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Strength predictions of GGBS based cement mortar with different M-Sands using Neural Networks

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Abstract- This study presents the compressive strength predictions of Ground Granulated Blast Furnace Slag (GGBS) based cement mortars containing two different types of M Sands (normal M sand and white M sand) which have been replaced effectively with the ordinary Portland cement. The defined mix ratios of mortar cubes are examined for compressive strength at 7, 14 and 28 days. Artificial Neural Network is a useful tool to predict various data's strengths, making the work much more comfortable. Then the obtained compressive strength results of GGBS based cement based mortars varied with two types of M-sands at different days were feed into ANN tool box in MATLAB software to acquire the strength predictions. Experimental results indicated that the compressive strength results of GGBS based mortar with white M-sand showed superior results than the normal M sand. The predicted compressive strength results of GGBS based cement mortars obtained from ANN framework was in good agreement with the experimental results.

Keywords: Artificial Neural Network, Ground Granulated Blast Furnace Slag, M Sand, Compressive strength.

1. Introduction

Different types of mortars have been employed in the construction practices depending on the type of work involved. Generally mortars were used to hold the various weathered bricks. When the mortar becomes rigid and it behaves as a sacrificial element to the structure [1]. The mortar is not that much expensive which is used in the building blocks. The most common binder used from 20th century is lime, lime mortar and gypsum in the form of plaster of paris used to repair the monumental old structures. It consists of a mixture of Portland cement and limestone and hydrated lime, increasing the setting time, water retention period, and durability. When the mortar cement is mixed with different types of sand and water, there should not be any additional hydrated lime which is not recommended for unit masonry construction [2].

The mortar materials are batched for making its strength, and therefore, proper curing and testing should be carried out so that specimen could withstand more strength and durability. The quality of workmanship and ambient conditions play significant role in this process. Mortar with proper workability which is of soft will spread through the surface easily and without smearing and dropping. Expansion of mortars will cause disintegration in masonry due to unsound ingredients present in it [3, 4]. Fineness, time of setting, air content and water retention play a significant role in its performance with its workability [5, 6]. Mason needs to confirm the workability of the mortar to the application to achieve watertight construction. In this, the machine batching is not mandatory and is done by gentle water addition into it.



2. Cement Properties

Several properties should be followed that will give us a detailed cement report to be used in the site investigation. The important criteria's to be followed while preparing and handling different types of mortars are listed below

- **Consistency-** It is defined as the quantity of the water required to make cement paste of standard consistency. In this process, initial setting time and final setting time were involved mainly due to the influence of tricalcium silicate and tricalcium aluminate.
- **Soundness-** It is defined as the time taken for the hardened cement paste to regain its original volume. Thus, the cement paste must not undergo any changes in its volume after it has set. It is also defined as the volume stability of the cement paste.
- **Strength-** There are three types of strength characteristics namely compressive, tensile and flexural. These strength properties were greatly affected by several properties like water/cement ratio, size shape of the specimen, and loading conditions.

3. Sand Properties

Since there is a greater demand for the river sand, we need to shift our focus towards the m-sand where it has been crushed from the various rocks of huge mountains that differ from its mineralogical and physical properties.

1. The M-sand's durability characteristics nature makes it resistant against the high climatic conditions thereby preventing the formation of honeycombing and corrosion of steel [4].
2. It has a smoother surface with texture and elongated flaky particles which improves the durability and longer life span.
3. It is 30% cheaper than the normal river sand, reducing the environmental disaster like groundwater depletion and scarcity of water, which will be a threat to the human race [1].
4. Its proper cubical and granulated size particle gives a very smooth texture, consisting of a micron size of 150 which yields good flexibility and workability properties [7].

4. Artificial Neural Network (ANN)

The artificial neural network is a numerical model that controls the whole system and imitates the functions of a human brain [8]. It can adapt new and changing the environment, analyzing the unclear, fuzzy information and making its own judgment [9,10]. Our brain has its complex organ, which will control our whole body. It is also a primitive animal that has the capacity of the most advanced computer. Its control is for all the body's physical parts and learning, thinking, dreaming, and visualizing. Our brain will think beyond the limits bounded by our computer technology. It has the world's powerful source than any other one capacity of the most advanced computer.

There are several problems in ANN; they do need a supervised or unsupervised approach. The handling of the data requires several tactics that should be involved with several inputs and outputs [11, 12]. This will be composed of several layers called bias, in which the data will be hidden to the bias and undergo several iterations, and it has been repeated continuously until we arrive at accurate results [13,14,15]. The one-layer network has four neurons, which have its own four weights leading to its bias, which is always equal to one. However, the weights leading from the bias is changed towards its nodes. The second layer has six neurons in which two is in the first layer, and four is in the second or in its output layer. It is understood that the input signals are normalized between 1 and 0. To overcome its consistency, the input is regarded as a non-active layer where the neurons will be serving the first layer of its active neurons. There are also variables of three input variables and four input variables.

5. Mix Proportions

In this study, totally six mix proportions were arrived in which the amount of GGBS cement is gradually increased from 0% to 50% in the parts of cement by maintaining constant water content ratio of 0.45. The proportions have been taken in the ratio 1:3 by trial and error. The mix ratios adopted in this study are shown in Table 1.

Table 1. Mix ratios adopted in the study.

Mix ID	Cement Content (%)	Water Content (%)
1	100	0
2	90	10
3	80	20
4	70	30
5	60	40
6	50	50

6. Results and Discussion

6.1 Compressive Strength

The compressive strength of GGBS based mortars with different types of M sand were evaluated using compression testing machine. Figures 1 and 2 show the specimen which are been tested.



Figure 1. Testing



Figure 2. Mortar specimens

Compressive strength obtained with white M sand is 3-4 % more when compared to normal M sand. Further the compressive strength comparison for the two types of M sand were displayed in Figures 3-5.

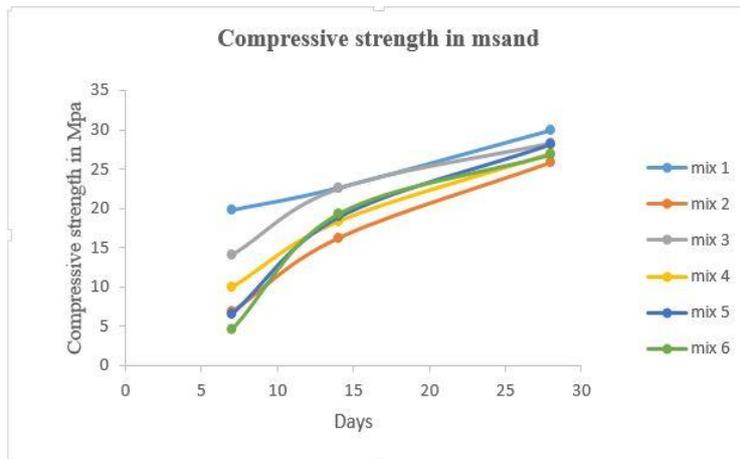


Figure 3. Compressive Strength with M Sand.

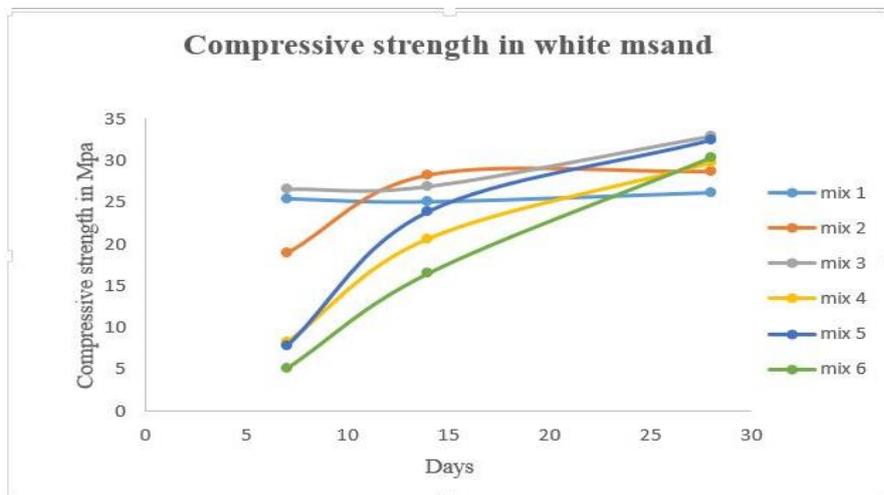


Figure 4. Compressive strength with White M Sand.

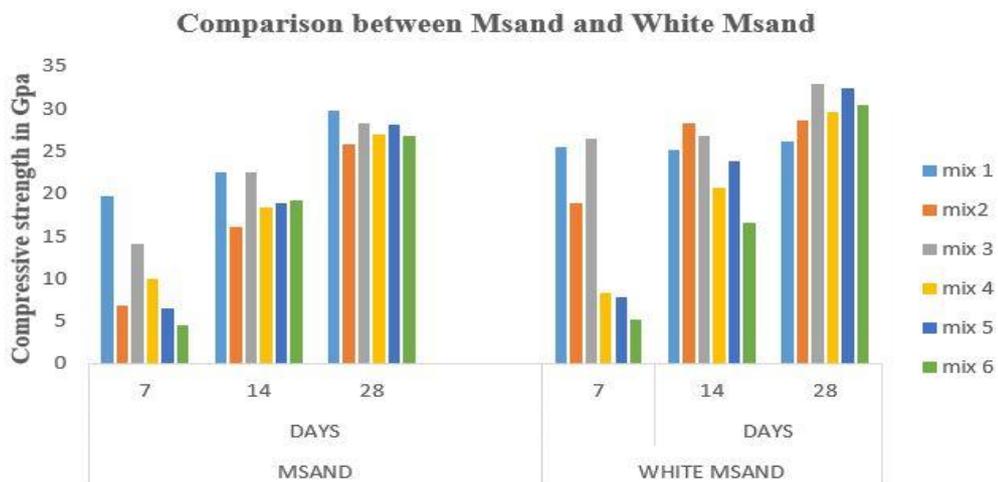


Figure 5. Variation of Compressive strength.

6.2 ANN Predictions M Sand and White M Sand

Figure 6 and 7 depicts the predictive performance of the compressive strength results obtained from ANN framework for two different types of M sand (normal and white) in of GGBS based cement mortars.

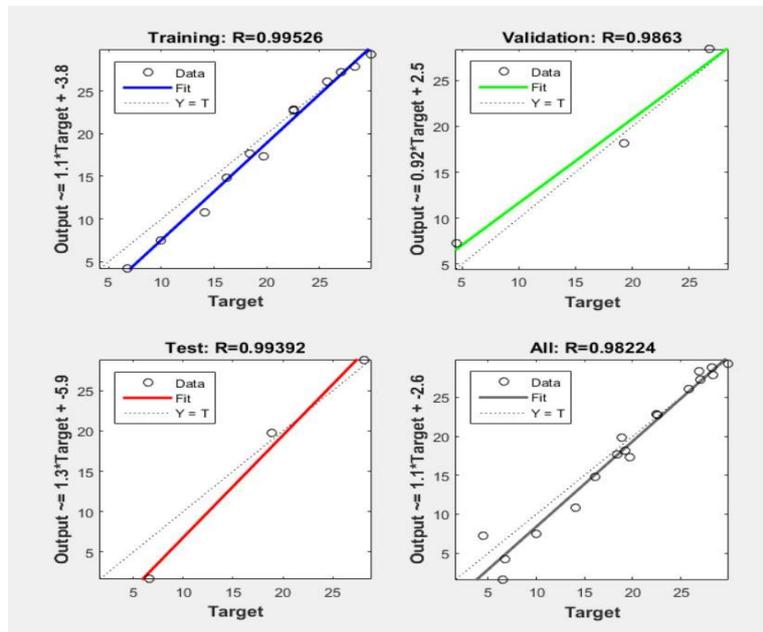


Figure 6. ANN Predictive performance for normal M Sand.

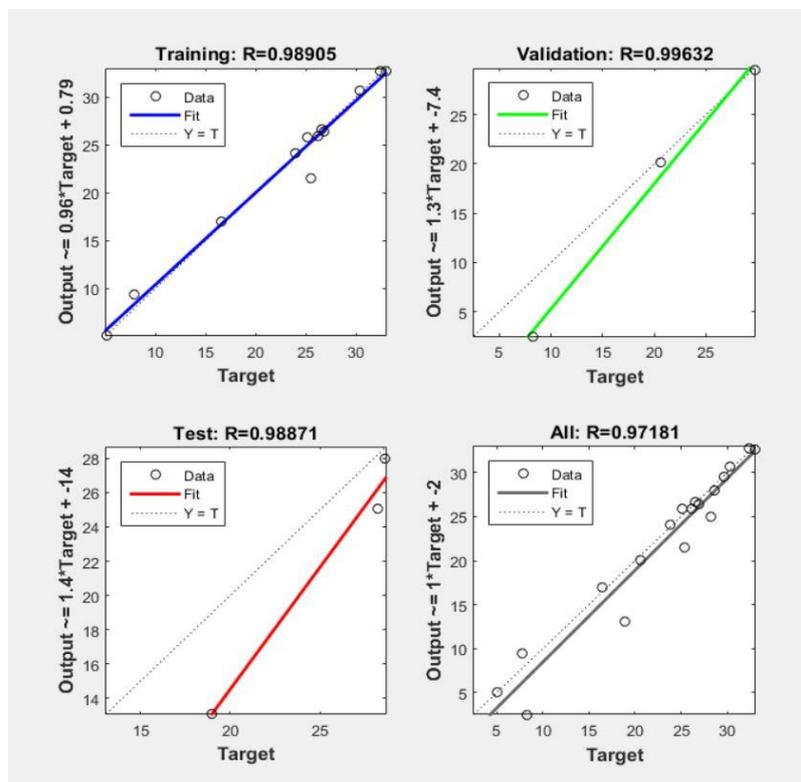


Figure 7. ANN Predictive performance for White M Sand.

6.3 Comparison of Results

Figure 8 and 9 presents the ANN prediction of the various graphs which consists of training, Validation, and Test data that have been plotted in resource graph. As the prediction and the actual data that has been collected is 99% these will elaborate us that the White M Sand will have the slight variation with the compressive strength corresponds to its prediction data.

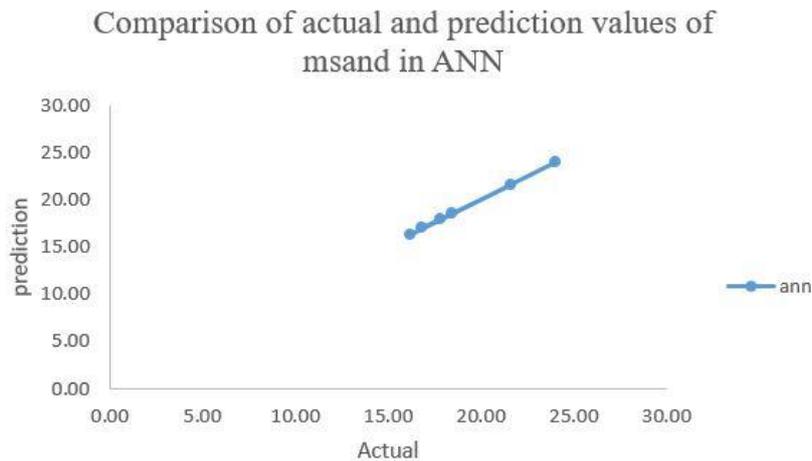


Figure 8. Comparison of values for M Sand.

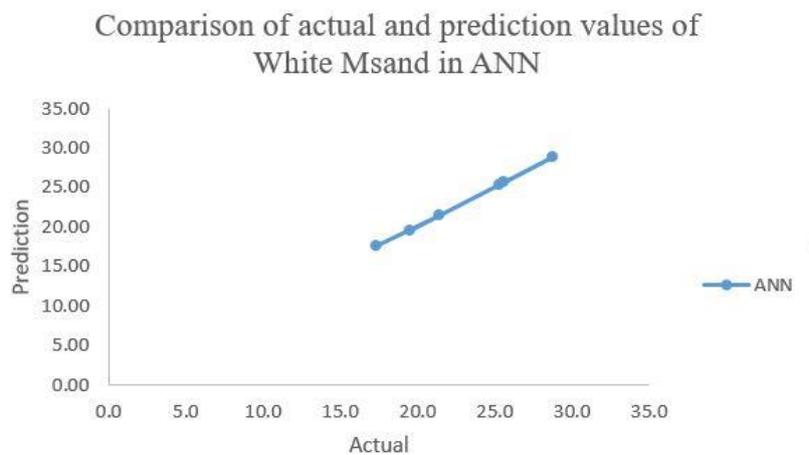


Figure 9. Comparison of values for white M Sand.

7. Conclusion

Based on the experimental and predictive results the following conclusion were drawn:

- From the test results it was observed that the mix 1 yields 4% higher compressive strength compared to mix no 6 and then strength increased gradually at later ages.
- It was observed from graph 2 that the strength of the mix 3 increases gradually and showed 5 % higher compressive strength than mix 1 which has no GGBS content.
- From the experimental results it can be concluded that white M Sand showed 3-4% increase in compressive strength compared to normal M Sand.
- The figure 6 and 7 depicts the ANN prediction results of compressive strength having two types of M sands showing 99% accuracy.

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