Slope stability analysis by artificial neural network

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ABSTRACT: Artificial neural network (ANN) is well trained and estimated factors of safety by the network are in permissible limit with calculated values of Bishop's modified method. Three cases have been covered to see the advantage of use Expanded polystyrene (EPS) blocks as lightweight fill in the embankment. Due to its very low unit weight material when used as fill increases the factor of safety. Thus embankments are made quite stable by introducing EPS blocks as fill materials. The use of EPS blocks along with reinforcement provides greater factor of safety. Thus use of EPS blocks can be recommended where the subsoil is weak and loads acting on this subsoil are high.

1 INTRODUCTION

Artificial Neural Network (ANN) is a new technique emerged to meet the requirements of engineers to solve various complex problems. It is rather based on decision making hence it is gaining log of popularity compared to other computational techniques. It is constructed from a set of simple processing units, which can be arranged easily. Duncan (1996) has given a very extensive note on the prevalent methods of deformation analysis, Griffiths and Lane (1999) have used Finite Element method to determine the slip surface and factor of safety. The method of slices, developed by Bishop (1955), gave a breakthrough to the practical aspects of slope stability evaluation. Fredulund and Krahn (1977) have reported a detailed comparison of different limit equilibrium methods. Some generalized methods applicable to any arbitrary shape of slip surface were developed (Morgenstern and Price, 1965, Chowdhury, 1978, Bhowmic and Basudhar, 1989) Venetsanopoulos (1993) suggested a methodology for a network with one hidden layer that selectively deactivates the redundant hidden nodes during the training process. Fletcher et al. (1998) has reported a recursive algorithm to optimize the number of hidden nodes based on non-linear regression. Slope stability evaluation under the purview of limit equilibrium method, has been the topic of research for quite a long time. It can be released from the literature that a fairly good amount of work has been done on the methods to compute a factor of safety on a known slip surface. Usually, the factor of safety calculated by rigorous methods involve many simplifying assumptions regarding these factors and, at times, it may be difficult to quantify the effects of these simplifying assumptions on the value of factor of safety. A sensitivity analysis would be of help to quantify the effect of each factor on the stability. Collection of data is certainly a difficult task though mathematical tools such as Artificial Neural Network (ANN) are of great help for processing the same leading to sensitivity analysis. For slope stability problem, there are large numbers of input parameters. Factor of safety calculated depending on such large number of input parameters requires many trials to be adopted to set the satisfactory solution. Factor of safety depends on many factors hence even for homogeneous soil case, we require large number of trials. ANN makes this whole process of trial and error method simple.

2 METHODS OF TRAINING ARTIFICIAL NEURAL NETWORK

Training of neural network is done by following methods.

1. Back propagation method
2. Cascade correlation method.

- Back propagation method

This is easy and best-known method of ANN analysis. It consists of one or more hidden layers. This is called back propagation method as back propagation of error signals is transmitted through the network. A network is trained in following steps.

1. All weights are initialized to small random values.
2. Feeding input vectors.
3. Output from ANN analysis.
4. Calculation of % error between ANN output and desired output.
5. The weights are adjusted in such a manner to reduce the % error.
6. The repetition of step 2 to 5 until % error is within the acceptable limit.

- Cascade correlation method

1. The learning rate is very fast.
2. Size of network is decided by network itself.
3. It retains its structure even if the training set is changed.

3 METHODOLOGY

The various steps for prediction of factor of safety by ANN are as follows:

1. Selection of input parameters.
2. Generation of input data.
3. Normalization of data
4. Training the neural network.
5. Problem solving.

4 SELECTION OF INPUT PARAMETERS

The first step is very critical. The whole process of modelling may affect if sufficient and necessary input parameters are not included in the modeling. When the problem involves complicated field conditions, then choice of input parameters become difficult.

5 GENERATION OF INPUT DATA

The input data can be obtained from field data or any other analytical methods. The soil properties as well as material properties of EPS geofoam material are taken in the permissible range. The effect of pore water is also included.

6 NORMALISATION OF DATA

Before applying ANN, it is necessary to normalize the input data. Normalization of data means expressing each input parameter between 0 and 1, then the input data takes following normalized form.

$X_{norm} = (X_a - X_{min=}) / (X_{max} - X_{min})$ (1)
where X_{max} and X_{min} are the maximum and minimum values of a given parameter.
X_a – The value to be normalized.
X_{norm} – Normalized value of given parameter

7 TRAINING THE NEURAL NETWORK

The training process is carried through a large number of cycles to achieve a reasonable accuracy. The number of hidden nodes is important parameter for attaining precision in the result. A weight matrix is generated at the end of training process which can map inputs on the outputs. The weight matrix also has to be checked to understand its validity. For this purpose some data is reserved. If the expected factor of safety, then it can be said that the neural network is well trained and now it is able to predict factor of safety for different cases, but if the factor of safety predicted by the network does not hold within the range of computed one, then we have to train the neural network again.

8 PROBLEM SOLVING

After well training the network, estimation of factor of safety becomes quite simple rather than going for rigorous conventional method taking too much trails. Instant estimation of factor of safety is possible with the help of neural network.

Input data for Artificial Neural Network

Following are the cases which are investigated by Artificial Neural Network.
Case 1 : Clay embankment on clay subbase layer.
Case 2 : Embankment made of EPS blocks on clay subsoil layer.
Case 3 : EPS embankments with reinforcement on clay subsoil layer.
Input data for all three cases is included in the report (Nimbalkar, 1999).

9 RESULTS AND DISCUSSION

Fig. 1 shows various input parameters used for slope stability analysis by Bishop's modified method. Results of Bishop's modified method are shown in Fig. 2 and 3. Fig. 2 shows case for clay embankment on clay subsoil. Fig. 3 shows case for EPS embankment with reinforcement on clay subsoil. As shown in fig. 2 and 3 factor of safety increases as the application of EPS geofoam as embankment fill material is done instead of other conventional type of fill materials. When EPS along with reinforcement is used, the factor of safety increases further showing embankment slope more stable. Thus, EPS improves slope stability. The output data of ANN analysis for three cases are illustrated in Table 1. The factor of safety obtained from ANN are found to be good agreement with the results obtained from Bishop's method.

Table 1.

	Factor of Safety		
	Bishop's Modified Method Result	Artificial Neural Network Results	Percentage of Error in ANN Analysis (%)
Unreinforced	0.5494	0.548792	0.1106157
Goefoam	1.0237	1.017186	0.636317
Geofoam and Geogrid	1.3535	1.352895	0.044710

10 CONCLUSIONS

Bishop's modified method for slope stability has been done to investigate factor of safety for various cases. There is increase in factor of safety when EPS blocks are introduced as a filling material in the embankment. Also if has been proved that EPS geofoam can successfully used along with the reinforcement of geotextile and geogrid to increase factor of safety.

Artificial neural network is successfully applied for slope stability analysis of embankment on soft soils and it's results are found to be in good agreement with the results of Bishop' modified method.

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