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# Prediction of Mechanical Characteristics of Pebbles Sand Concrete Using Artificial Neural Networks (ANN)

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**Abstract**
An innovative and successful method for producing concrete mixtures that are ideal for their intended usage is artificial neural networks. Several test batches of concrete were made in the lab for this study to assess the mechanical characteristics of pebbles sand concrete, and the outcomes of the trials were documented for predict of mechanical properties of pebbles sand concrete, Data was gathered from the accessible literature and entered into a database. 146 specimens' worth of data were utilised to predict the compressive strength. The split tensile strength was predicted using data from 152 specimens. Since there were few data available, 92 specimen data were utilised to predict the flexural strength. Any type of concrete strength can be precisely predicted utilising controlled software approaches. In this study, MATLAB R2015b were used to predict the mechanical properties of pebbles sand concrete. In ANN, samples are used for testing, validation, and training in proportions of 70%, 15%, and 40%, respectively. All mechanical characteristics of pebble sand concrete were accurately predicted by the generated multi-linear regression models, with correlation coefficients ($R^2$ values) which is closer to 1. The scatter plot graphs indicate a strong correlation between the experimental and predicted outcomes.

**Keywords:** Pebbles Sand, ANN, MATLAB R2015b, Multi – Liner Regression, Database.

## 1. Introduction

Cement, water, sand and gravel are combined to create concrete, a pourable mixture that hardens into a very durable building material. Aggregates are crucial ingredients in concrete. In addition to having an economic impact, they give concrete body and reduce shrinkage. The aggregate in concrete holds the cement paste together and acts as structural filler. Concrete's workability, density, temperature, and shrinkage qualities are all impacted by the aggregate particles, as well as the material's strength and durability. The kind and size of aggregate used can also affect the appearance and texture of the finished concrete surface. According on their size, aggregates fall into the categories of coarse aggregate and fine aggregate, with fine aggregate being any particle smaller than 4.75mm. Concrete and mortar both depend on fine particles. This study focused exclusively on fine aggregate. The availability of construction materials is currently limited due to increased demand. Rivers and exploitation currently generates environmental issues while also increasing prices and demand. In addition to harming the ecosystem, river excavation has resulted in rivers collapsing, bridges failing, and other retaining walls failing. River sand has become more expensive as a result of a shortage in supplies. Nearly 35,000 Rupees are spent on each truck load, which is 34 times more than what the government is selling it for at the quarry point. As a civil engineer, it is our responsibility to discover new, less expensive sources of river sand. In this study, river sand is partially substituted by pebbles sand. The pebbles are broken down, passed through a 4.75mm screen, and used as river sand. Although a pebble is a portion of river sand, its size prevents it from being used as fine aggregate. Pebbles sand has silicon dioxide as its primary chemical component, followed by a small amount of iron oxide and trace elements like manganese, copper, aluminium, and magnesium. Pebble Manufacturing Process These five steps can be used to categorise the stages of crushing sand: coarse crushing, secondary crushing, fine crushing (sand plastic), screening, sand washing, and pebble sand manufacture.

**2. Artificial Neuron Network (ANN)**

The Artificial Neural Network (ANN) is the result of extensive research on machine learning techniques based on artificial intelligence. ANN is designed after the human brain in how it solves problems. A neuron is the fundamental unit of computation in an ANN. The arrangement of layers of neurons is a possibility. A layer's neurons are interconnected with those in the layer above and below. The intricacy of the network architecture will vary depending on how many ANN layers are employed and how many neurons are included in each layer. There are three different kinds of layers, as shown in Fig. 1: the input layer is the first layer, the output layer is the last layer, and the hidden layer is the middle layer.

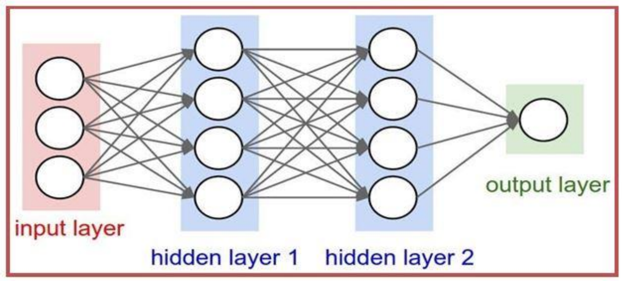



**Fig 1 Architecture of ANN**

**3. Experimental Investigation**

In this experiment, river sand was used in place of pebbles sand. There are six alternative ratios for mixing when replacing pebbles sand with river sand at a 20% weight replacement increment. Concrete mixtures were chosen in accordance with IS 10262-2019's specification. The target compressive strength is 30 MPa with a w/c ratio of 0.45. The concrete mixture was kept at a 50-75mm slump. The ratio of 1:1.48:2.9 was chosen as the standard for the concrete mix.

**Compressive Strength**

The test, which was carried out in line with IS 516-1959, was done to determine the compressive strength of concrete at ages of 7 and 28days curing. Concrete cube specimens of 150 x 150 x 150 mm were employed. The compressive strength test is the most common because it determines the majority of mechanical characteristics. Concrete with a 40% and 60% mixture of river sand and pebble sand was able to reach its maximum strength. The compressive strength of concrete increases with a 60% substitution of fine aggregate with pebble sand, and the strength declines in subsequent concrete mixes. Table 1 contains the test results information.

**Split Tensile Strength**

A concrete cylinder specimen with a 150 mm diameter and 300 mm height was tested for split tensile strength at the age of 28 days using the universal testing machine. A horizontally positioned cylinder specimen was placed between the loading surfaces, and the load was continuously applied until the specimen failed. These results are shown in Table 1. Perform a split tensile strength test to determine the tensile strength of cylindrical specimens. The split tensile strength of concrete made of 60% pebbles and 40% sand is almost the same as that of normal concrete. The remaining combinations, which contain 80% and 100% replacements of pebbles and sand in place of sand, have lower split tensile strengths when compared to regular concrete.

**Flexural Strength**

There were 18 prism examples in total, each measuring 100 x 100 x 500 mm, and they were all cast. According to the requirements of the Indian code, flexural strength tests were conducted. Flexural strength tests are performed to study the bending behaviour of prisms under two-point static loading circumstances. The combination four or 60% pebble sand concrete, performed well when compared to conventional concrete prisms. The flexural strength of pebble sand concrete somewhat decreases when additional pebble sand is used in place of river sand. These results are shown in Table 1.It exemplifies the quantity of pores present in concrete compositions. 40% river sand and 60% pebble sand make up the solid matrix of the concrete.

**Table 1 Experimental Results**

| Sl. No. | Mix ID | Mix Designation | Compressive Strength in Mpa | | Split Tensile Strength in Mpa | Modulus of Rupture in Mpa |
|---|---|---|---|---|---|---|
| | | | 7 Days | 28 Days | | |
| **1** | **R100%** | **CC** | **26.9** | **39.89** | **4.88** | **7.32** |
| 2 | R80% + P20% | RP 1 | 26.61 | 37.21 | 4.46 | 5.15 |
| 3 | R60% + P40% | RP 2 | 25.15 | 34.82 | 4.49 | 5.24 |
| **4** | **R40% + P60%** | **RP 3** | **27.91** | **39.5** | **5.18** | **7.7** |
| 5 | R20% + P80% | RP 4 | 24.32 | 32.05 | 3.93 | 4.9 |
| 6 | R0% + P100% | RP 5 | 23.95 | 31.29 | 3.93 | 4.85 |

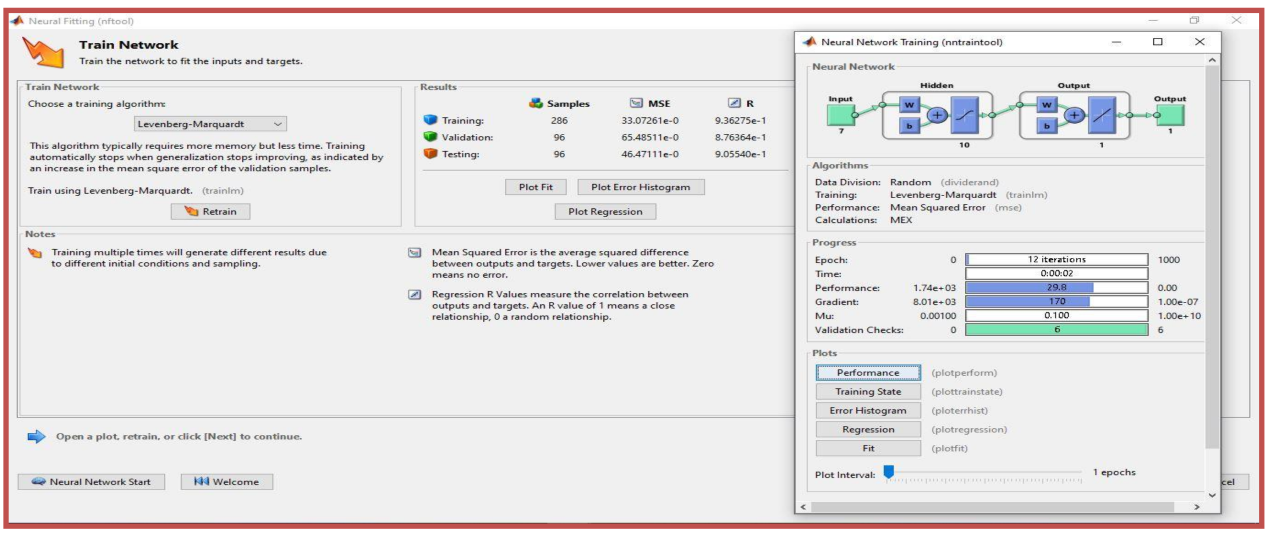



Fig 2 Network Layer of ANN

**4. Developing Ann Network**

Pebbles and sand concrete's mechanical properties can be predicted by A database was filled with information that was compiled from the available literature. The compressive strength was predicted using data from 146 specimens. 152 specimens' worth of data was used to forecast the split tensile strength. Since there were little data, the flexural strength was predicted from 92 specimen data. The mechanical properties of pebbles sand concrete were predicted in this work using MATLAB R2015b. In ANN, samples are used for testing, validation, and training in proportions of 70%, 15%, and 40%, respectively. The Network model for the experimental data was developed using MATLAB's Network/Data Manager tool. The Network Layer as shown in figure 2 The Network/Data Manager was started with the *nftool* command. The inputs included cement, River sand, Pebbles Sand, Coarse aggregate, water content, superplasticizer, and water cement ratio, with all input data measured in kilogrammes per cubic metre.

**5. Statistical Indicators**

The Levenberg-Marquardt method have all been utilised in this work, which was based on a back propagation network. The accuracy of projected results can be estimated using statistical indicators such the root-mean-square error (RMSE), mean absolute percentage error (MAPE), and coefficient of determination R-squared ($R^2$), which is a percentage of the variance for a dependent variable.

1. Root-Mean-Square Error (RMSE),

$$\sqrt{\sum_{i=1}^{n}\frac{(Ypre-Yexp)^2}{n}} = RMSE \quad (6.1)$$

2. Mean Absolute Percentage Error (MAPE),

$$\sum_{i=1}^{n}\frac{|Ypre-Yexp|}{Yexp} = MAPE \quad (6.2)$$

3. Coefficient of determination R-squared ($R^2$),

$$1-\left[\frac{\sum_{i=1}^{n}(Ypre-Yexp)^2}{\sum_{i=1}^{n}(Ypre)^2}\right] = R^2 \quad (6.3)$$

Where,

*Ypre* – Predicted Values
*Yexp* – Experimental Values
*n* – Number of Data

**6. Result and Discussion**

The General Regression Neural Network (GRNN) did well in its prediction of the mechanical properties of concrete, including its compressive strength, split tensile strength, flexural strength, and elastic modulus results are compared to experimental using ANN. The outcomes of the predictions are closer to those of the experiments, as shown by the Performance, Training State, Error Histogram, and Regression Diagram.

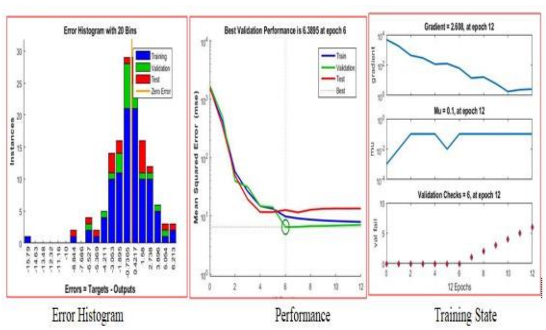



Fig 3 Outcomes of ANN for Compressive Strength

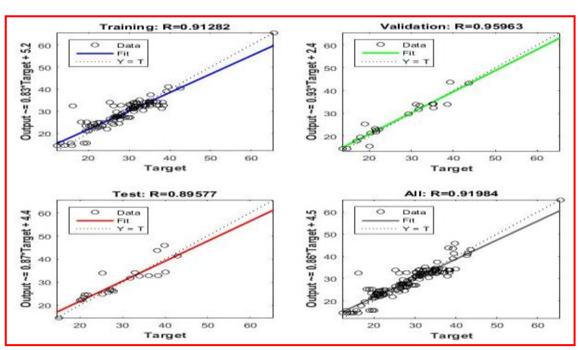



Fig 4 Regression for Compressive Strength

**Compressive Strength**

The Levenberg-Marquardt Algorithm are utilised in Artificial Neuron Network (ANN) and are highly predictive of the compressive strength results. The Performance, Training State, Error Histogram (Figure 3), and Regression Diagram demonstrate (Figure 4) that the outcomes of the predictions are more similar to those of the experiments, and the Regression ($R^2$) is closer to 1, which indicates that the test results and the predictions from the ANN are nearly identical. Diagram (Figure 5) of the scatter plot was shown in relation to experimental and predicted data for compressive strength.

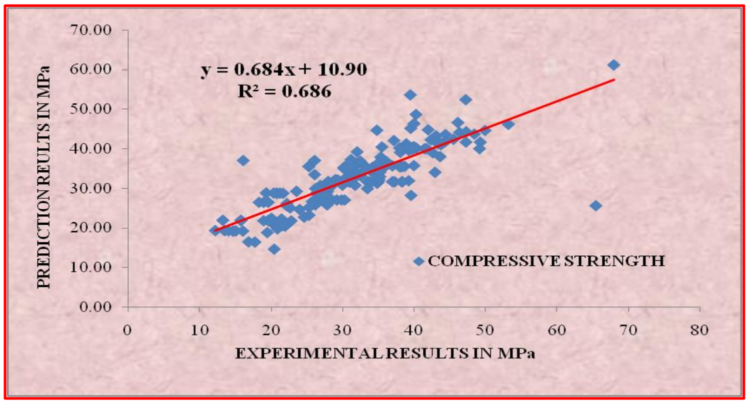



Fig 5 Scatter plot for Compressive Strength

**Split Tensile Strength**

The Split Tensile Strength results are very well predicted by the Levenberg-Marquardt Algorithm when used in Artificial Neuron Networks (ANN). Performance and Training State findings from ANN modelling are good at epochs 6 and 12, respectively. 20 Bins produce good results, according to the error histogram.

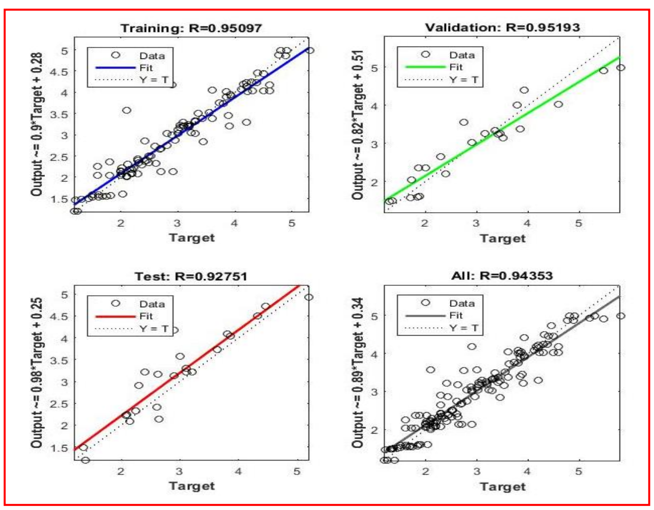



Fig 6 Outcomes of ANN for Split Tensile Strength

These ANN outputs are depicted in fig 6.

The regression diagram in fig 7 clearly demonstrates the relationship between the experimental and prediction outcomes. Since the test outcomes and the ANN predictions are so similar to one another, the Regression ($R^2$) is closer to 1. In relation to experimental and anticipated split tensile strength data, the scatter plot was displayed. The scatter plot of split tensile strength is depicted in fig 8.

**Flexural Strength**

When applied to Artificial Neuron Networks (ANN), the Levenberg-Marquardt algorithm makes excellent predictions about the Flexural Strength results. At epochs 6 and 12, respectively, performance and training state results from ANN modelling are good. The error histogram shows that 20 Bins give good results. In fig.9, these ANN outputs are shown. The correlation between experimental and predicted results is clearly shown by the regression diagram in Fig. 10. Given how comparable the test results and ANN forecasts are, the regression ($R^2$) is closer to 1. The scatter plot was shown in connection to experimental and predicted Flexural strength data. Figure 11 shows the Flexural strength scatter plot.

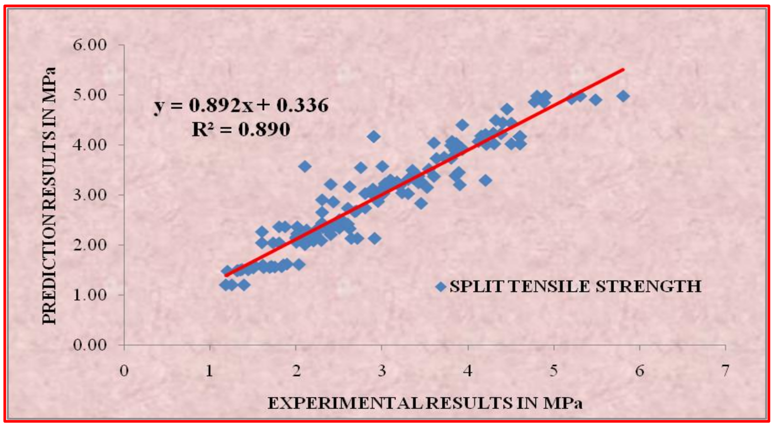
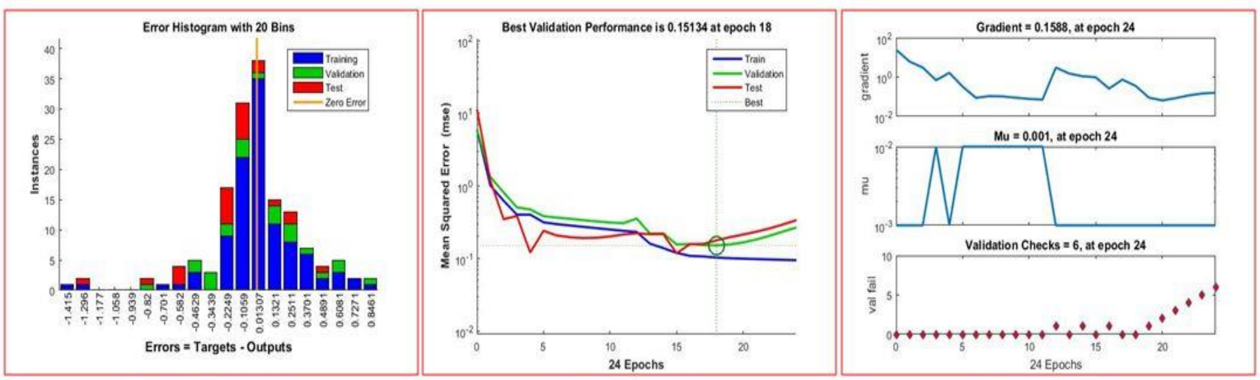
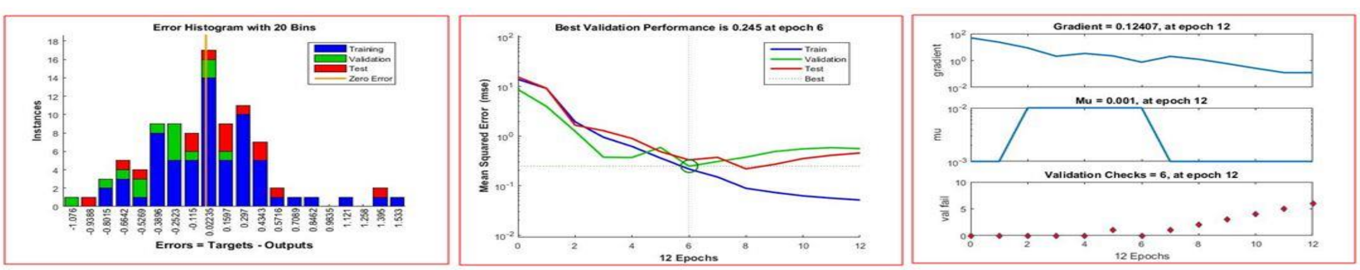



Fig 7 Regression for Split Tensile Strength




Error Histogram Performance Training State

Fig 8 scatter plot for Split Tensile Strength




Error Histogram Performance Training State

Fig 9 Outcomes of ANN for Flexural Strength

**Conclusion**

The following conclusions can be reached based on the investigation's findings:

- Comparing pebble sand concrete to standard concrete, the mechanical qualities of the former show good results. It demonstrates the similarity between the chemical, physical, and engineering characteristics of pebble and river sand.
- The Matlab Neural Fitting tool was used to train the models. It is possible to draw the conclusion that all models indicate satisfactory behaviour with the provided topologies after training, validation, and testing.
- The statistical indicator results for compressive strength $R^2$, RMSE, and MAPE are 0.9792, 4.7706, and 12.9158 respectively. Utilising the Levenberg-Marquardt algorithm in MATLAB R15b, these values were discovered. The coefficient of correlation R2 value is almost one. This indicates that the compressive strength results were strongly predicted.
- $R^2$, RMSE, and MAPE were found for split tensile strength to be 0.9804, 0.4639, and 11.9705, respectively. Same as were found to be 0.9785, 0.8406, and 11.7980 for flexural strength, respectively.
- The scatter plot graph provides the slope equation as well as demonstrating the strong correlation between experimental and predicted findings.
- For performance assessment of the model, the root mean square error (RMSE) and $R^2$-value were utilised as benchmarks and criteria. According to the results based on the standard conditions, there is a strong correlation, which suggests that the independent variable may accurately predict the dependent variable.
- The outcomes of experimental experiments and the outcomes of the generated artificial neural network model were compared. When the average forecast and experimental data were compared, they were relatively close, showing that the model could accurately and successfully predict the concrete mix ratio.

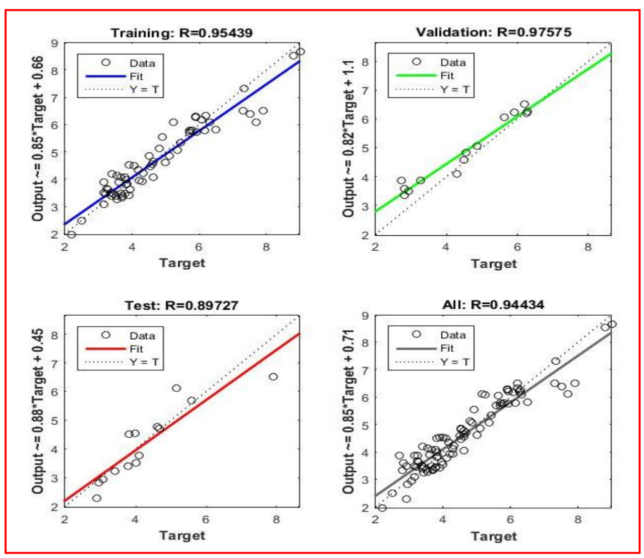



Fig 10 Regression for Flexural Strength

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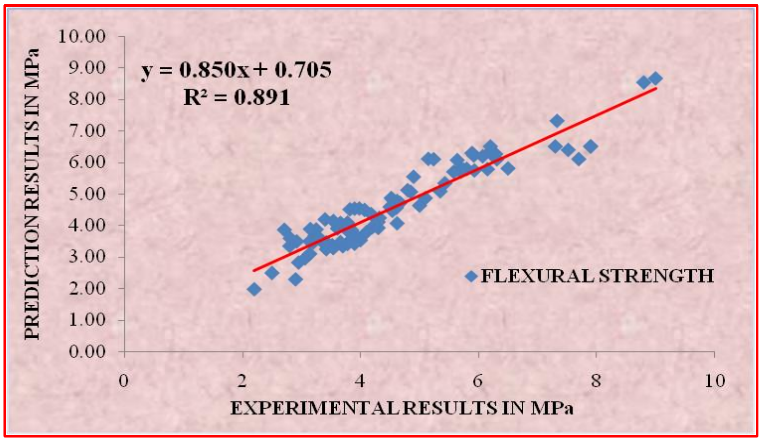


Fig 11 scatter plot for Flexural Strength

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