PREDICTION OF CBR FROM INDEX PROPERTIES OF SOIL THROUGH ANN MODELLING

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ABSTRACT

California Bearing Ratio (CBR) value is an important soil parameters for design of Flexible pavements and runway of air Fields. It can also be used for determination of sub grade reaction of soil. It is one of the most important engineering properties of soil for design of sub grade of rural roads. CBR value of soil may depends on many factors like Liquid limit (LL), Plastic limit (PL), Plasticity Index (PI). An attempt has been made here to correlate soaked CBR value with LL, PL, PI and grain size distribution of some soil sample collected from different locations of Tirunelveli District of Tamil Nadu, India. Correlation Coefficient (R^2) of each of these properties with CBR is determined and their significance is tested by using Statistical Test. Finally a Linear multiple regression models were developed by using Artificial Neural Network (ANN) Modelling Statistical Six Sigma software and liner statistics of Microsoft Excel for determination of CBR value involving the above mentioned soil parameters. The ANN predictions for CBR correlation coefficient (R^2) of 0.951003 for training set for the network topology of 56.MLP 5-52-1. Similarly for testing set the ANN predictions for CBR yield a correlation coefficient (R^2) of 0.949158. Thus this model is used for predicting the CBR values of the Silty Soil.

Keywords: CBR, LL, PL, PI, Grain Size Distribution, Artificial Neural Network (ANN), Multi Linear Regression, Coefficient of Correlation (R)

1.0 INTRODUCTION

Roads have a very significant contribution to economic development and growth as well as bring crucial social benefits. In our country most of the highways system

consists of flexible pavement. The load from the pavement surface ultimately goes through the different layer of pavements such as sub base, sub grade layer. So the suitability must be checked before the pavement design.

California Bearing Ratio (CBR) is the strength parameter of sub grade soil. The thickness of pavement layer depends on the CBR value. For high CBR value the thickness of maybe lower and for lower CBR the thickness must be greater. But the CBR test is very complex, time consuming and required comparatively large amount of sample. To overcome this problem a correlation can be developed between CBR and other soil index properties using ANN Modelling Statistical Six Sigma software.

In the present study soaked CBR is correlated using simple correlation with the properties of soil like liquid limit, plastic limit and plasticity index, grain size distribution as well as finally a numerical equation is developed to predict CBR by using ANN Modelling Statistical Six Sigma software.

The design of pavement thickness in road construction requires the strength of subgrade soil, sub-base and base-course material to be expressed in terms of California Bearing Ratio, so that a stable and economic design achieved. A road section for which a pavement design is undertaken should be sub-divided into subgrade areas where the subgrade CBR can be reasonably expected to be delineated uniform, i.e. without significant variations, in order to utilize it in the design of pavement thickness. It is also used to rate the conditions of an existing pavement layers.

On the other way, the value of CBR is an indicator of the suitability of natural subgrade soil as a construction material. If the CBR value of subgrade is high, it means that the subgrade is strong and as a result, the design of pavement thickness can be reduced in conjunction with the stronger subgrade. Conversely, if the subgrade soil has low CBR value it indicates that the thickness of pavement shall be increased in order to spread the traffic load over a greater area of the weak subgrade or alternatively, the subgrade soil shall be subjected to treatment or stabilization.

2.0 LITERATURE REVIEW

The main focus of this paper is to correlate the CBR value with the soil index properties and the grain size distribution from the data collected from the laboratory. In the previous study, Venkatasubramanian et al.[1] proposed a technique to correlate CBR values with the soil parameter of various types of soils taken from the three different districts of Tamil-Nadu. A relation was developed with the help of Artificial Neural

Network System (ANN) and Multiple Regression Analysis (MLR).Muley and Jain [2] developed a correlation to predict CBR of stone dust mixed with poor soil.Korde and Yadav [3] proposed a correlation to determine the CBR value of some soils collected from different parts of Jabalpur city based on index properties like liquid limit(LL), plastic limit (PL), plastic Index (PI) and compaction characteristics i.e. optimum moisture content (OMC) and maximum dry density (MDD). Yildirim & Gunaydin [4] proposed following correlation for CBR soaked value with index properties of fine grained soils. ANN has been employed successfully in many geotechnical Engineering projects, including forecasting Soil organic matter content, underground tunnel design, and many others. Perhaps the most successful application of ANNs in geotechnical engineering is the prediction of driven pile capacity and soil behaviour[5].

3.0 MATERIALS AND METHODS

3.1 Study Area

The soil samples were collected from Tirunelveli district. These soil samples are tested for CBR, Liquid Limit, Plastic limit, Plasticity Index, and Grain Size Distribution. The results obtained from the study area have silty soil.

Fig 1 Location of the study Area

The Grain size distribution and the Atterberg's limits were obtained as test results from the Public Works Department, Tirunelveli. These tests were done per IS code specifications. And these test results can be correlated with the flexible pavement thickness of both highway roads and for the air field roads. Outcome of these tests are used to perform Regression Analysis. The correlation between the CBR and the other soil properties are done through the multiple linear regression. The main objective of this paper is the prediction of soaked CBR through the ANN modelling.

Table 1. Location of soil samples in Tirunelveli District.

S.No	Area	Location	Total Samples
1.	2	Tirunelveli-Pottalpudur	11
2.	2	Tirunelveli-Shenkottai	7
3.	1	Rajapalayam-Sankarankovil	7
4.	4	Palayamkottai	16
5.	1	Meenamangalam	2
6	2	Veeranamangalam	10
7.	1	Aralvoimozhi-Nedumankadu	2
8.	1	Balamore	2
9.	1	Alankaramoolai-kadambadivilakam	4
10.	1	Vazhaithottam	4
11.	1	Pilavilai Bridge-Viyannoor	6
12.	1	Pulichilmavilai-Saarur	6
		Total	**72**

3.2 ANN Model

Neural computing is an information processing paradigm inspired by biological system composed of large number of highly interconnected processing elements(neurons) working in unison to solve specific problems. A neural net is an artificial representation of the human brain that tries to simulate its learning process.

ANNs are widely accepted as a technology offering an alternative way to tackle complex and ill-defined problems. An ANN is an information processing pattern which works in a way that a human brain processes information. The Structure of this information processing system is composed of highly interconnected processing elements, called neurons working in parallel to solve problems.

A neural network helps when it is highly complex to formulate an Algorithmic solution and also where there is a need to pick out the structure from the existing data. Neural networks learn by example and they cannot be programmed to perform a specific task. They are fault-tolerant, that is, they are able to handle noisy and incomplete data, are able to deal with non-linear problems and once trained can assist in prediction and generalization at high speed. In more practical terms, neural network is a non-linear statistical data modelling tool. The tasks for which ANNs are useful fall into various applications such as control, pattern recognition, forecasting, optimization, etc. In this study, ANN is applied for the prediction of CBR value from soil properties.

An artificial neural network (ANN) is often called a neural network or simply Neural Net (NN). Traditionally, the word neural network is referred to a network of biological neurons in the nervous system that process and transmit information. Artificial neural network is an interconnected group of artificial neurons that uses a mathematical model or computational model for information processing based on a connectionist approach to computation.

The artificial neural networks are made of interconnecting artificial neurons which may share some properties of biological neural networks. Artificial neural network is a network of simple processing elements (neurons) which can be exhibit complex global behaviour determined by the connections between the processing elements and element parameters.

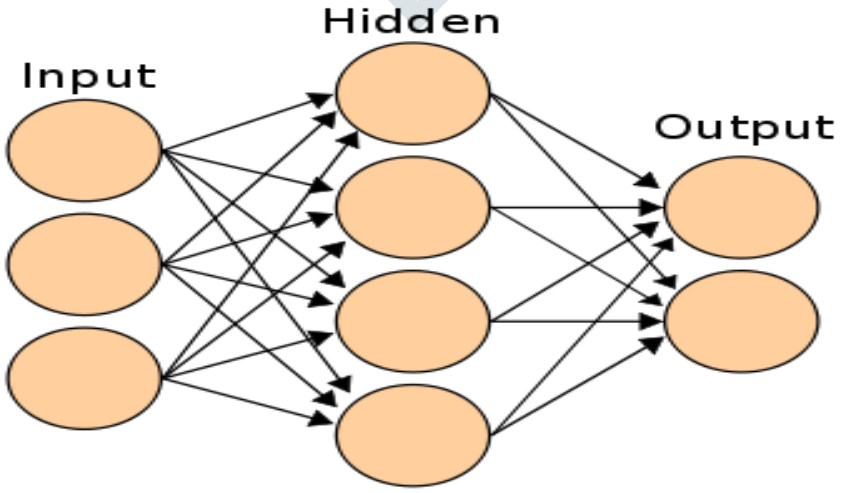
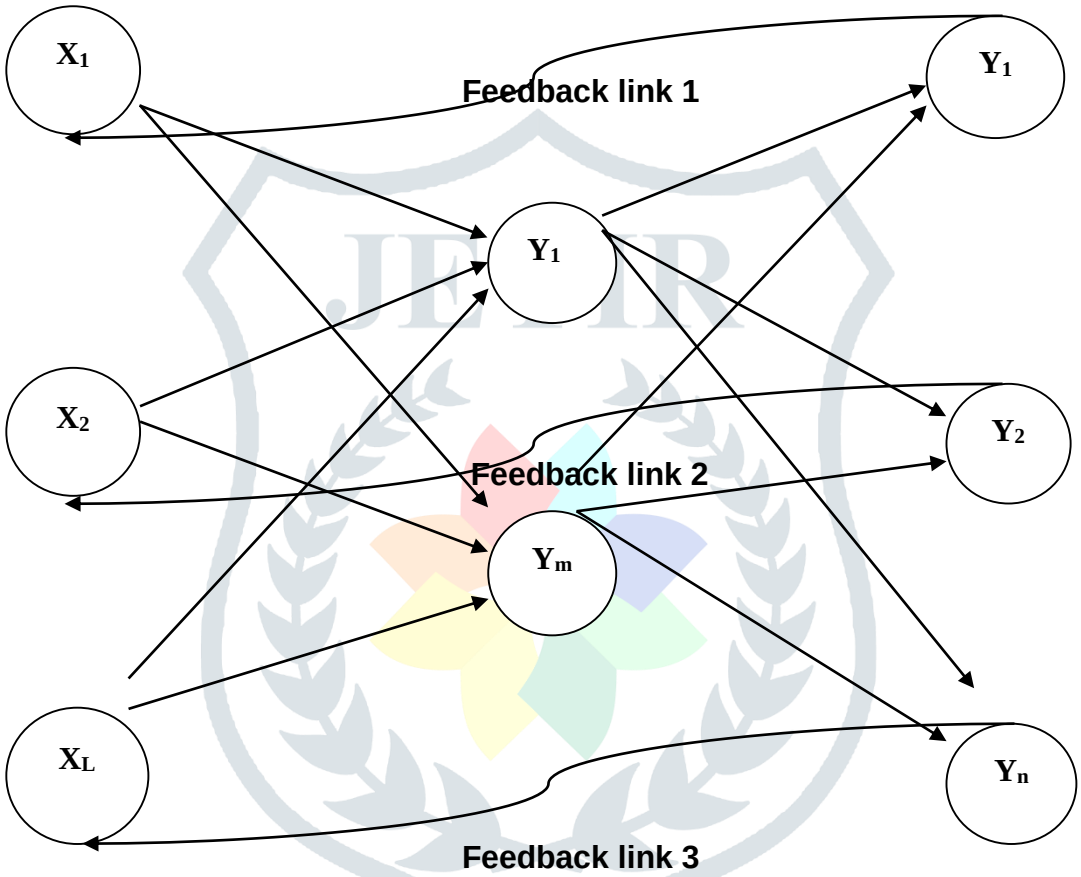


Fig 2 Architecture of ANN

Artificial neural network is an adaptive system that changes its structure based on external and internal information that flows through the network. An ANN is configured for a specific application such as pattern recognition or data classification through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons.

The recurrent networks differ from feed forward architecture. A recurrent network has at least one feedback loop. There could be neurons with self-feedback links.



Input layer neurons hidden layer neurons output layer neurons

Fig.3 Multi-Layer Output Recurrent Network

4.0 RESULT AND DISCUSSION

A multilayer perceptron propagation algorithm is implemented using STATISTICA 8 software to develop the CBR prediction model. Training is performed in batch mode. Normalization of data is essential as the variables used for the study are of different units. The database is constructed with the soil data obtained from the highway department in Tirunelveli dist. The values such as liquid limit, plastic limit, plasticity Index, 425 micron and 75 micron sieve size as the inputs whereas CBR is taken as the

output. As they were taken into the STATISTICA 8 software, the training and the testing are done simultaneously. The network used here is the Multi-layer perceptron, Hidden activation function as logistic and output activation function as exponential. The obtained prediction value is almost similar to that of that of the experimental value.

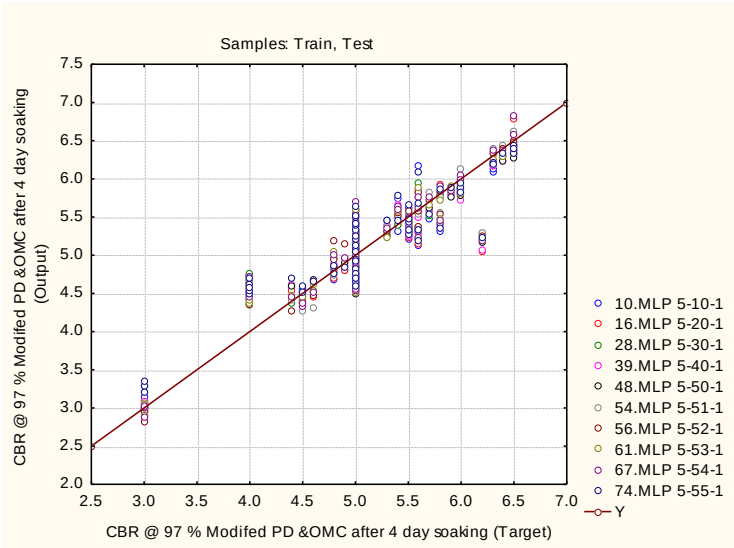


Fig 4 Graph for test and train values of CBR

The stability of the developed correlation is evaluated by Statistical Six Sigma software. From the results of this study the following conclusions are drawn.

Multiple Linear Regression equation expresses a linear relationship between a response variable y (dependent variable) and two or more predicted variable (dependent variable)

$$CBR = 4.52 – 0.239LL + 0.303PL + 0.182PI + 0.0304\ G_1 – 0.0720G_2$$

Where G_1 = 425 micron sieve size, G_2 = 75 micron sieve size

The P value less than 0.001 it is identified that the regression model is statistically significant with an R^2 value of 69.1 %. Positive values are significant values make an influence in the CBR value.

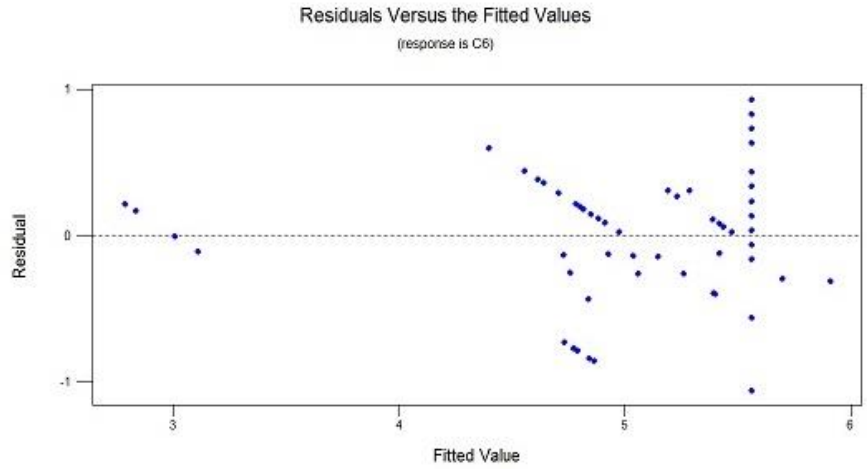


Fig 5 Residual versus Fitted Values

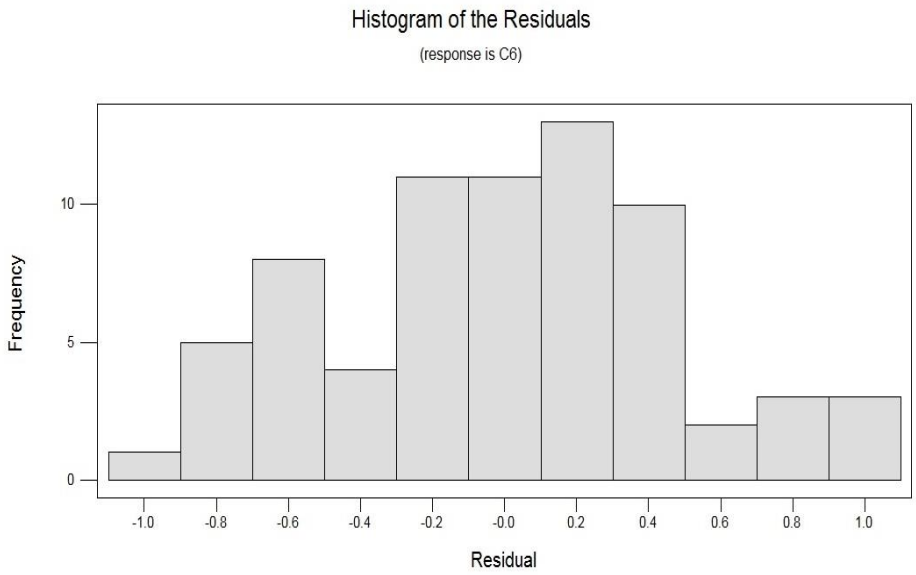


Fig 6 Histogram of residuals

This is how the analytical correlations between the CBR with other soil parameters are related through the equation.

From Fig 6, the histogram of the residuals is that the training period is performed at the equal intervals from -10 to 10.

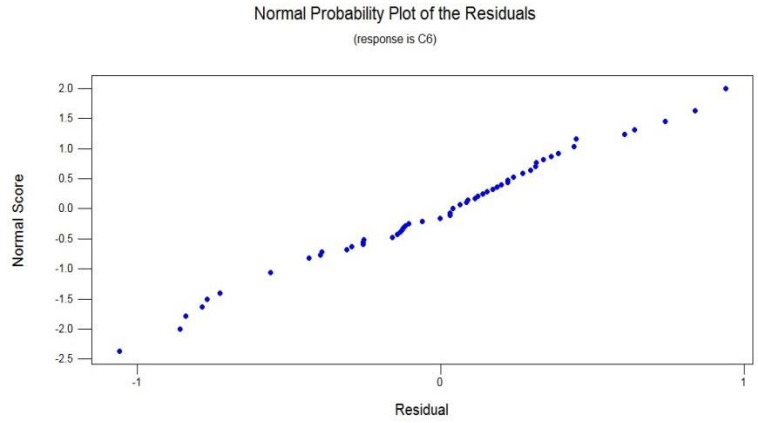


Fig 7 Normality probability plot of the Residuals

The Fig 7 says that the prediction of the CBR is significant and it can be possibly done.The correlation coefficient (R^2) values were close to 1 for both the training and testing data Test when the hidden neurons were increased. The ANN predictions for CBR correlation coefficient (R^2) of 0.951003 for training set for the network topology of 56.MLP 5-52-1. Similarly for testing set the ANN predictions for CBR yield a correlation coefficient (R^2) of 0.949158. Thus this model is used for predicting the CBR values of the Silty Soil.

REFERENCE

1. Venkatasubramanian, C., &Dhinakaran, G. (2011).“ANN model for predicting CBR from index properties of soils.” International Journal of Civil & Structural Engineering, 2(2), 614-620.
2. Muley, P., & Jain, P. K. (2013). “Betterment and Prediction of CBR of stone dust mixed poor soils”. *Proceedings of Indian Geotechnical Conference, December 22-24, 2013.* Roorkee: IIT.
3. Korde M., YadavR.K., (2015),”A Study of Correlation between CBR Value and Physical Properties of Some Soils”
4. Yildirim B., and Gunaydin O (2011) , “Estimation of California bearing Ratio by using Soft Computing Systems, Experts systems Applications, 38, 6381-6391.
5. R. Rasmin, “Comparison between sieve size analysis & Hydrometer with laser particle analyzer to determine particle size distribution”, Masters Thesis, University Malaysia Pahang, 2011.
6. Specifications for Road and Bridge Works, Ministry of Surface transport, 1998, Third Revision, IRC, New Delhi.

7. Dilip Kumar Talukdar (2014), A Study of Correlation Between California Bearing Ratio (CBR) Value with other Properties of Soil, International Journal of emerging Technology and Advanced Engineering, Volume 4, Issue 1, January 2014.
8. T. Taskiran "Prediction of California bearing ratio (CBR) of fine grained soils by AI methods" Advances in Engineering Software-41 (2010).
9. O. Gunaydın "Estimation of soil compaction parameters by using STATISTICAl analyses and artificial neural networks" Environmental Geology (2009).
10. Zelalem Worku Ferede "Prediction of California Bearing Ratio (CBR) value from index properties of soil"-Addis Ababa University, April(2010).
11. F. Sarmadian and R. Taghizadeh Mehrjardi "Modeling of Some Soil Properties Using Artificial Neural Network and Multivariate Regression in Gorgan Province, North of Iran"- Global Journal of Environmental Research (2008).
12. Patel, Rashmi S. Desai, M.D "CBR Predicted by Index Properties for Alluvial Soils of South Gujarat", Indian Geotechnical Conference-December(2010).
13. Saklecha P.P, Katpatal Y.B "Correlation of Mechanical Properties of weathered Basaltic Terrain for strength Characterization of foundation using ANN" International Journal of Computer Applications-Nov(2011).
14. Mehmet Saltan, Mesut TI Gdemir, Mustafa Karasahin "Artificial Neural Network Application for Flexible Pavement Thickness Modeling"-Turkish J. Eng. Env. Sci.,(2006).
15. Dr. K.V.Krishna Reddy, "Benefit Analysis of Subgrade and Surface Improvements in Flexible Pavements", International Journal of Civil Engineering & Technology (IJCIET), Volume 4, Issue 2, 2013, pp. 385 - 392, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.
16. Mukesh A. Patel and Dr. H. S. Patel, "Correlation Between Physical Properties and California Bearing Ratio Test on Soils of Gujarat Region in Both Soak and Unsoak Condition", International Journal of Civil Engineering & Technology (IJCIET), Volume 3, Issue 2, 2012, pp. 50 - 59, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.
17. Dr. K.V.Krishna Reddy, "Correlation Between California Bearing Ratio and Shear Strength on Artificially Prepared Soils with Varying Plasticity Index", International Journal of Civil Engineering & Technology (IJCIET), Volume 4, Issue 6, 2013, pp. 61 - 66, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.