness for commercialization. The incorporation of silica fumes into fly-ash based geopolymer concrete is anticipated to enhance mechanical properties and diminish porosity further exploration is needed to understand the role of silica fumes in bolstering the durability of geopolymer concrete particularly in aggressive environments like sulfuric acid and sodium chloride solutions the formulation and characteristics of fly is based your polymer product hinge on factors such as the purity and concentration of alkali solutions, raw materials, and curing condition.[31], [32], [33]. The introductory section furniture details on the composition of Binder and the physical characteristics of natural aggregates employed in this study geopolymer concrete blends where cast at room temperature, and the alkaline solution was prepared 30 mins prior to casting to access the vocabulary of fresh GPC mixtures, the slump cone method was employed, revealing that the addition of water enhanced the vocabulary of the mixture., the slum value of the mixture exhibits variation based on percentage replacement of silica fumes, with higher silica fumes percentages correlating with increased slump values. This study delves into the exploration of diverse geopolymer mixture, encompassing on based on fly ash (FA) and three variation incorporating different weight fractions of silica fumes (SF) as replacement of family ash (FA).[24]. It underscores the importance of precise measurement and analysis of structural responses under diverse loading scenarios. This paper seeks to explore the performance of structures under varying loading conditions and scrutinize the impact of load magnitude on structural response. Specifically, the investigation concentrates and analysing how structure behaves when subjected to loads spanning from 20.00 KN to 70.00 KN, incremental increasing by 5.00KN steps. The overarching goal of this research is to enhance the comprehension of structural behaviour offering valuable prospects that can inform the design and analysis process in civil engineering for more robust structure. [28]. Geopolymer concrete (GPC) Stands out as an environmentally sustainable material, utilizing fly ash as its primary binding agent. Renowned for its expectation resistance to chemical attack and impressive fire performance, GPC is synthesized from aluminosilicate materials, primarily fly ash, through alkaline solutions. The chemical interaction between alkali-polysialate and aluminosilicate dictate the unique properties of geopolymers critical mix parameters including molar concentration and alkaline solution ratio, significantly influence the workability and the mechanical properties of GPC. Equally impactful are curing temperature and curing time on GPC properties. Innovatively, machine learning models like Artificial neural network (ANN) emerge as potent tools for predicting GPC's compressive strength. ANN, inspired by biological neural networks, adeptly learns from examples, extracts insights from incomplete tasks, and autonomously grasps the relationship between independent and dependent variables. Comprising nodes with dense parallel connections, ANN excels in analyzing intricate data to forecast outcomes without the need for specific model equations. Notably, ANN proves effective in predicting GPC compressive strength based on input parameters such as NaOH concentration, alkali activator-fly ash ratio, and curing condition[22].

2. LITERRATURE REVIEW

The literature review explores advancements in predicting the comprehensive strength of Geopolymer concrete through deep learning techniques analyzing existing studies this review aims to synthesize insights into the application of various machine learning algorithms for accurate strength predictions. Evaluating methodologies, data sources, and model performance, it provides a comprehensive overview of the current state of research understanding the strengths and limitations of existing approaches is crucial for developing robust model that enhance the predictive capabilities of geopolitical compressive strength using Artificial Neural Network (ANNs) machine learning techniques.

2.1 Developing an ANN prediction

This research aims to deal with different parameters and their effects, for example, alkalinity ratio, NaOH molarity, curing temperature, time, period, and other parameters which affects the mechanical properties like compressive strength of GPC. Geopolymer has granted significant research attentions particularly in its utilization of fly ash, as it exhibits properties comparable to traditional cement while offering sustainable environmental advantages. The study employs artificial neural network modelling to forecast the strength properties of fly-ash geopolymer concrete, leveraging experimental data for accurate prediction. The research proposes the potential for conducting sensitivity analyses on various permutations of input parameters in future studies, aiming to enhance the modelling accuracy and compressive strength.[Rao et al. (2023)].

2.2 Geopolymer concrete at ambient curing condition

In ambient curing conditions, geopolymer exhibits excellent compressive strength range between 40 and 42 MPA. As per the study elastic modulus of geopolymer concrete is 20-30% less OPC at the same strength at 28 days which makes geopolymer concrete more practical and cost-effective. This study shows insights into the effects of different additives and curing conditions on compressive strength and also the properties of GPC, which allow for the optimization of mixtures suitable for low to medium compressive strength. [Nath et al. (2016)].The study assisted the initial and final setting time of geopolymer concrete paste by examining varying concentrations of NAOH. The presence of calcium accelerates the setting time of geopolymer concrete in ambient condition. [Ramineni et al. (2018)]. The geopolitical concrete which has low initial strength exhibits higher activity. Geopolymer concrete cured at ambient conditions are supported by ductility measurements, if we do heat during then the ductility of the material is reduced. [Reed et al. (2014)]. It is found that rather than ambient temperature curing heat curing gives better result in increased compressive strength, modulus of Elasticity, and other mechanical properties of geopolymer concrete. Attaining favourable outcome in Jeopardy requires careful condition of appropriate mix proportions and precise control over curing conditions including temperature regulation. [Hassan et al. (2019)].

2.3 Effect of silica fumes

The mixing of silica fumes in the fly ash geopolymer concrete increases its strength and durability Geopolymer concrete mixed with fly ash gives economical benefit rather than OPC and also it is activated by alkali to form geopolymer which makes the process cleaner. GPC with 20% silicon fumes gives long-term durability and resistance to chemical attack. Visual examination of jeopardy concrete containing 20% silica fume shows and no erosion, no deterioration of the surface when it is exposed to 5% sodium chloride solution for 90 days. [Okoyeet al. (2017)].Silica fumes added as an admixture to fly ash-based geopolymer concrete shows a significant effect on the development of different mechanical properties, including compressive strength. The study shows that the density of silica fumes-based geopolymer is lower than fly ash-based GPC due to the low specific gravity of silica fumes. [Jena et al. (2018)]. Silica fumes that replaced fly ash as mass function in this research were 0,5, 10, 15 wt. %. The use of 10 wt. % of silica fumes results in 4.3% reduction in slump flow but the benefit is that the compressive strength of geopolymer concrete is increased by 6.9%. Once the replacement of silica fumes exceeds 10% there is a decline observed in the hardened properties of the concrete. [Memon et al. (2013)].

2.4 Effect of Sodium hydroxide solution

This study focuses on how adding water, using a plasticizer, and the mix of chemicals in the liquid part affect how well geopolymer concrete made from fly ash works. The best mix has a 16 M strength for the liquid part (NaOH solution) and a 0.40 ratio of liquid to fly ash. But if we use more of one of the chemicals called NaOH compared to another called Na2SiO3, it actually makes the geopolymer concrete not work as well. It also explores how adding water, changing the balance between sodium hydroxide and sodium silicate, and adjusting the strength of the sodium hydroxide solution impact the characteristics of geopolymer concrete made from fly ash. [Aliabdo et al. (2016)]. Self-compacting geopolymer concrete (SCGC) stands out as a cement free alternative that doesn’t need traditional compaction methods. The study delves into the impact of superplasticizer dosage and the strength of sodium hydroxide (NaOH) alkaline solution on the workability, microstructure, and compressive strength is SCGC, eliminating the need for ordinary Portland cement. Surprisingly, increasing the NaOH solution strength from 7 to 15 M resulted in reduced workability but increased strength in the concrete samples. The research provides details on the specific gravity and size of coarse and fine aggregates used. The alkaline solution, comprising Na2SiO3 and NaOH, plays a pivotal role in geopolymer synthesis. Previous research has already demonstrated that SCGC, when made with fly ash, not only enhance workability but also improves the overall properties of the concrete once it has set. [Nuruddin et al. (2011)]. The primary view is to create geopolymer concrete by utilizing fly ash and to investigate how varying concentrations of sodium hydroxide impact its strength and durability properties. Notably, this highlights that the freshly prepared fly ash based geopolymer concrete remains manageable for up to 120 minutes without any indication of setting and without compromising its compressive strength. Additionally, there is increment in compressive strength of GPC over time. [Tabassun et al. (2015)].

2.5 Properties influencing compressive strength

This talks about how different factors affects the compressive strength of geopolymer concrete made from fly ash. The use of low calcium fly ash (Class F) from a local power plant as the main material. The experiments look at changing the amount of total aggregate, the concentration of NaOH, and the curing temperature to see how it impacts the strength of geopolymer concrete. Geopolymer concrete is a type of inorganic composite hat replaces cement with materials rich in aluminosilicates, like fly ash. This also focuses on the characteristics of fresh geopolymer concrete and how it behaves when it’s still new. [Chithambaram et al. (2018)]. The research information on geopolymer concrete is existing literature. Previous studies by the authors have concentrated on the production process and the effects of various factors on the compressive strength of geopolymer concrete, ranging from use in marine structures to precast items and as a material fro repairing concrete structures. The regression analysis and the response optimizer method are employed to refine and optimize the numerical algorithm for predicting the compressive strength of geopolymer concrete regression analysis allows for the identification of relationships between input variables and compressive strength adding in the development of a predictive model the response optimizer method further fine tunes the algorithm optimizing parameters to enhance accuracy and reliability. By integrating these techniques, the study seeks to improve the precision and prediction and contribute to the advancement of geopolymer concrete research through a sophisticated numerical approach [Rai et al. (2017)].

2.6 Setting time, strength and bond of high calcium

Geopolymer concrete is an innovative construction material that replaces cement with fly ash. To assess its bond strength with reinforcing steel pullout tests are conducted the result indicate that geopolymer generally exhibits good bonding with reinforcing steel. While limited experimental studies using pullout test support this fine name further investigation into the bond behaviour of geopolymer concrete with reinforcing steel is essential for design considerations. [Sarkar et al. (2011)]. The setting time, the bond properties of geopolymer concrete made from high calcium fly ash sodium silicate and sodium hydroxide solutions were used as alkali activators in all mixes. The finding revealed that fresh geopolymer concrete exhibited a short setting time of 28 to 60 minutes, attributes to the high calcium content of the fly ash. The strengths and modulus of elasticity increased with higher NaOH concentration, with the optimal NA2O content of compressive strength at around 12% of fly ash a high strength geopolymer concrete, achieving a 28-day compressive strength of five 4.44 megapascal was attached attained with a mix containing 15M NaOH. notably, the bond strength suppresses the value specified in the current design code. [Topark-Ngarm et al. (2015)]. From an experimental study and analysis on the strength and behaviour of reinforced slender columns made from geopolymer concrete. Twelve columns were subjected to testing under axial load and uniaxial bending in a single curvature mode the test variables included the longitude null reinforcement ratio, load eccentricity and different compressive strength of concrete (40 Mpa to 70 Mpa). The result encompassed load carrying capacity, load deflection characteristics and failure mode of the column. Analytically, the ultimate strength of test columns always was calculated using method from available literature and design provisions from the standards. This concludes that the design provision in current standard and code are applicable for designing column made of reinforced fly ash based geopolymer concrete result affirms that heat cured low calcium fly ash paste geopolymer concrete holds significant promise for application in the precast industry. [Sumajouw et al. (2007)].

3. Methodology used.

The artificial neural networks stand out as a prominent model in machine learning and data mining drawing inspiration from the intricate neural networks of the human brain comprising, interconnected notes, this model is tenable to predict desired outputs based on given inputs. Unlike traditional computational models the an doesn’t necessitate assumption or predefined constraints regarding the models from showcasing flexibility. Its notable capability lies in discerning and interacting complex nonlinear relationships with data autonomously. Additionally, during training the ANN can extract and comprehend patterns, contributing to generalization.

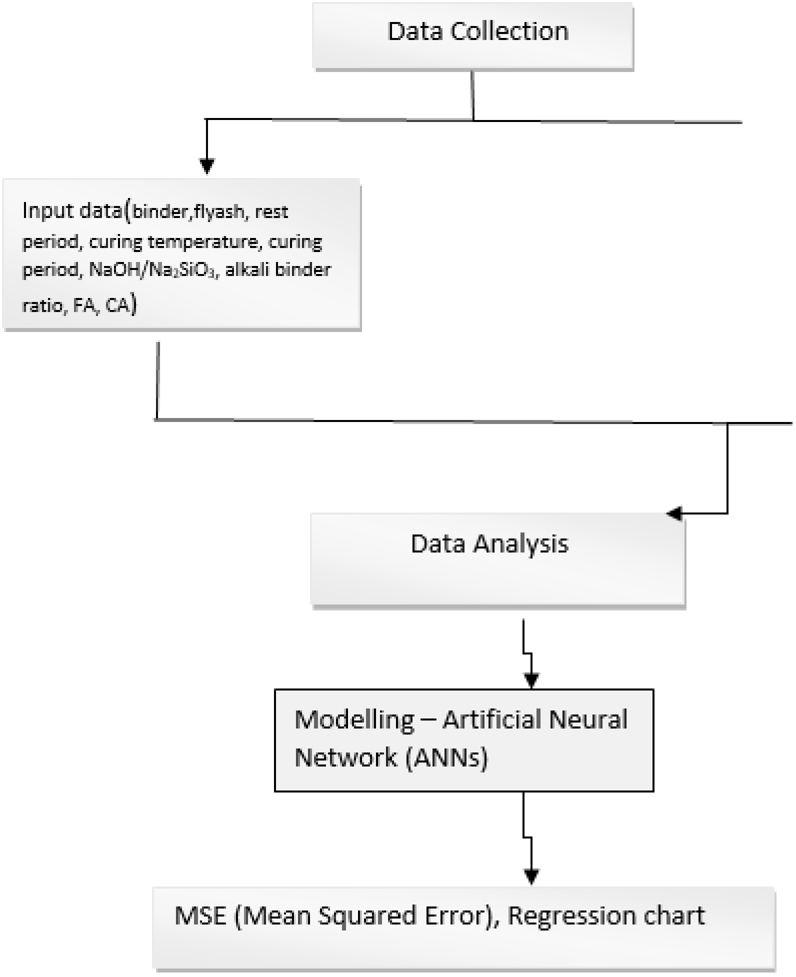

Figure 1Current methodology flow diagram chart
*CA – Coarse Aggregate.
*FA – Fine Aggregate.
*ANN – Artificial Neural Network.

An inherent strength lies in its parallel processing capability, rendering its particularly potent in managing large-scale data challenges. The architecture of an A and N comprises three fundamental components: input layers,

hidden layers, and output layers, this study specifically adopt an ANN model with five hidden layers strategically chosen to facilitate intermediary Computations for mapping inputs to Outputs this choice reflects a deliberate effort to harness a capacity for intricate and nuanced data processing, making it well suited for complexities inherent in studies objectives.

The utilization of Artificial Neural Network (ANN) in this study to predict the compressive strength of geopolymer concrete involved various steps (figure 1).

Establishing the parameters before data collection is a critical step to ensure a systematic and well-defined approach to your study on predicting compressive strength in geopolymer create using an Artificial Neural Network (ANNs), the parameters used are- binder, fly ash, rest period, curing temperature, curing period NaOH/Na2SiO3, SP, extra water added, molarity, alkali binder ratio, fine aggregate, coarse aggregate, compressive strength. By clearly all the parameters and specifying any additional material used.

Some precautions were made during the process like-

i. Consistency- units and measurements standard across all parameters.
ii. Using accurate techniques to avoid errors.
iii. Verifying the reliability and accuracy of data sources to minimise inaccuracies.

iv. Establish a review process to ensure data accuracy and consistency before the actual analysis.

3.1 Artificial Neural Network

Artificial neural networks (ANNs), commonly referred to as neural networks, are algorithms inspired by biological neural networks, comprised of artificial neurons that emulate human brain behaviour. The advantages of ANNs includes: (a) the ability to learn directly from examples, (b) extracting information even from incomplete tasks to produce nearly correct responses, and (c) automatic assimilation of the relationship between independent and dependent variables, in contrast to regression models. There are three learning paradigms in ANNs: (a) Supervised learning, it is a type of machine learning paradigm where the algorithm is trained on a labelled data set meaning that the desired output (target) is provided along with the corresponding input data during the training phase. The goal of supervised learning is for the algorithm to learn the mapping between the input and output by generalizing patterns; (b) Unsupervised learning, it is a machine learning paradise where the algorithm is trained on unlabelled data meaning that the input data provided during training does not have corresponding output labels. The primary goal of unsupervised learning is to discover patterns common relationships, or structures within the data without explicit guidance on what the model should learn, where desired outputs itis provided during training, it is the ability to learn directly from examples; (c) Reinforcement learning, Reinforcement learning is a type of machine learning paradigm where an agent learns to make decisions by interacting with an environment. Agent receives feedback in the form of rewards or punishment based on the actions it takes, and its objective is to learn and strategy or policy that maximizes the cumulative reward over time similar to supervised learning but with rewards instead of target outputs.

ANNs have found successful applications in various engineering fields, demonstrating promising results in determining concrete properties. Research proposed three ANN models to predict the elastic modulus of normal and high strength concrete. Each model varied in the number of layers and neurons in the hidden layer. ANN I and ANN II had one hidden layer with three and five neurons, respectively, while ANN III featured two hidden layers each with three neurons the applications underscore the versatility and efficiency of ANNs in modelling complex relationships within concrete properties.159 data sets were used in this study in which 126 training set and 33 data sets as testing sets. The values of R2 for both training and test data were 0.9007, 0.9204, 0.925, 0.912, 0.9206, 0.869, respectively. In this study it was reported as the performance of ANN model is far better that any other model used [40]. After conducting a series of trials involving systematic adjustments to the number of neurons in the hidden layer, the researcher proposed an optimal three-layer Artificial Neural Network (ANNs) model. The recommended architecture includes eight units in the input layer 1 hidden layer with 6 neurons employing a sigmoid activation function and an output layer designed for predicting the compressive strength of high strength concrete this configuration emerged as the most effective choice among the tested variations, showcasing its superiority in accurately predicting compressive strength based on experimental evaluations. A total of 106 data sets were used in the research, out of which 75 datasets were used for training and 31 for testing the value of R2 for training and test data sets where 0 .9589 and 0 .9503, respectively [41]. In a separate experiment a four-layer Artificial Neural Network (ANNs) model was developed for the prediction of both compressive strength and slum in a high strength concrete. The model featured an input layer with several neurons a first hidden layer with five neurons and a second hidden layer with three neurons. Sigmoid activation function was applied to both hidden layers and the model had two output units corresponding to compressive strength and slump. The input parameters encompassed crucial factors such as water to binder ratio, water content, fine aggregate ratio, fly ash replacement ratio, air entraining agent ratio, silica fumes replacement ratio, and super plasticizer content. This configuration was designed and tested to effectively capture the complex relationship between these input parameters and the desired output variables in high strength concrete. 186 data-sets were used in this study in which 169 and 18 data sets were used for training and testing data, respectively. [42]

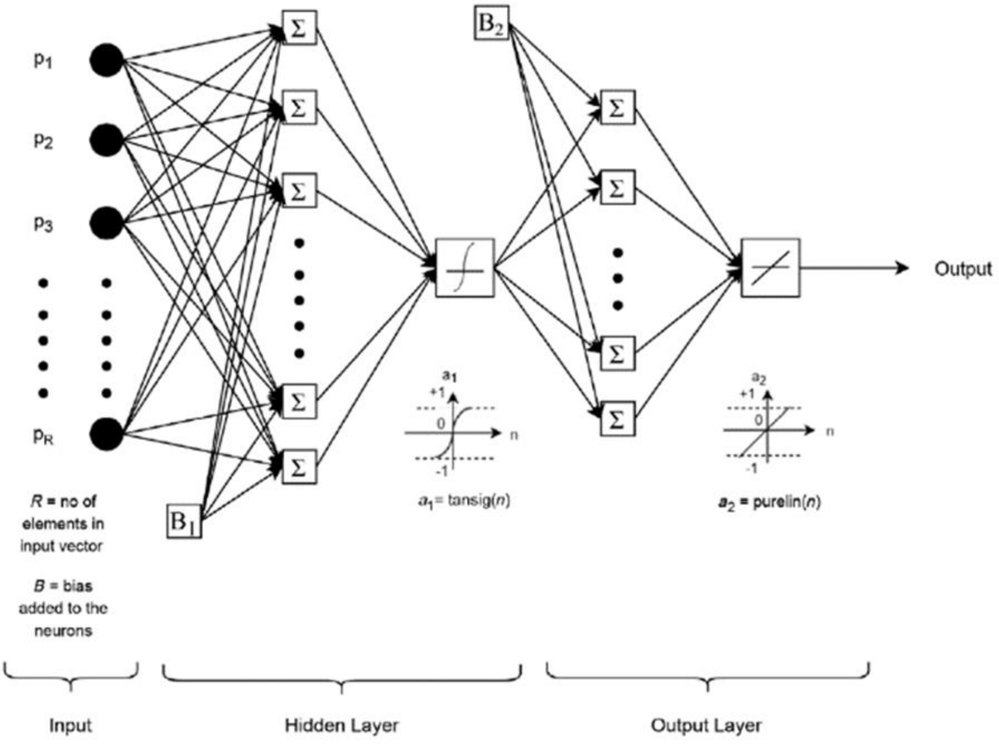

Figure 2 The typical algorithm that an ANN follows. Artificial Neural Network (ANNs)

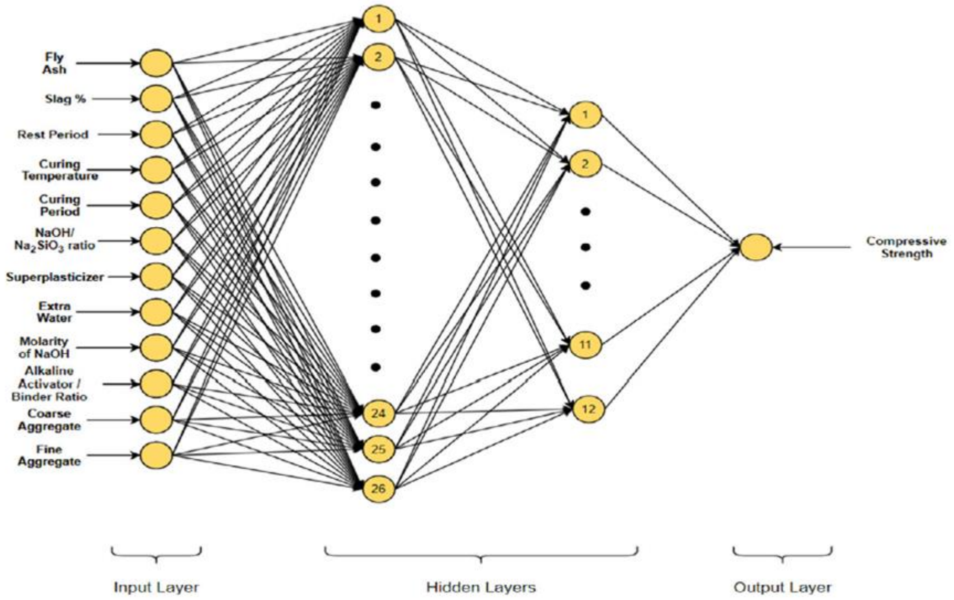

Figure 3 AnANN architecture used in the present study. ANN, Artificial Neural Network

Figure 2 illustrate the algorithm that the Artificial Neural Network (ANN) follows in this study. The activation function employed in the hidden layer is the tansig function, and in the output layer, it is purelin function. The specific ANN architecture utilized in the research in outlined in figure 3, featuring 12 input parameters, 26 neurons in the first hidden layer, 12 neurons in the second hidden layer, and the respective output parameters.

4. Prediction of compressive strength using ANN

The precise prediction of compressive strength through artificial neural network model necessities a judicious selection of input parameters. Table 1 enumerates the parameter influencing compressive strength, and the correlation between outputs and targets in the network was evaluated using the R-value to train the network and update weight and bias values, the trainlm function of the MATLAB platform was employed leveraging the Levenberg-Marquardt optimization technique.

Figure 4 illustrates the training state of Artificial Neural Network (ANN) model. Observing the figures, it is noted that the error pattern repeats six times after epoch 4 and continues until epoch 10 this repetitive error pattern commencing from epoch 5 indicates potential overfitting of the Tata. Consequently, epoch 4 is identified as the baseline, and it is its weight are chosen as the final weights. A validation check is implemented, halting the process after the errors are reported six times, as a measure to monitor and control the training process effectively.

Figure 5 depicts the performance of the network in terms of validation and Mean Square Error (MSE) ranging from a large value to reduce one.The plot comprises three lines representing distinctstages of training, validation, and testing. Optimal validation performance is absorbed at epoch 8, and the occurrence of error repetition after epoch 4 promotes the termination of the process of eat epoch process at epoch 6. To enhance the model's performance a neural network with a hidden layer containing 60 neurons were selected to minimize Mean Square Error (MSE) and maximize R, resulting in an R value of 0.82 the most favourable validation performance with an error of 77.0164 is achieved at epoch 8 furthermore figure 6 represents a recreation plot illustrating the performance across validation, testing, and training phase of the model.

To ensure robust validation of the train neural network a data set comprising experimental results of compressive strength as detailed in the preceding sections was meticulously compiled utilizing the dual parameter listed in table number one, the input layer was configured, and

the ANN model's architecture included a hidden layer with 16 neurons all employed the log sigmoid function as their activation of the objective of the output neurons is to predict the compressive strength of geopolymer concrete (GPC). Upon comparing the theoretical results with the experimental findings, a remarkable alignment is absorbed as depicted in figure 7. This strong agreement underscores the model's validity, its capability to accurately predict the compressive strength of GPC based on specified input parameters.

Table 1. The input and output data parameters used for developing a model

	and testing of the model	
Input data	Minimum	Maximum
Flyash(B)(kg/m^3)	276	427
Slag(S)(%)	0	100
Restperiod(RP)(h)	0	72
Curing temperature(CT) (°C)	25	100
Curingperiod(CP)(h)	8	72
NaOH/Na_2SiO_3(SH/SS)	0.398	1
Superplasticizer(SP) (kg/m^3)	0	7.94
Extra water (EW)(kg/m^3)	0	52.5
MolarityofNaOH(M)	0	16
Alkalineactivator/binderratio(AA/B)	0.35	0.6
Coarseaggregate(CA)(kg/m^3)	1091	1294
Fine aggregate (FA) (kg/m3)	547	659
Output value		
Compressive strength (CS) (MPa)	9	71.63

Table 2. Data used for testing of models.

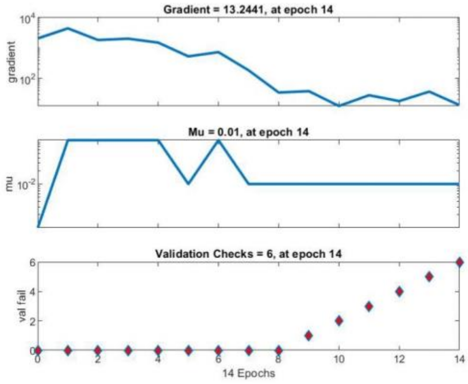

Figure 4 – Training state for ANN model

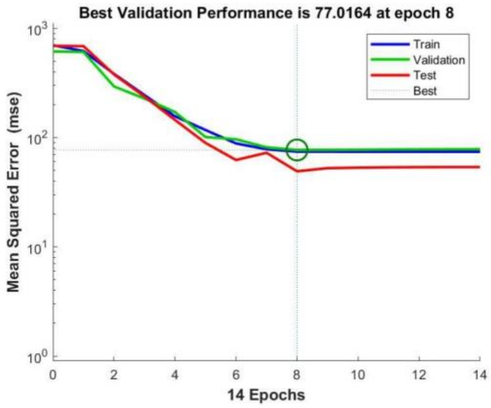

Figure 5 – Performance of network

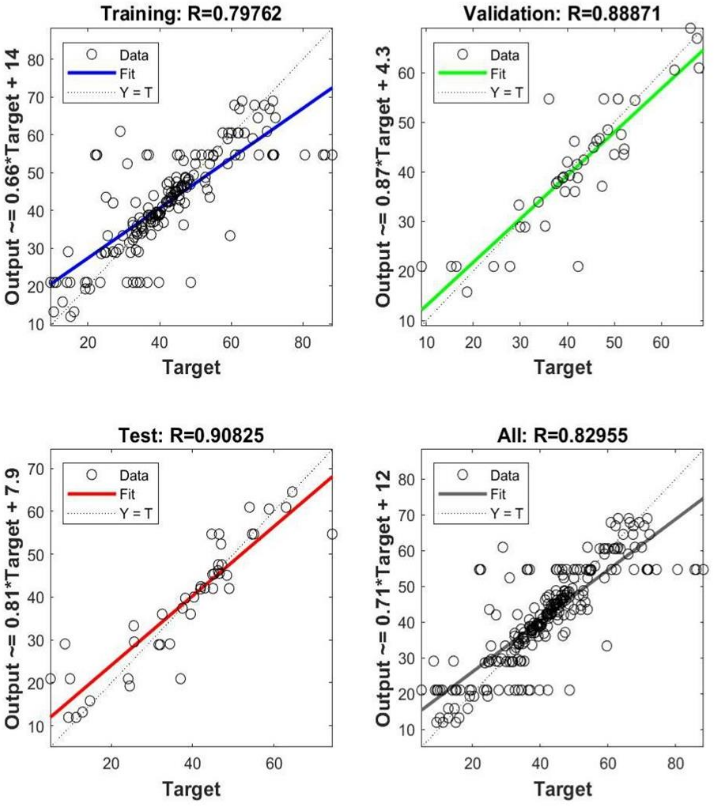

Figure 6 – True and predicted

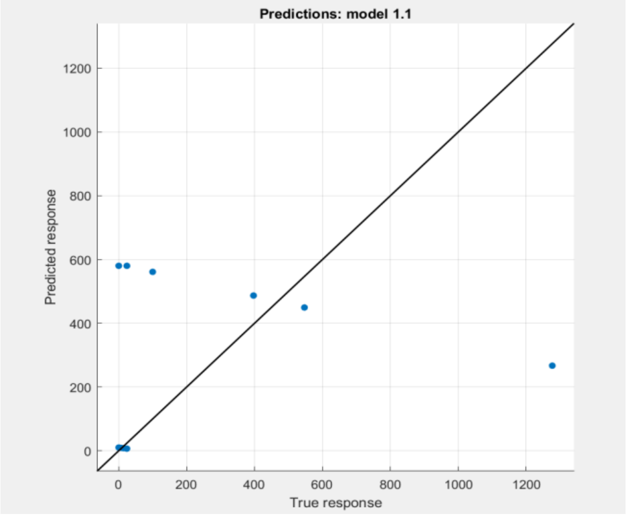

Figure 7 – True and predicted response.

Conclusion

This research aims to explore the impact of variables such as alkalinity ratio ($NaOH/Na_2SiO_3$), NaOH molarity, curing temperature, curing time, alongside other influential factors, on the compressive strength of GPC. Vishnu Lee, the study utilized an Artificial Neural Network (ANN) model in cooperating dual distinct input parameters to predict the compressive strength of GPC the findings derived from this investigation leads to the following significant conclusion:

- The study’s findings suggest that the ANN model exhibited greater efficacy in forecasting the compressive strength of GPC.
- The sensitivity analysis revealed that the SH by SS ratio exerted a sustainable influence on the compressive strength of GPC. Furthermore, parameters like super plasticizer tosses, curing temperature, additional water content, and coarse aggregate had notable effects on compressive strength the incorporation of a higher number of prediction parameters contributed to enhance accuracy in predicting the compressive strength of fly ash-based GPC.
- Through empirical investigation, it was determined that the compressive strength of GPC demonstrates an upward trend with increasing $NAOH/NA_2SIO_3$ ratio, NAOH modularity, curing temperature up to 90 °C, and curing time however, a noteworthy observation was made at a curing temperature of 120 °C, the compressive strength of GPC experiences at decline beyond 24 hours of curing time.

Moreover, the experimental investigation highlighted that the optimal conditions for achieving the maximum compressive strength of GPC involves a $NAOH/NA_2SIO_3$ratio of 1:2.5, NaOH molarity set at 14 M, curing temperature maintained at 120 °Cand a curing time of 24 hours.

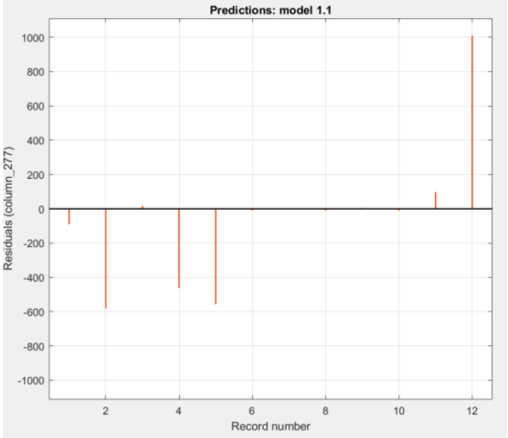

Figure 8 –Residual plot.

- The outcomes of the ANN modelling affirms that artificial neural networks can be effectively employed to predict the intricate behaviour of compressive strength in GPC considering the influence of 12 distinct parameters.
- To validate the ANN model, this study utilized the training data presented in this paper for a comparative analysis between the predicted and experimental result of GPC. The findings indicate a satisfactory relationship between the predicted and experimental values of compressive strength with an acceptable coefficient of determination (0.82955) underscoring the validity and utility of the model.

Future scope

In the future expanding the scope of Artificial Neural Network (ANN) applications for predicting the compressive strength of geopolymer concrete holds promise.Refinement through sensitivity analysis on diverse input parameter combinations can enhance accuracy. Exploring novel ANN architectures and incorporating advanced ensemble learning methods may further optimize predictive models. Integration of real time monitoring data and continuous model updating can provide dynamic insights.Collaborative effect efforts with emerging technologies like machine learning and data analytics offers avenues for comprehensive and sophisticated predictive capabilities.Continuous research and innovation in an application stands to revolutionize the precision and reliability of compressive strength predictions in geopolymer concrete.

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