Estimation of Atterberg Limits of Soils by Artificial Neural Networks

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Abstract

Soils intended to support structures, pavements or other loads should be evaluated by geotechnical engineers to predict their behavior under conditions of applied forces and varying humidity. Soil mechanics tests in geotechnical laboratories measure particle size distribution, shear strength, moisture content, and the potential for expansion or contraction of cohesive soils. Atterberg limit tests determine the moisture content at which fine-grained clay and silt soils transition between solid, semi-solid, plastic and liquid states. Artificial neural networks (ANN) is an information processing technology inspired by the information processing technique of the human brain. In this study, the determination of the Atterberg limits, which are frequently used for the determination of soil properties in geotechnical engineering and their comparison with experimental data, were determined and the results showed a very similar pattern.

Keywords: Plasticity Index, Liquid Limit, Geotechnical Engineering, Artificial Neural Networks, Civil Engineering

INTRODUCTION

Applications of Artificial Neural Networks (ANNs) in civil engineering, including geotechnical, have increased. Işık and Özden (2013) used ANN prediction models to estimate the compression parameters of both coarse and fine-grained soils. A total of 200 soil mixes were prepared and compacted in standard Proctor energy. Compression parameters were estimated through ANN models using different input datasets. ANN prediction models have been developed to find which index features are well correlated with compression parameters.

Transition fine content ratio (TFR) was defined as a new input parameter in addition to the soil index parameters. It has been shown that the optimum water content (Wopt) and maximum dry unit weight estimation can be made with high accuracy using the parameters of the foundation soil index. However, the desired predictive accuracy and generalization ability can be achieved by properly normalizing and dividing the data.

In this study, it is aimed to determine the Atterberg limits from the soil properties experimentally and to estimate them using artificial neural networks and compare the values. Such studies have been carried out before in geotechnical engineering experiments. To give one recent example, Azadmard et al. (2020) conducted a study to compare the effectiveness of multiple linear regression (MLR) and hybrid GA method with ANN for the prediction of nearly saturated soil hydraulic properties. The results of the MLR analysis showed that this method has the potential to predict nearly saturated soil hydraulic properties in the study area. The higher performance of the GA-ANN models compared to the MLR models confirmed the existence of nonlinear relationships between the physical and chemical properties of the soil and the hydraulic properties.

MATERIALS AND METHODS

In fine-grained soils (cohesive), the softness and hardness of the soil is indicated by the consistency. As the amount of water in the fine-grained soils increases, it varies in a wide range from a very solid state to a fluid liquid consistency. Accordingly, there are great differences in engineering properties such as strength, strain under load, and compression.

In order to experimentally determine the changes in the consistency of fine-grained soils depending on the water content, some limit water content values have been defined. Experiments developed by Swedish scientist Atterberg are used to determine these values, known as consistency limits.

The liquid limit is the water content when the soil changes from a plastic material to a flowing material. There are several methods for determining the liquid limit. Among these, the Casagrande Method is widely used. The Casagrande liquid limit instrument is placed on a solid rubber block by 1 cm when the handle is turned. It consists of a hemispherical brass bowl falling from a height.

Performing the Liquid Limit Experiment:

a) Some amount is taken from the ground that has been dried and passed through the sieve no. 40, placed in a porcelain bowl and mixed by adding some distilled water.

b) Wait for a while for the sample to cure.

c) A little is taken from the mixed sample. The rice bowl is placed. It is smoothed out with a spatula. The sample in the bowl is divided into two with a slit cutter. Once again, the upper part is corrected, while dividing it into two, care is taken to ensure that both parts are of equal size.

d) Then the handle of the tool is turned and the stone is 1 cm. It is dropped from height 2 times per second. With the effect of falling, the cavity begins to close, and the two separated parts begin to approach each other.

e) Each stroke from the start, the slot 1.12 cm. counted until closing. As soon as it is closed, some sample is taken from here to determine the water content and the number of strokes is recorded.

f) The bowl is cleaned, a little more distilled water is added to the sample in the mixing bowl and mixed.

g) Operations c, e, f are done sequentially. This process should be repeated at least 4 times.

At the end of the experiment, a logarithmic scaled stroke number – water content graph is drawn. The water content value corresponding to 25 strokes from the graph is determined as the liquid limit value.

Plasticity is a feature of fine-grained soils and means being able to be shaped without breaking. The plastic limit is defined as the water content at which cracks appear on the surface of the wet soil during kneading. In other words, the plastic limit is the water content value at which the soil transforms from a semi-solid material to a plastic material.

Performing the Plastic Limit Experiment:

a) A portion of the sample, which has been passed through the sieve no. 40 and used for the liquid limit test, is rolled on the frosted glass with the palm of the hand.

b) 3 mm formed during rounding with the palm. thick bars, when cracks and self-breaking occur, they are taken into the sample cup to determine the water content.

c) The sample weighed together with the sample container is left for drying in the oven.

d) If the ground rods do not crack or split even though the diameter is below 3 mm, the ground is considered to be plastic yet.

e) It is expected that the water content will decrease for a while. The experiment is continued by repeating the rounding process with the palm of the hand, and it is applied for options b and c.

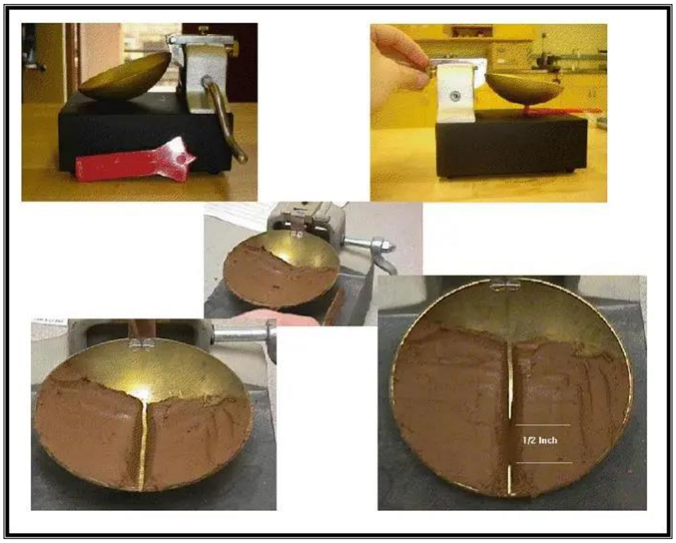

Figure 1. Casagrande Apparatus

RESULTS and DISCUSSION

Figures 2 and 3 show the graphical comparison of Liquid limit and plasticity Index values, respectively. The X-axis shows the experimentally calculated data, while the Y-axis shows the predicted data by the ANN. As can be seen from the figure, the estimated and data overlap very significantly with the experimental data. So much so that the R^2 values are very close to 1.

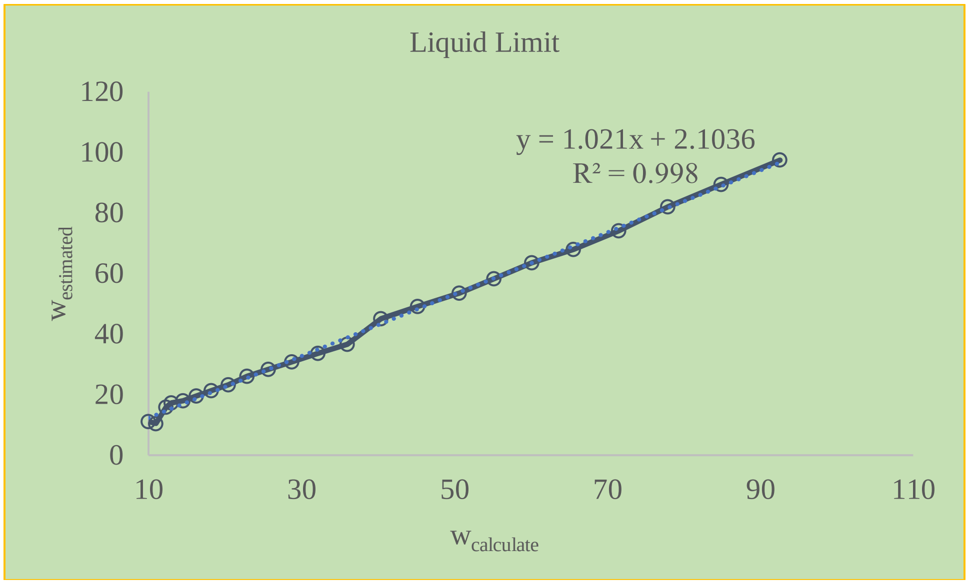

Figure 2. Liquid Limit Comparison

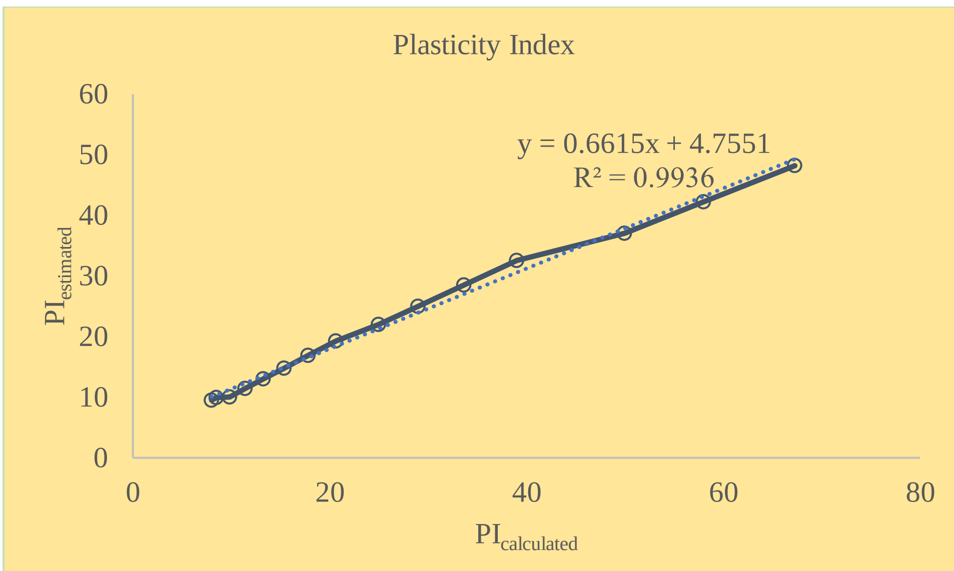

Figure 3. Plasticity Index Comparison

CONCLUSION

In recent years, the use of expert systems such as machine learning or artificial intelligence methods has become widespread in the creation of soil properties and soil behavior prediction models. It is seen in the literature that soil properties are successfully estimated using expert systems. This study, it is aimed to introduce new generation methods for determining soil properties (Atterberg limits) and explaining soil behavior in geotechnical engineering. Artificial intelligence methods such as artificial neural networks and fuzzy logic are frequently used today to determine soil properties and explain soil behavior. Artificial neural networks are an advantageous method compared to traditional regression methods.

It should be emphasized that once the model has been trained and tested, it can be used as an accurate and fast tool for estimating settlements under specified conditions. It is thought that a new phase has been passed with the use of these new-generation trends in geotechnical engineering.

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