Adaptive Neuro Fuzzy Approach for Permeability Prediction of Fly Ash and RHA Stabilised Soil

Patil N.L.
Research Scholar
Civil Engineering Department
NITTTR Chandigarh

Sanjay Sharma, PhD.
Professor and Head
Civil Engineering Department
NITTTR Chandigarh

Hemant Sood, PhD.
Associate Professor
Civil Engineering Department
NITTTR Chandigarh

ABSTRACT
Permeability of soil is an important parameter in pavement performance. Permeability of stabilised soil is quite different than the parent soil. Fly Ash and Rice Husk Ash (RHA) are the waste products, which can be utilized as a potential stabilization material for altering the permeability of soil subgrade. Present study undertakes to establish the methodology to predict the permeability of fly ash and RHA stabilized CL soil (USCS classification) using Adaptive Neuro Fuzzy Approach. Voids ratio and degree of saturation noted during the permeability measurement in laboratory forms the basis for development of Adaptive Neuro Fuzzy Inference System (ANFIS) model. For the purpose of study 16 data sets of different combinations of fly ash and RHA are used for training the ANFIS model and testing was performed with 11 data sets of different combinations for the same soil. The study reported average training error of 0.00010878 and testing error of 0.001238. The developed architecture can be used to predict the permeability of stabilized soil subgrade (CL soil) with varying proportions of fly ash and RHA.

General Terms
Subgrade strength; pozzolonic material; Adaptive Network; ANFIS architecture; Membership function; Training Error; Testing Error.

Keywords
Permeability; Fly ash; Rice Husk Ash; Soil Stabilisation; Voids Ratio; Degree of Saturation; Adaptive Neuro Fuzzy Inference System.

1. INTRODUCTION
Permeability of subgrade soil is an important parameter affecting the pavement design. Nowadays subgrade stabilization is essentially carried out to modify the subgrade strength properties. Various methods of stabilization [1][2] are required to be carried out to meet the design requirements. Fly Ash and Rice Husk Ash (RHA) are the pozzolonic soil stabilisers which are effective in improving the various soil properties [3][4][5][6]. Permeability of subgrade soil changes considerably [6][7][8] when stabilised with fly ash and RHA.

This paper primarily focuses on predicting the permeability of the CL soil (Low plasticity clay) (USCS Classification) stabilised with varying proportions of Fly ash and RHA. An Adaptive Neuro Fuzzy approach has been applied to determine the permeability of stabilised soil.

2.0 ANFIS APPROACH
Adaptive Neural Fuzzy Inference System (ANFIS) is an algorithm defined by J.S. Roger Jang in 1992. This algorithm creates a fuzzy decision tree to classify the data into linear regression models to minimize the sum of squared errors (SSE). ANFIS is an adaptive network. An adaptive network is a network of nodes and directional links. A learning rule, back propagation or hybrid is associated with the network. It's called adaptive because some, or all, of the nodes have parameters which affect the output of the node. These networks are learning a relationship between inputs and outputs. Figure 1 shows Sugeno type ANFIS architecture. Layer-0 is ANFIS inputs layer, Layer-1 states the membership function of each node that computes the membership value

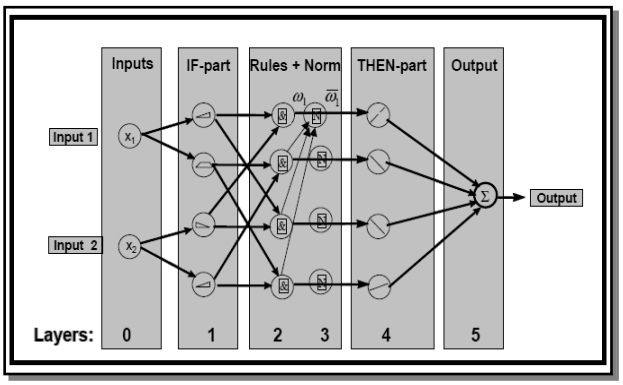


Figure1: ANFIS ARCHITECTURE

Layer-2 is rules layer computing the rules matching factor. Layer-3 is Normalization layer which contains fixed nodes calculating the ratio of firing strength of the rules. Layer-4 weighs the results of its linear regression fit in the function layer. The nodes in this layer are adaptive and perform the consequent of rules generating the rule output. Layer-5 is a single node that computes the overall output.

3. EXPERIMENTAL INVESTIGATIONS
Permeability studies are carried out in Highway Research Laboratory of National Institute of Technical Teachers Training and Research, Chandigarh, India. Low plasticity clayey (CL - USCS classification) soil collected from the nearby road sites was used for investigating the effect of stabilisation on permeability. F-class Fly ash from Ropar Thermal Power Plant and uncontrolled burnt RHA from the nearby rice mills around Chandigarh have been used to determine permeability of stabilised soils. The experimentations were performed with 10%, 20%, 30% and 40% fly ash content and 8%, 12 %, 16% and 20% RHA content by weight of dry soil. The study was carried out with these proportions independently with fly ash and RHA and in combinations of these two with the CL soil by variable head method. Voids ratio and degree of saturation of the soil are the important measures influencing the permeability of soil. In

order to develop an ANFIS model voids ratio and degree of saturation during the permeability measurement are determined. Permeability results are tabulated in the Table-1.

Table 1: Permeabilty of stabilised soil (CL)

FLYASH / RHA %	Permeability cm/sec
CL	4.34E-08
CL+10 %FA	1.86108E-08
CL+20 %FA	4.40628E-08
CL+30 %FA	1.11252E-07
CL+40 %FA	6.21717E-06
CL+8 %RHA	3.24702E-05
CL+ 12%RHA	1.31919E-05
CL+16 %RHA	1.35213E-05
CL+ 20 %RHA	1.19524E-05
Fly Ash	0.000029
RHA	0.000368577

4. ANFIS ARCHITECTURE

Soil properties are mainly governed by the soil water characteristics properties. Different Neural Network and fuzzy techniques are used for modeling the soil behaviour [9][10][11][12][13][14]. The permeability of a stabilised soil is a complex parameter, greatly influenced by the voids ratio and degree of saturation. The adaptive approach of ANFIS can be suitably applied to predict the reasonable estimates of the permeability of the fly ash-RHA stabilised soil. The CL soil content, Fly ash and RHA content, voids ratio and degree of saturation during permeability measurement after complete saturation are considered as the input parameters to predict the permeability. The ANFIS structure developed for the purpose of study is shown in Figure 2.

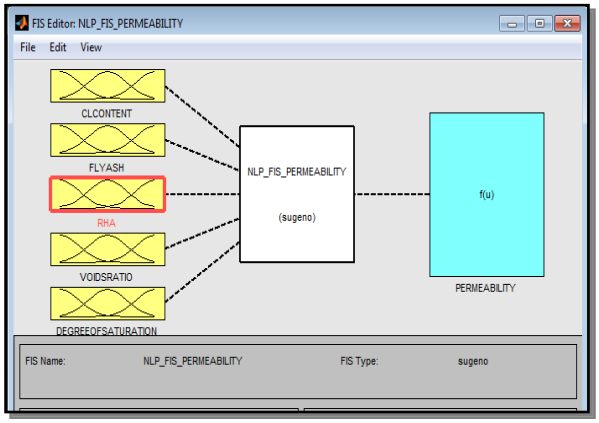


Figure2: ANFIS STRUCTURE

The Sugeno type structure was preferred for these investigations. Back propagation feed forward method have been adopted for optimization of the FIS model. The Fuzzy inference system was trained with 16 data sets of different combinations of fly ash and RHA content. The testing of the model was carried out with 11 data sets of different combinations of fly ash and RHA.

The average testing error reported during the execution was noted to be 0.00010878 and average training error was 0.001238 for 1000 epochs. The training error computation is shown in Figure 3.

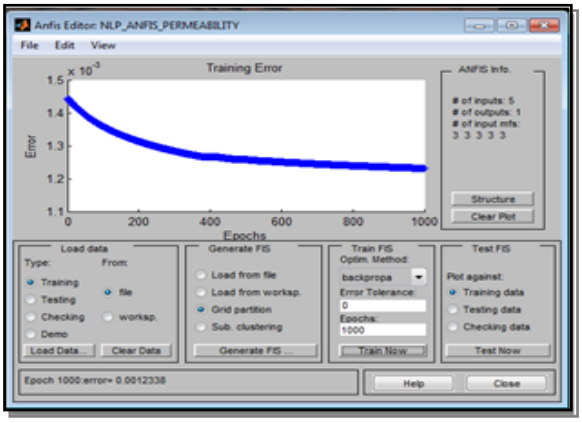


Figure 3: TRAINING ERROR FOR 1000 EPOCHS

The number of rules and other details of the ANFIS structure generated are as below:

Number of nodes: 524

Number of linear parameters: 243

Number of nonlinear parameters: 45

Total number of parameters: 288

Number of training data pairs: 16

Number of fuzzy rules: 243

Number of testing data pairs: 11

Figure 4 shows the FIS structure generated for five input variables namely CL, Fly ash and RHA content, voids ratio and degree of saturation used in the study.

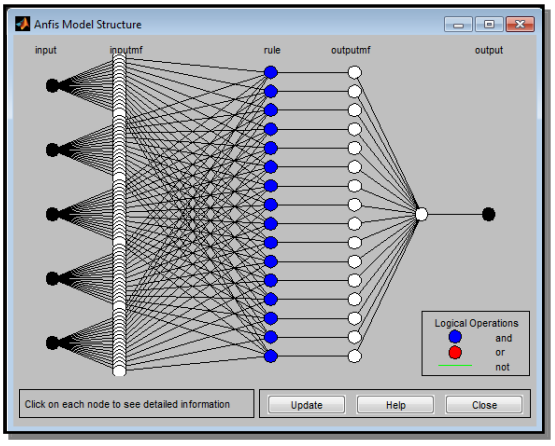


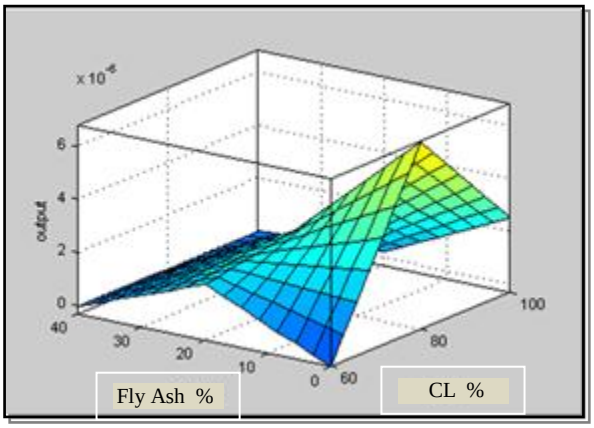
Figure 4: FIS generated for Five Inputs

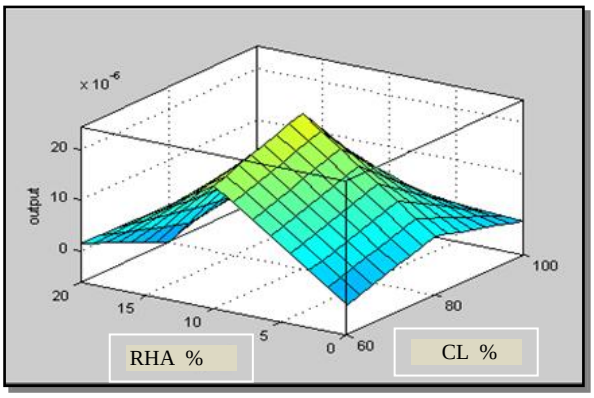
5. RESULTS AND DISCUSSIONS

ANFIS for permeability prediction of CL soil with five input parameters was successfully developed. The surface plot for varying proportions of fly ash and CL soil, RHA and CL soil, and Fly Ash and RHA are obtained. These surface plots are based on the voids ratio and degree of saturation obtained during the permeability measurement. These plots can be used to determine the permeability (cm/sec) of fly ash and RHA stabilised CL soil. Figure 6 shows the surface plots generated by ANFIS.

6. CONCLUSIONS

1. Fly ash and RHA independently, as well as in suitable combinations can be used to modify the permeability characteristics of subgrade soil.
2. Voids ratio and degree of saturation of stabilised soil subgrade can be used effectively for development of permeability prediction ANFIS model.
3. Permeability of stabilised subgrade soil can be determined by using ANFIS approach.
4. Surface plots can be developed for reasonable prediction of permeability
5. Optimum doses of fly ash and Rice Husk Ash can be determined using the surface plots for the required permeability of stabilised soil subgrade.





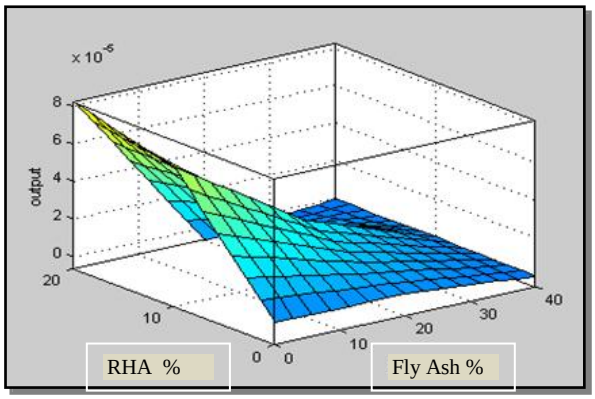


Figure 6: Surface plots for Permeability Prediction

FURTHER RESEARCH

The experimental investigations are extended to determine the effect of fly ash and RHA stabilization of different types of subgrade soils. The study also proposes to develop the ANFIS model for permeability prediction of these soils.

ACKNOWLEDGEMENT

Authors are thankful to Director, National Institute of Technical Teachers Training and Research Institute, Chandigarh, India for allowing undertaking the study in the Highway Research Laboratory of the institute. The financial assistance provided under QIP (Poly.) scheme by All India Council for Technical Education, New Delhi, India is also duly acknowledged.

REFERENCES

[1] Guidelines on use of local materials, Pradhan Mantri Gram Sadak Yojana (PMGSY), National Rural Roads Development Agency India Annexure 5.4.

[2] Sanjay Sharma Hemant Sood and Patil N. L. 2010 Subgrade Strengthening with Geosynthetics and Non-biodegradable Wastes: A Perspective Journal of Engineering and Technology Education, 4(1) 2010 7-14

[3] Agus Setyo Muntohar 2002 Utilization of uncontrolled burnt rice husk ash in soil improvement Dimensi Teknik Sipil 4(2) 100-105.

[4] Dr A K Choudhary and Dr B P Verma 2005 Behaviour of Reinforced Flyash Subgrades IE (I) Journal.CV, 86(May) 19-21.

[5] D.S.V. Prasad and G.V.R. Prasada Raju 2008 Evaluation of Different Reinforced Subbases on Expansive Soil Subgrades International Association for Computer Methods and Advances in Geomechanics (IACMAG) The 12th International Conference of 1-6 October 2008 Goa, India 3621-3627.

[6] Patil N. L. Sanjay Sharma and Hemant Sood 2011 Soil Stabilization Techniques For Pavement Subgrade National Seminar on Emerging Trends in Civil Engineering NITTTR Chandigarh India.

[7] Patil N. L. Sanjay Sharma and Hemant Sood 2012 Pavement Subgrade Stabilisation With Rice Husk Ash National Conference on Technology and Management Visnagar Gujrat India January 2012.

[8] Praveen Kumar and Shalendra Pratap Singh 2008 Fiber-Reinforced Fly Ash Subbases in Rural Roads, J. Transp. Engg. 134(4) 171-180.

[9] Sezer A Göktepe A.B. and Altun S. 2009 Estimation of the permeability of granular soils using neuro-fuzzy system AIAI-2009 Workshops Proceedings Department of Civil Engineering, Ege University Izmir, Turkey, 333-342

[10] Sarmadian F. Taghizadeh R Mehrjardi and Akbarzadeh, 2009 A Modeling of Some Soil Properties Using Artificial Neural Network and Multivariate Regression in Gorgan Province, North of Iran Australian Journal of Basic and Applied Sciences 3(1) 2009, 323-329.

[11] Deng, He-pu 2009 Developments in Fuzzy Multicriteria Analysis Springer and Fuzzy Information and Engineering Branch of the Operations Research Society of China, 1103-1109

[12] Venayagamoorthy V and Allopi D. 2009 Use Of Neural Networks In The Prediction Of Bearing Capacity Of Pavement Structures Proceedings of the 26th Southern African Transport Conference (SATC 2007) 9 - 12 July 2007 320-327

[13] Sarat Kumar Das, 2011 Using Neural Networks for Prediction of Some Properties of Fly Ash Electronic Journal of Geotechnical Engineering 13(D) 1-14.

[14] Khaled Ahmad Aali Masoud Parsinejad Bizhan Rahmani, 2009 Estimation of Saturation Percentage of Soil Using Multiple Regression ANN and ANFIS Techniques Computer and Information Science Journal, 2(3) 127-136.