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PREDICTION OF COMPRESSIVE AND TENSILE STRENGTHS OF ZEOLITE BLENDED CONCRETE IN RIGID PAVEMENT USING ARTIFICIAL NEURAL NETWORK

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Abstract

Tremendous amount of CO2 emission is carried out due numerous human events. It is projected that construction sector is alone accountable for release of nearly 50% of Greenhouse gases. Cement production itself produces about 7% Carbon Dioxide. Zeolite is one of the few Supplementary Cementitious Materials (SCM's) which can be used as a partial substitution of Cement in concrete without hampering the properties of Concrete. One of the major benefits of blending zeolite in Concrete is its tendency to adsorb CO2. This study tries to blend Natural Zeolite in Concrete and to be used in rigid pavement which was not tried earlier. In this study, Neural Network tool of MATLAB is used to predict the mechanical properties (Compressive Strength and Split Tensile Strength) of Zeolite Blended concrete and to validate the results with the actual test results. Economic Analysis of Rigid Pavement blended with zeolite is also carried out to compute the effect of this blending on the economy of pavement.

Keywords: Rigid Pavement; Zeolite; Neural Network; Concrete; MatLab

I. Introduction

Concrete which is one of the most widely adopted Construction material due to its various properties like strength, Durability etc. The role of Cement in Concrete plays very important role with regard to the characteristics properties of Concrete. In order to accomplish Economical, Environmental and social profits, it is advisable to add mineral additives in concrete.

Per year about 4000 MT of cement is produced, that may upto 6000 MT per year in next 40 years. Manufacture of one ton of cement emits 900 kg of CO2. [Kami 2019] To reduce the impact on environment, various SCM have been tried to substitute cement in concrete manufacture. Some of well-known mineral additives with pozzolanic properties are industrial waste (Fuel Slag, ashes) and natural pozzolanas (Pumice, Diatomite and Zeolite). Zeolite can be extensively used due to their abundant availability and excellent pozzolanic activity despite of the crystalline structure. [1].

According to Greenhouse gas emission statistics of IEA (International Energy Agency), 25% of global CO2 emission is produced by transport industry network. It appeared that construction of

1km of Expressway produced 9729 tonne of CO2 emission per lane.

Use of mineral admixture in concrete has many advantages in economic, ecological and technological aspects. [4].

The word Zeolite is derived from Greek words: Zeo (to boil) and lithos (Stone) which means 'Boiling Stone'. Zeolites are crystalline alumina silicates with even pores, channels, and hollows. They hold special properties, such as ion exchange, molecular sieves, a big surface area, and catalytic activity, which make them a desirable material for various industrial applications. Numerous researches have been carried out related to addition of Zeolite in order to adsorb harmful gaseous substances and to improve water quality. Zeolite is having very high adsorption capacity (≈ 40% of its own weight) so it can act as an internal water curing agent. [13]

Zeolite containing SiO2 and Al2O3 reacts with CH in presence of water to create cementitious products (3CaO.2SiO2.3H2O and 3CaO.Al2O3.6H2O) [13]

$$2SiO_2 + 3Ca(OH)_2 \rightarrow 3CaO.2SiO_2.3H_2O$$

$$Al_2O_3 + 3Ca(OH)_2 + 3H_2O \rightarrow 3CaO.Al_2O_3.6H_2O$$

Addition of Zeolite in concrete densifies the Microstructure of cement paste which also reduces porosity and permeability. [13].

Usually it is not advisable to expose RCC to CO2 as it neutralizes the concrete hence reducing the strength so concrete with Zeolite can be used in Pavement. [11]

In this study, it is proposed to examine the effect of blending of Natural Zeolite in Concrete. Neural Network tool of MATLAB is used to predict the Strength properties of Zeolite blended concrete. This result is validated with the test results conducted in Laboratory. Economic Comparison between Concrete with and without Zeolite is carried for One Kilometer stretch of National Highway designed for Heavy Traffic..

II. Material Characterization

To study the effect of Zeolite on Concrete, Chemical Composition of both Cement and Natural Zeolite is compared. Following table 1 shows the Chemical Compositions.

Table 1: *Chemical Composition*

Parameter	Cement	Zeolite
pH	12.2	7.34
Fe2O3	3.36%	8.86%
SiO2	21.26%	71.76%
CaO	61.68%	0.08%
MgO	2.04%	0.04%
Na2O	0.08%	6.68%
Al2O3	5.56%	6.20%
K2O	0.00%	4.36%
Bulk Density	2.81 gm/cm3	0.81 gm/cm3

Table 2: *Chemical Properties of Zeolite as per ASTM C618*

Chemical requirements	Class N, ASTM C618	Zeolite
SiO2 + Al2O3 + Fe2O3 (%)	Min, 70.0	86.82%
Sulphur trioxide (SO3) (%)	Max, 4.0	0.00%

Ordinary Portland cement (OPC 53 Grade) available in local market is used in the research. Locally available well-graded, clean, M- Sand having fineness modulus of 2.6 following to IS 383-1970 [9] is used as fine aggregate. Crushed angular granite aggregate of size 20 mm obtained from local market is used as Coarse Aggregate.

IIa. Design of Rigid Pavement

Laboratory Experiments need to be carried out to find the various Mechanical Properties of Concrete. Mix Design of M30 Grade concrete using IS 10262 (2009) [8] is performed. The Mix Proportion obtained for M30 Grade concrete is 1:1.45:2.79 with Water to Cementitious Material ratio as 0.420.

In this research, a rigid pavement is designed as per IRC SP 62 (2014) [6]. The Details of Rigid Pavement design with reinforcement details is shown in Fig. 1

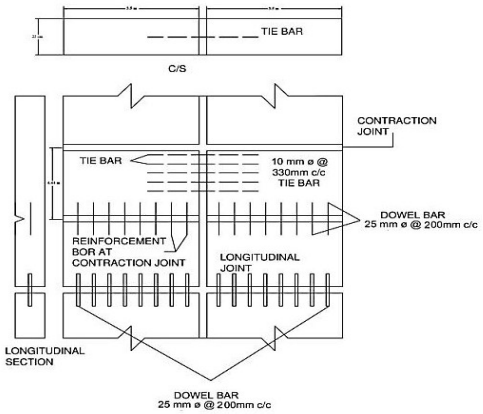

Figure 1: *Pavement Design*

III. Testing of Concrete

To Study the effect of Zeolite on Concrete, the dosages of Zeolite ranged from 0% to 20% of mass of cement.

Sample ID's are generated according to Zeolite Percentage (i.e. NZ05 represents Natural Zeolite 5% by mass of Cement).

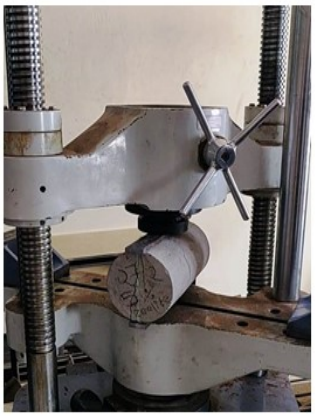

Figure 2: *Compression Testing Machine*

Figure 3: *(a) Split Tensile Test on Cylinder (b) Failure Pattern*

The tests carried out to identify Mechanical Properties are Compressive Strength Test and Spilt Tensile Strength. Assembly and Testing of Concrete Samples can be seen in Fig. 2 and 3.

The results obtained in Compressive Strength Test and Split Tensile Strength is tabulated in Table 3.

Table 3: *Laboratory Test Results*

Sample ID	Compressive Strength in N/mm2		Split Tensile Strength in N/mm2	
	7 Days	28 Days	7 Days	28 Days
NZ00	20.39	30.89	1.59	2.79
NZ05	20.18	31.07	1.71	2.54
NZ10	**24.93**	**35.90**	**2.14**	**3.26**
NZ15	23.38	34.83	1.47	2.96
NZ20	18.31	32.65	1.29	2.92

From the above the test results, it can be concluded that with 10% replacement of Cement by Zeolite give satisfactory results in terms of Concrete Properties. The same is adopted in later chapter for economic analysis.

IV. Artificial Neural Network

Artificial Neural Networks (ANNs) are algorithms simulating the human neurons. They are forms of artificial intelligence, which attempts to simulate the networks of the nerve cell (neurons) of the biological central nervous system. [5].

An artificial neuron, also called a unit or a node, takes several input connections which are assigned certain weights. The unit then computes the sum of the weighted inputs and applies an activation function. The result of the unit is then passed on using the output connection. [12]

In recent years, Artificial Neural Network has been applied successfully in various fields of Science and Engineering. It has been proved that ANN based models can be successfully used in prediction of various parameters.

Artificial Neural Networks has capabilities to model nonlinear relations among the sets of input and their corresponding outputs. The information used to prepare the ANN models are categorized into different subsets (i.e., training set, testing set, and validation set). This research paper analyses the prediction of the compressive strength, Split Tensile Strength of concrete using ANN.

In this research, ANN is designed with 5 inputs and 1 output for Compressive Strength as same for Tensile Test. It Contains 10 hidden Layers of neurons and 1 output layer. Feed Forward backdrop type train with "Gradient Descent with Momentum and adaptive LR" (traingdx) train function and transfer function "logsig" is adopted in Neural Network Training as shown in Fig. 4. 70% of data is used for training, 15% data is used for testing and 15% data is used for validation.

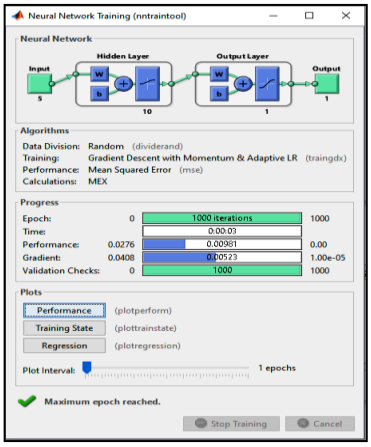

Figure 4: *Neural Network Tool*

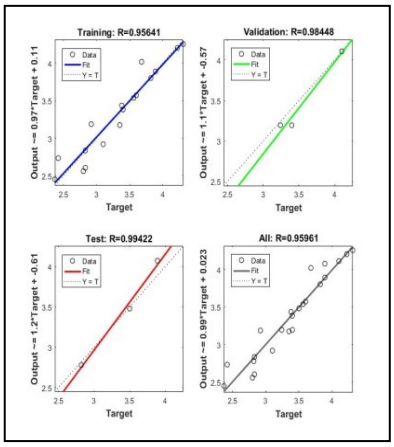

Figure 5: *Regression Values after Training*

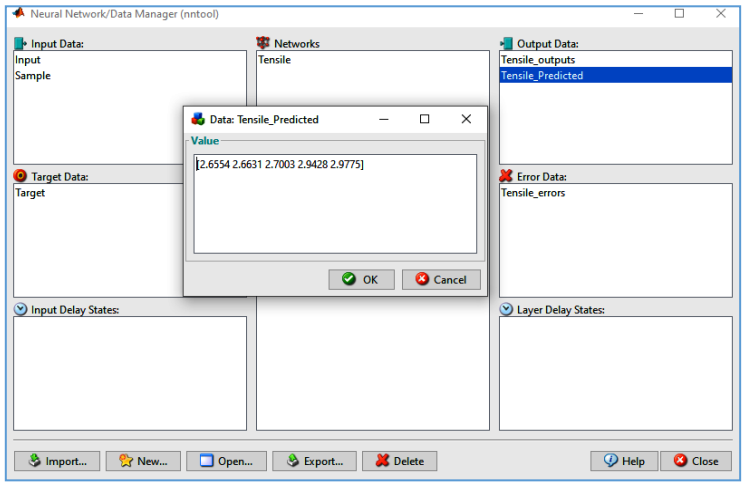

Figure 6: *Predicted Values after Simulation*

Separate Training of ANN is carried out for both tests to predict the Values. Two different data sets have been prepared for training of Neural Network. The data consists of five inputs (Weight of Cement, Coarse Aggregate, Fine Aggregate, Water and Zeolite per cubic meter of concrete) and one output as either Compressive Strength or Split Tensile Strength. The input data set has been referred from previous literature for training purpose.

Once a Neural Network is successfully trained (with value of regression ≈ 1) then that network is simulated with the sample data. The Sample data consists of weights of different constituents of Concrete derived from Mix Design of M30 Concrete as elaborated earlier. After simulation is carried out successfully, Neural Network provides "Predicted values" of Compressive Strength or Split Tensile Strength for the provided Sample Data. These predicted values are compared with actual values obtained from laboratory Tests carried out.

The Predicted and Actual Test result have been tabulated in table 4.

Table 4: *Comparison between actual and Predicted Values*

Sample ID	NZ0	NZ05	NZ10	NZ15	NZ20
	Split Tensile Test				
Predicted Result	2.6554	2.6631	2.7003	2.9428	2.9775
Actual result	2.79	2.54	3.26	2.96	2.92
	Compressive Strength Test				
Predicted Result	35.09666	34.9765	34.7301	34.2254	33.2808
Actual result	30.89	31.07	35.90	34.83	32.65

V. Economic Analysis

As stated earlier that use of mineral additives has economic significance too. During Concrete Testing, it was found that optimum blending percentage of Zeolite in Concrete is 10% so for economic comparison, so this substitution is adopted for further calculations. Material Rates in calculation are referred from District Schedule of Rates (DSR) of Pune Region for year 2019.

For the calculation, one Kilometer Stretch of Highway with a designed thickness of 0.25m and width of 14m is considered.

Table 5: *Material Cost of Rigid Pavement per Kilometer*

	Without Zeolite	With Zeolite	Cost Reduction	% Reduction
Total Material Cost (in Rs.)	1,81,77,724	1,78,60,926	3,16,798	**1.743%**

V. Conclusion

In this research, testing and validation of Zeolite blended concrete is carried out using ANN and Laboratory Test. ANN tool is a supplementary tool used for data validation. ANN itself is a modelling tool so relation between input and output of trained model need not to be elaborated.

Reasonable accuracy can be seen between Predicted results from trained ANN and the actual results. So it can be said that cost and efforts of experimentation can be reduced.

Zeolite which is one of the Supplementary Cementitious Materials (SCM's) can be used in Concrete without hampering its properties. It also shows economic advantages. Various environmental benefits can also be achieved with procurement and application of Zeolite in concrete it's properties. It also shows economic advantages. Various environmental benefits can also be achieved with procurement and application of Zeolite in Concrete.

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