

Prediction the Ground Water Level and Deformation of Adjacent Foundation for Saturated Sand Soil by ANN Approach

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Abstract

Geotechnical engineering is important, as can be seen in excavation sites for new buildings being built next to existing ones. It is a major problem that population density in urban cities was on the rise, leading to an actual crisis in housing and vertical building constructions at city centers demanding stability of foundations and soil hydraulics studied and investigated with various soil types.

This research studied the influence of hydraulic properties of saturated sandy soil using experimental method for simulating the fields, a laboratory device with three gradations sandy soil saturated, a (135) experiments were carried out with different parameters, varying excavation depth next to sheet pile, distance between foundation and sheet piles, and apply three vertical loads on the shallow foundation besides measuring both foundation settlement and water table downstream. including practical experiments for each type of soil.

Results confirmed that as the intensity of excavation was increased, both the foundation displacement and water level rose; these results gradually decreased with finer soils; meanwhile, as far as a distance between adjacent foundation and sheet pile is concerned, it has a reverse proportionality to displacement and water level—so smaller the equilibrium status appears critical—so larger the distance from adjacent structure. As for the context applied to stress on shallow foundation, the correlation is directly proportional with the increment of value of stress, foundation displacement respectively, and incremental water level.

The prediction of soil behavior and stability of foundations was performed using the statistical analysis for experimental data, which is a proposed method using artificial intelligence technique based on weight in representation by neural networks.

approaches using artificial intelligence models can accommodate the mathematical relationships between independent and dependent phenomenon variables with sufficient fidelity to yield predictive solution structures accurately.

The results of the analysis showed that reasonable prediction accuracy was assumed by the artificial intelligence model; for the same outcome, 97% and 98% were regression coefficients related to the artificial intelligence model, respectively.

Key words: *Adjacent foundation, saturated sand soil, statistical expressions*

Introduction

This study illustrates the properties of saturated soils and the effects on adjacent foundations in a diverse set of scenarios, both experimental and statistical. Deep excavation projects sometimes affect ground water with or without its presence, as it is believed that the major issue here deals with not disturbing the neighboring foundation stability.

Oztoprak and Bolton (2013) An empirical formula with reasonable standard deviation and proper random of error based on the good data base for determination of sand soils adjacent to various structure buildings. This new point of view on nonlinear simply creates ability to use in filed. [1].

D. Esmaili & N. Hataf (2013) The purpose of this study is to review the geotechnical behavior of two types of shell foundations under axial loading stress and provide a detailed analytical formulation for their bearing capacity. In pursuit of this, A series of laboratory tests were carried out in six varieties of shell foundations(conical and pyramidal shell foundation) [2].

Nyuina et al (2016) A number of experimental testes on a section of shallow foundations using unsaturated sandy soils were carried out to represent that the bearing capacities under unsaturated conditions are significantly more than the saturated water in shallow foundations. The researchers introduced two types of square footing size, loaded as laboratory models to measure the matric suction and showed a nonlinear mathematical form relation between bearing capacity to matric suction [3].

Hakam et al (2019) The increase in pore water pressure in the soil mass can affect the bearing capacity of that foundation thereby endangering its stability especially in sandy soil where an increase in pore pressure may cause failure of foundation. The model was designed to reach saturated conditions. The test result shows that a sand boil emerged onto the soil surface at the last stage, which contributed to the foundation model failure. It also implies reduction of bearing capacity due to reduce in effective tension in soil mass [4].

Jan-David (2019) Buckingham's II-Theorem provides a method of approximating the form of physical equations by considering the dimensions (physical units) of relevant quantities. We will demonstrate Buckingham's Theorem quantitatively, which is "purely mathematical" in that it does not explicitly involve physical units. [5]

Karthigeyan et al (2021) Long length excavations under plane strain and short length ones under three-dimensional conditions were considered. The results indicate that the response of a square footing to adjacent excavations is important and primarily controlled by excavation dimensions. More the depth of excavation, more is the vertical and horizontal displacement bending moment of footing [6].

Grzegorz and Jerzy (2021) pose a tricky safety challenge for both new and old buildings. During construction, temporary steel bracing is typically used to provide stability and prevent uncontrolled collapse of buildings or building components. Then as deep excavation deformations, it can cause a building to be reactive, which cannot be separated

from the accurate measurement of deformation and stress changes. Soil movement can impose threats such as building deformation, cracks, etc., in order to minimize damage and prevent failure on buildings the application of protective measures is necessary along with current innovative technologies while usually using temporary bracing structures utilize steel bar braces in this Push-Pull Props system [7].

Syed Ubai& Syed Uzair (2021) Dimensional analysis is the best practice to create data, organize data, validate experiment results. In dimensional analysis, the Buckingham Π theorem is important because it considers products of quantities of no dimension. This post discusses Buckingham theorem extensively and its applications. In addition to experimental data design and presentation, we will show how the effective visualization of scientific findings in terms of dimensionless data can promote a more multifaceted interpretation of results. Thus, for nondimensional experiments it becomes easier to reduce output tables or"-volumes down to a single set of curves, or even just curve. So, we can do this by dimensional analysis.[8]

Trejo-Alonso et al (2021) applied single-layer and multi-layer perceptions artificial neural networks for estimating saturated hydraulic conductivity (KS), using 900 samples measured from Irrigation District 023, San Juan del Rio, Queretaro State in Mexico. All models consist of two hidden layers, a back-propagation learning method and a logistic function for nonlinear transfer. By choosing the array of hidden layers, you can explore this only by rebooting the neural network for each hidden layers array and using the one with low Root Mean Square Error (RMSE) value. compare the results to pedotransfer functions and other neural networks reported in the literature. The outcomes suggest that artificial neural networks reached RMSE scores of 0.0459 to 0.0413 and R2 values from 0.9725 to 0.9780, consistent with the prior studies.” Also, reducing input data yields better results [9].

Mohamed et al (2023) Excavation of deep pits in presence of pile foundations, new buildings very close to high rises are built due to congestion in cities. When a new construction project is excavated in proximity to existing piled structures, nearby buildings may settle or tilt. Thus, predicting soil movement and pile behavior becomes essential in the development phase of a building to avoid costly damage to its neighbors during its lifetime. Advances in Earthquake Engineering and Structures Further down, the study confirms how excavation depth affects pile settlement and cap tilting, with two piles close to the excavation exhibiting a large cap tilt while also small pile group settlements. [10].

Jiachao et al (2023) Due to the excavation of a foundation causes variation in stress field and influence surface subsidence of adjacent buildings, deformation control is an important condition. On the other hand, numerical simulation and experimental results compared to verify the accuracy of a foundation pit excavation model also obtained independent of particle size effect reliable ratio of building width to average sand particle size. Surface settlement of excavation model test and law of distribution and variable. The natural deformation characterization of foundation and the correlation between pit depth, building load were also determined [11].

Khalil et al (2024) Laboratory loading tests have been performed on a model sandy soil footing at various saturation levels to investigate the effects of degree of saturation on bearing capacity and failure mechanism sandy soil, which an experimental method was used to address in this study for sandy soil samples taken from the Tartous and Palmyra locations In this study, experimental data was used to propose an empirical relationship to find a simulation of the bearing capacity of partially saturated sandy soil. The results also indicated that the saturation degree had a significant influence on the failure mechanism. Medium dense

soils were observed to have at certain saturation levels a mode of failure in the tested soils [12].

D. Esmaili & N. Hataf (2013) On this basis, this study investigates the geotechnical behavior of two different types of shell foundations subjected to axial stress and presents a comprehensive formulation for their bearing capacity. In this respect, a number of laboratory tests were performed on six different types for shell foundations, which are referred to as conical and pyramidal shell foundations. [2].

The analysis of shell foundation geometries was derived using the Buckingham-Pi theorem to determine the ultimate load capacity. The proposed formulations were used based on experimental results of earlier studies conducted into shell footings, as per the referenced literature. It becomes evident from the currently explained laboratory studies that pyramidal shell foundations, in comparison to conical foundations, have better bearing capacities and as synergy capacity rises so does a lower supporting capacity of the foundations. Dimensional analysis-based equations for load-carrying behavior (or capacity) of shallow shell foundations have shown good correlation with experimental data. [2]

Agyare et al., (2007) For hydro-ecological initialization, soil data are essential. Soil hydraulic characteristics are difficult to measure directly and must be computed. This study uses artificial neural networks (ANN) to calculate soil properties and topographical factors in order to assess the permeability of saturated soil (K), a critical soil hydraulic quality, at locations basin. Quantities, range, and distribution are examples of respectable data that are thought to be essential for an acceptable ANN approximation. With sufficient and sensitive data, ANN may evaluate K using soil factors such as clay, silt, sand, and organic. Terrain features can also enhance ANN in K estimate, although they are not as accurate as the individual input parameters for the study's size. Topsoil K s was significantly impacted by the training data source, but not subsoil [13].

Williams and Ojuri (2021) Because soils differ and their hydraulic conductivity varies, take into account the characteristics of easily accessible predictive approaches for hydraulic conductivity estimation. In order to anticipate permeability in different types of soil, this study compares the effectiveness of artificial intelligence using neural networks and regression data via multiple linear expression. ANN and MLR models were developed using six input variables. Three input variables are deemed statistically significant in the MLR model expansion. The mean square of error and coefficient of determination show the models of ANN and MLR achievement investigations. When compared to earlier models, the developed ANN and MLR seem to perform better [14].

Elbisy and Bostaji (2025) Because it shows the soil's capacity to transfer water depending on pore size and structure, the hydraulic conductivity of saturated soil is essential for creating efficient drainage systems. In order to assess saturated soil hydraulic conductivity (K field) in sandy soils impacted by saline and alkaline environments, this study used Artificial Neural Networks (ANNs) and tree boost models. The ANN models used were a General Regression Neural Network (GRNN) and a Multilayer Perceptron (MPNN). The physical and chemical characteristics of soil samples from El-Nubaria and Sinai in the western delta of Egypt were assessed in a laboratory. To assess the relationship between these characteristics and the K field, we employed statistical analysis. Five assessment criteria and cross-validation were used to train and assess the model. The tree boost model is more accurate and predictive than the ANN model, indicating that it may be used to calculate the K field in complicated soil or with little data [15].

Experiential Study

This examination was preceded by a series of experimental preparations to allow the behavior of saturated sandy soil under loading and the effect of adjacent excavations on nearby buildings and foundations. The proper experimental result remains behind the stage for no special treatment of sand sample preparation. The sand became gradually wet and the trapped air in between the grains is liberated when water was added slowly at a steady pace to achieve a field-like saturation. Three samples of uniform graded sand were selected according to three grades: The residue on sieve (No. 16) or (1.18 mm) represented the first sample while that on sieve (No. 30 or (0.6 mm) represented the second sample while that on sieve No.(50) or(0.3 mm) are taken as third sample.

The glass model is 60 cm in length, 40 cm in width and 30cm in height for three different sand samples so has been produced laboratory model representing behavior of saturated sandy soil influenced by loads and surrounding excavations under controlled conditions. This design makes it possible to provide a clear view of the environment of the sand, track the flow of water in its interior and record changes in pore pressure and potential collapses during excavation while also having measuring instruments installed on its glass walls for monitoring displacements...A wooden base was manufactured around the height-adjustable glass model at 10 cm, which allows for securing its protection and safe distance from conducting an experiment. Lab-fitting dimensions were chosen in this model, taking into consideration that the thickness is sufficient for laboratory work, and given the effective depth we need for the experiment is 20 cm, a depth of 30 cm was selected with additional margin. where the soil was composed of saturated layers (horizontally) with sandy soils where the model is filled—well enough to ensure complete saturation conditions, and which can also have a different orientation for vertical loads that gradually apply to show structural responses If we look closely, there is an aspect representing a sheet pile; here it shows only one glass plate inserted in horizontal curvature so that during excavation it will hold the arranged excavated soil from one side. The part is vital where structural positioning gives support work in this experiment.

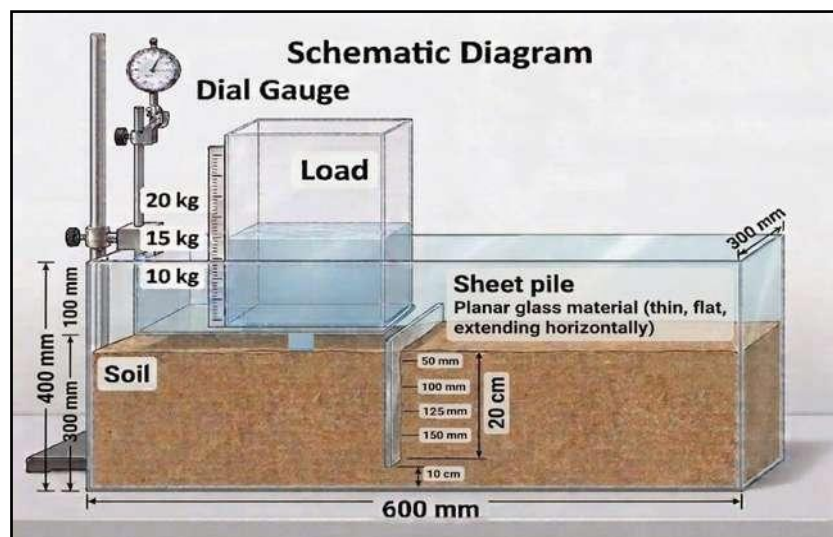


Plate1: Experimental model schematic diagram.

The foundation was modeled as a glass element; this is done so that no deformation occurs in the shallow footing when it stands on saturated sandy soil. This component was flexible on the soil surface, shallow basis on saturated sandy soil inside reasonably transparent glass tank represented by glass version basis measurement: 5 x 30 x 2 cm, used for both the tank walls and then the foundation to make it possible to immediately monitor changes which happen in the dirt if loads are applied, like water flow W as well as variations in water level or deformations and settlement from this soil layer surrounding the foundation..

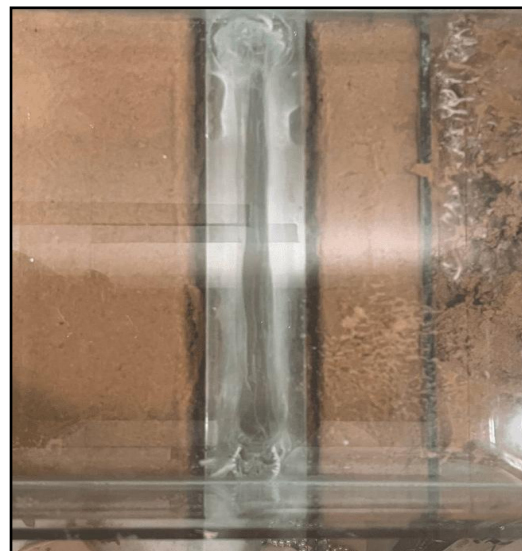
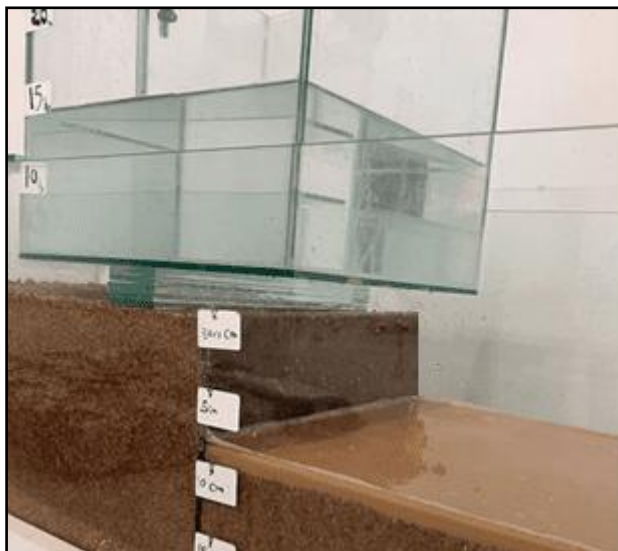


Plate 2: Foundation part.

The device is a precision measuring device used to determine variations in distance or displacements. It is often used in engineering labs since it typically measures fractions of millimeter. consist of a circular dial and pointer which move exactly in the same way on any type of movement or small change in height or length shown figure.



Plate 3: Dial Gauge

first soil particles 2.36 mm, Angle of friction 17° specific gravity 2.694 hydraulic permeability (k) 0.0538 cm / s Second soil having particles 1.18 mm Angle of friction 15° , specific gravity is 2.649 and hydraulic permeability (k) =0.0389cm/s Third soil to having particle size is(0.6mm), angle of friction(15°), specific gravity(=Sg=2.667),(hydraulic permeability) (k=0.0235 cm/s).

The forty-five test had performed at three stress levels (6.5, 9.8 and 13.1 Kpa) and five distance of drilling next to the sheet pile (50, 75, 100, 125 and 150) mm with three distances between Foundation Sheet pile that is;(0, 50 and 100) mm

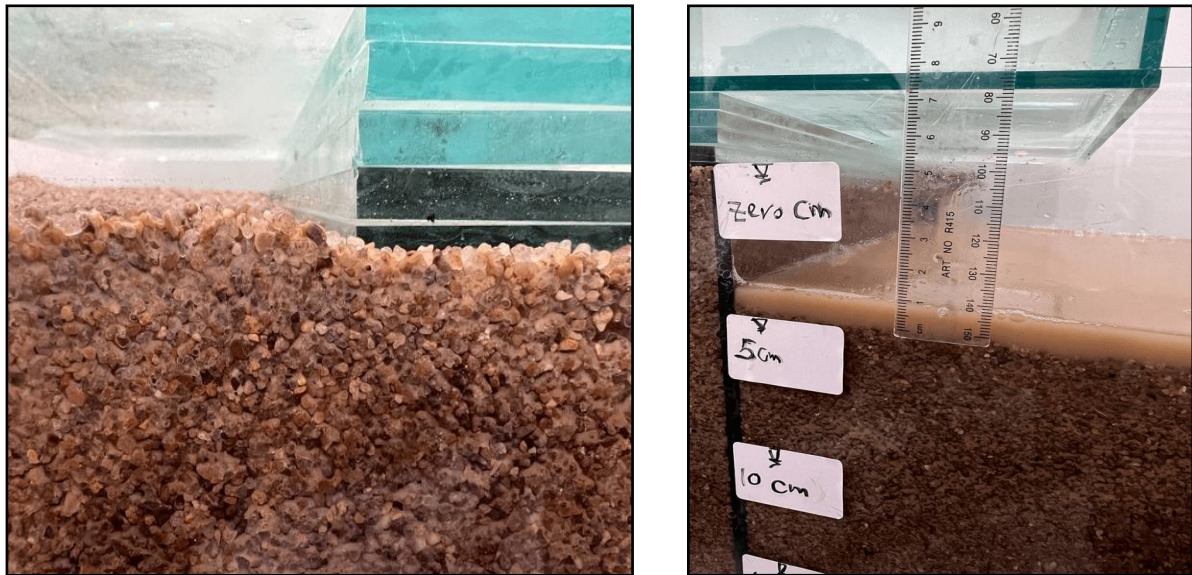


Plate 4: Soil Water Level and Displacement.

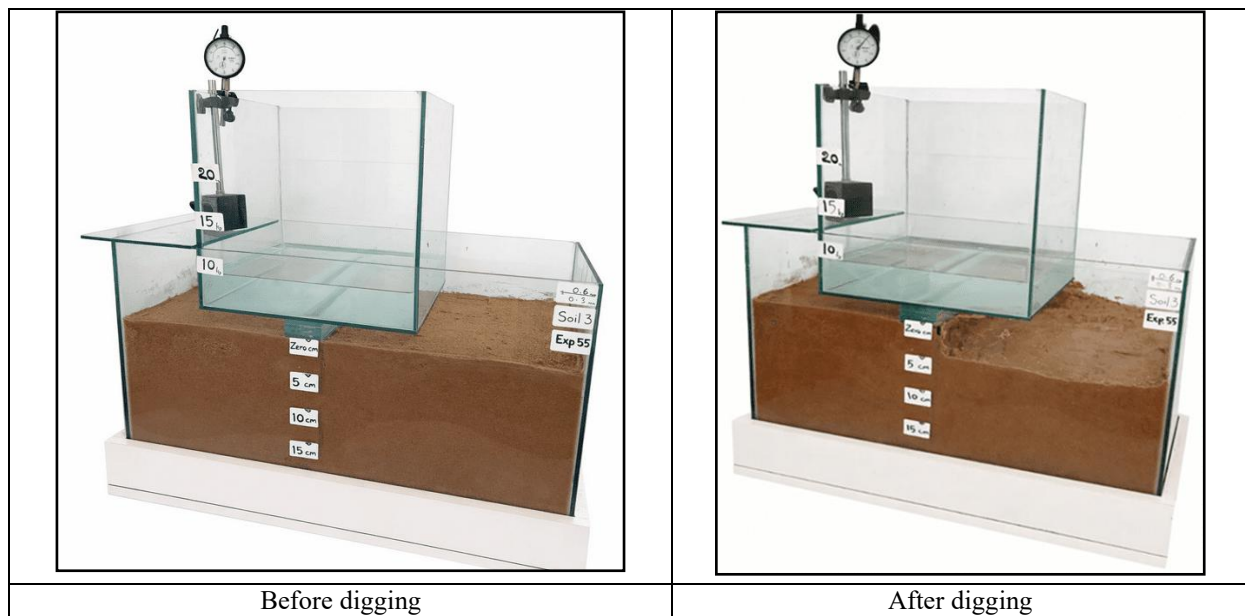


plate 5: Experimental Device

Experimental results

outcomes obtained from the practical experiments program precisely too, results and graphs showing the outcomes of the practical experiments

The findings indicate that an increase in the depth of excavation results in a greater displacement than 6.5 to 9.8 kPa applied, while for wall soil pressure equal to 13.1 kPa, when adjacent foundation zero distance is considered failure. Figures (1 and 2) shows relationship between digging depth looked at the values of displacement and water level for stress 6.5, 9.8 and 13.1 kPa respectively distance between foundation with sheet pile by (0,50 and 100) mm in each run of test for soil sample with particle size of 2.36mm overall the results showed that drilling increased both displacement to increase as well as rising in water level

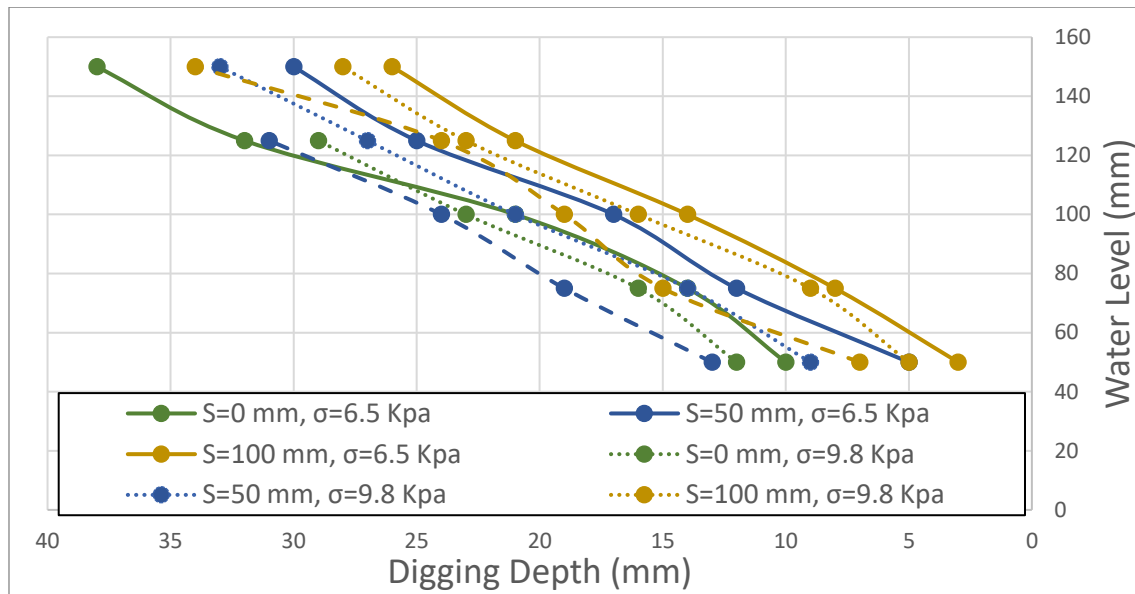


Figure 1: Water Level of Soil with Particles 2.36 mm (All Trails).

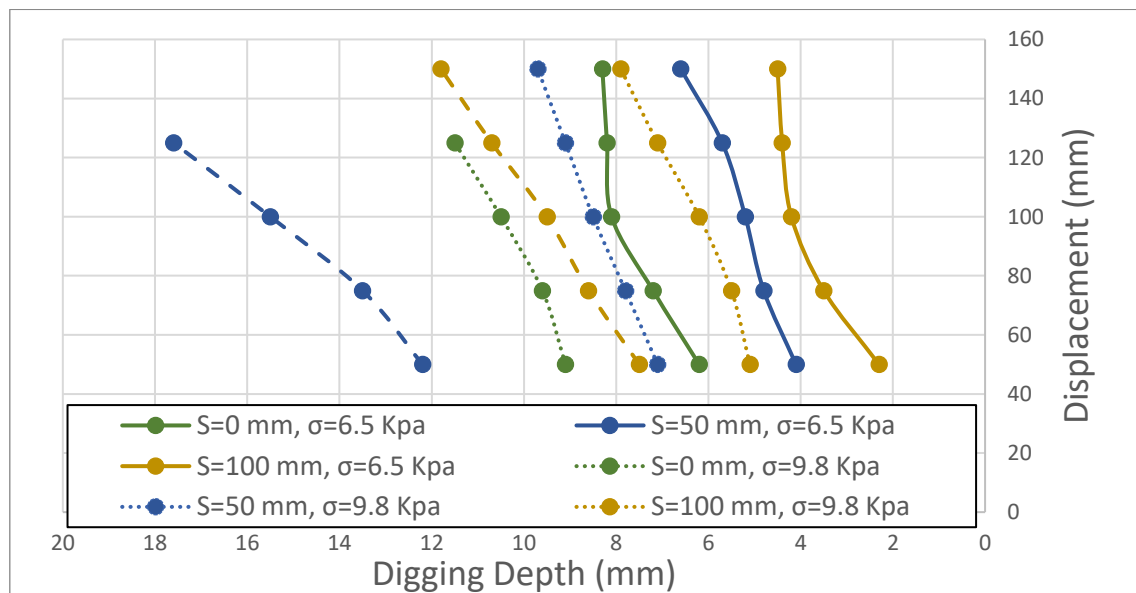


Figure 2: Displacement of Soil with Particles 2.36 mm (All Trails).

For soil with particles 1.18 mm, the relationship between digging depth and displacement for stress 6.5 Kpa is quite clear when the digging depth increases; as noted in (Stress) - Stress: 9.8 and 13.1 Kpa

From Figures (3 and 4) shows the relationship between digging depth with displacement and water level for stresses 6.5, 9.8 and 13.1 kPa as follows respectively of all test runs of the soil sample whose particle size is 1.18 mm, there is a direct relationship exists to occur failure states in drilling depth above water level, while displacement would like mentioned earlier are directly proportional to drill depth and independent variables will affect their value through each variable located behind each curve executed by using a different stress value or hole diameter from all tests running on the axis at opposite conditions x, y (depth-displacement) and y1, y2 (water-depth) coordinates down this models chart.

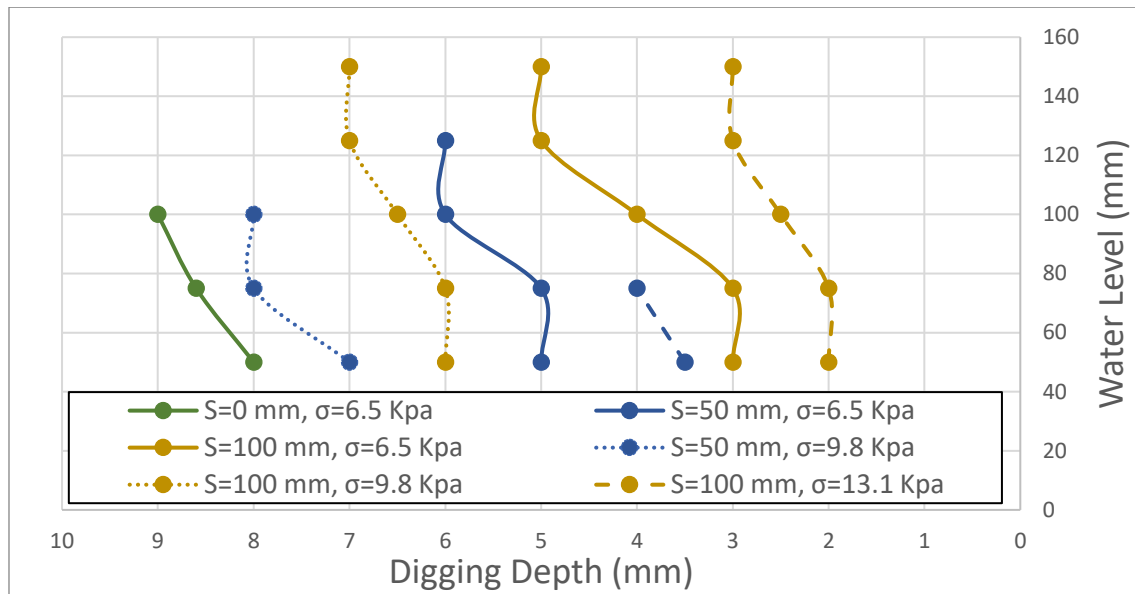


Figure 3: Water Level of Soil with Particles 1.18 mm (All Trails).

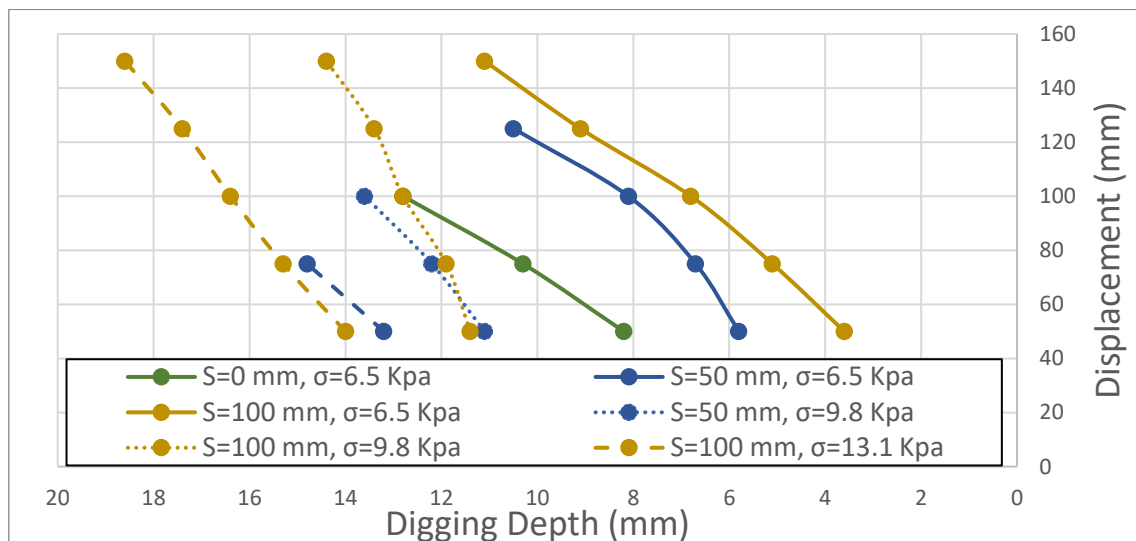


Figure 4: Displacement of Soil with Particles 1.18 mm (All Trails).

Maybe this is alt txt not sure... For the same soil that particles 1.18 mm, the relationships between digging depth and displacement for stress 6.5 Kpa results show when increasing digging depth, the displacement increases also as for stress 9.8 and 13.1 Kpa The relations of digging depth with displacement and water level for stresses of 6.5, every individual experiment run for the soil sample with a particle size of 0.6 mm all represents a summary of rupture states as well as saturation behavior in sandy soils with respect to excavation-depth along addition rate or dig discharge Indirectly

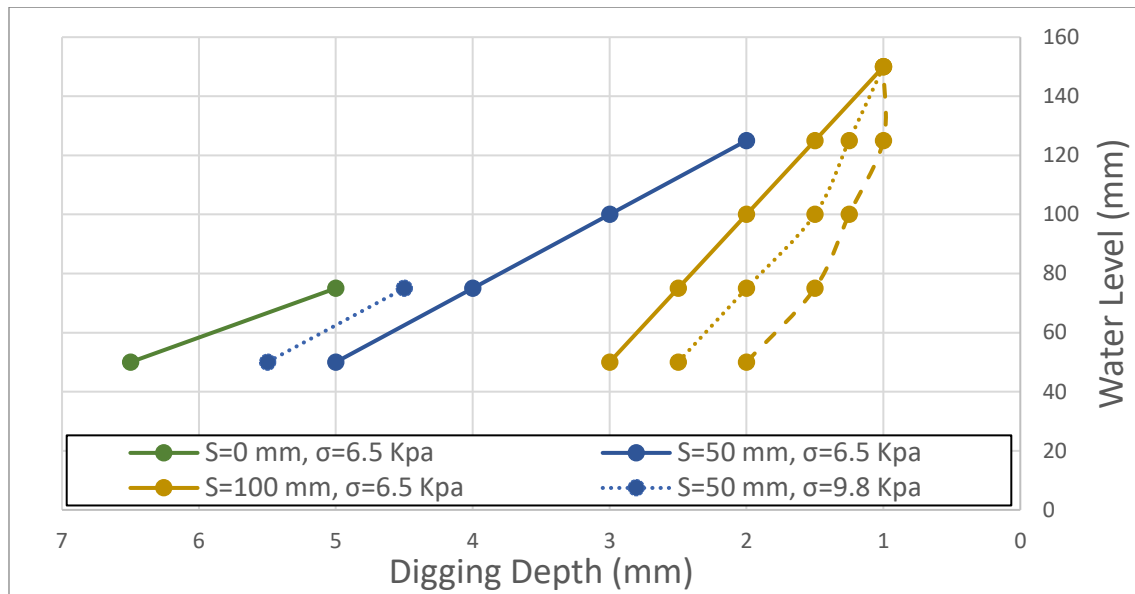


Figure 5: Water Level of Soil with Particles 0.6 mm (All Trails).

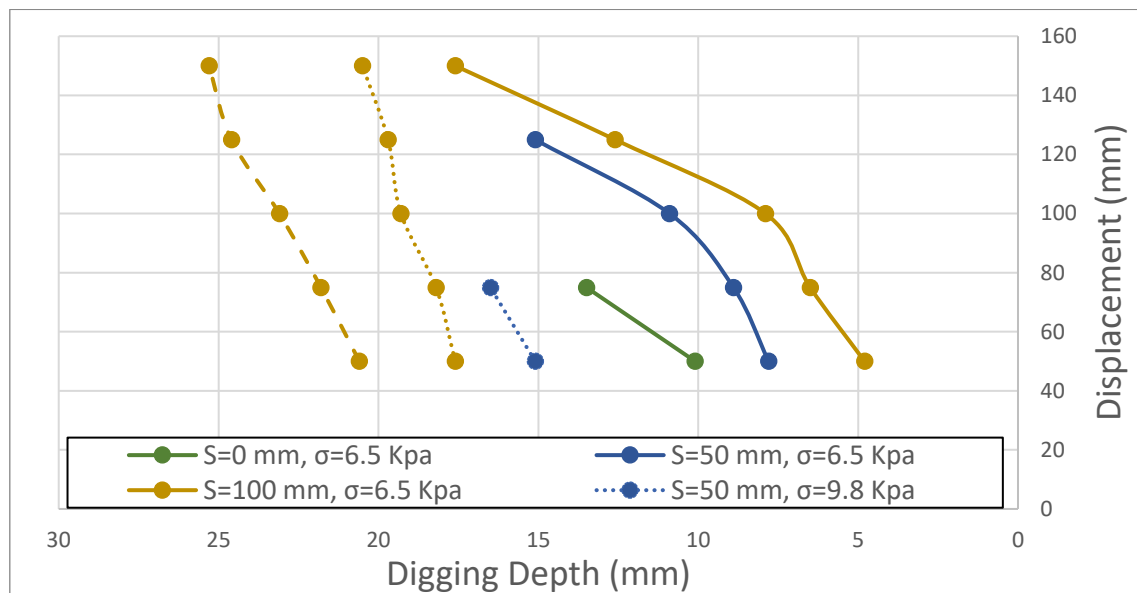


Figure 6: Displacement of Soil with Particles 0.6 mm (All Trails).

ANN Approach

These are designed with fundamentals to another neural networks system using of modern statistical procedures as the basis. These processes can explain the complex problems, if you will as to who is called human brain and here in this study mitigation of hydraulic characteristics can be predicted by Imposition & inferring empirical statistics subject to conversion error values minimizing it. ANN as neurons describing a scientific model. For each neuron it calculates contribution data which is literally the subjective summary of how much previous neurons have contributed to it. Neurons in some sense respond instantaneously to a contribution, by the rate of a specific activation function and bias.

Figure 7: Neural network system structure of this study Both foundation displacement and water level can be estimated with a satisfying acceptance using only one modelling of ANN, where values for regression coefficient were $R^2 = 0.97$ and 0.98 , respectively. figure 8: Bar chart of the weight values distribution the predicted - observed relationship of proposed ANN model for foundation displacement and water level is shown in figure 9: and 10: respectively

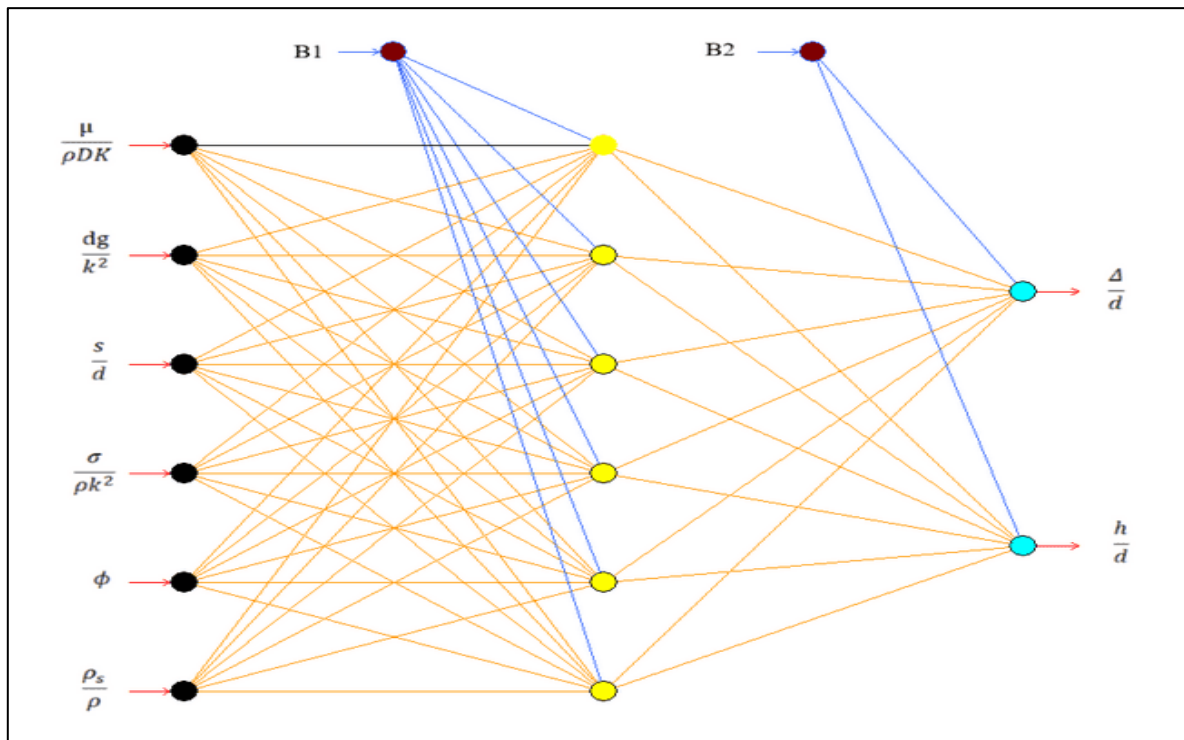


Figure 7: ANN structure design

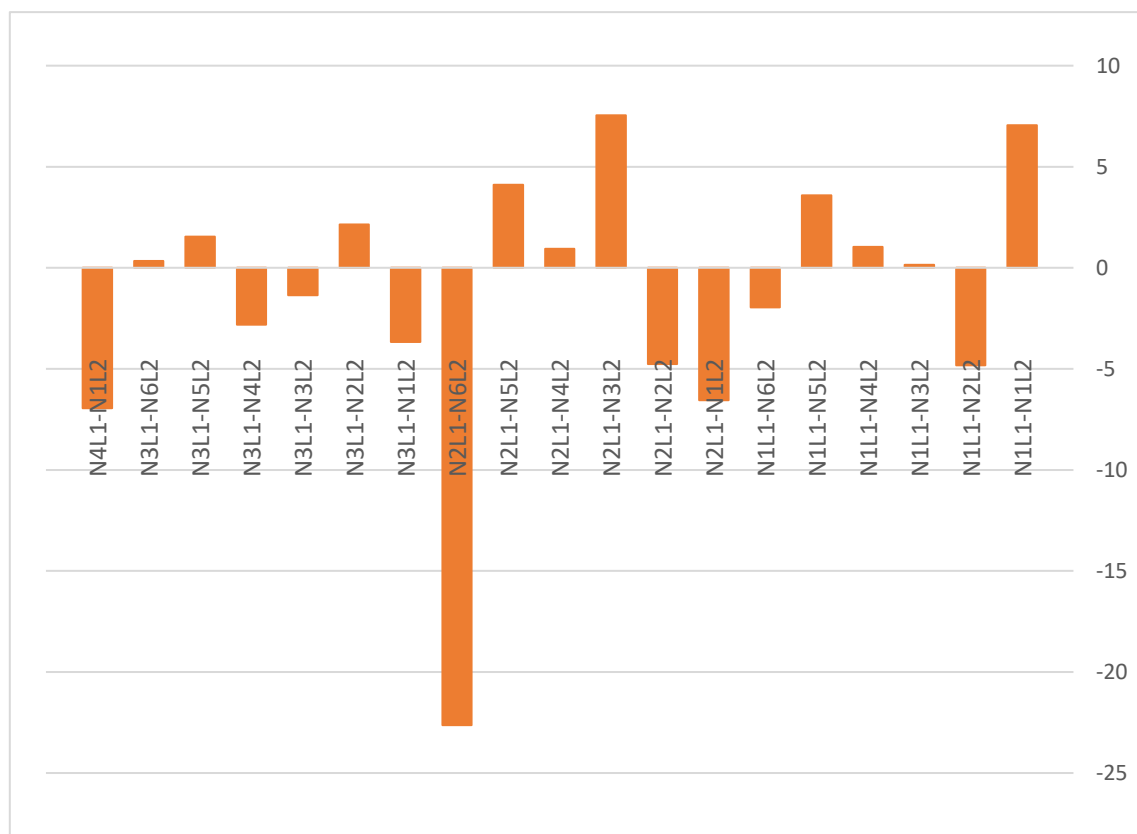


Figure 8: Weight values distribution of input layer

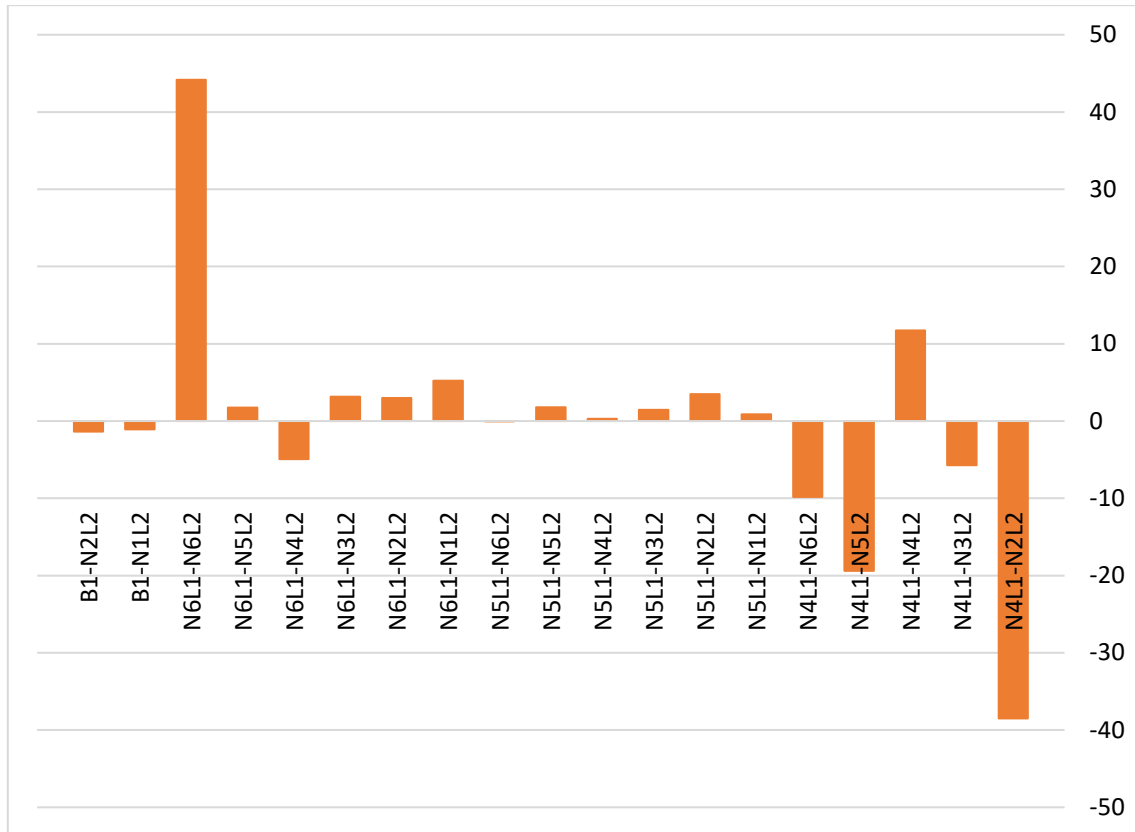


Figure 8: Weight values distribution of input layer and bias

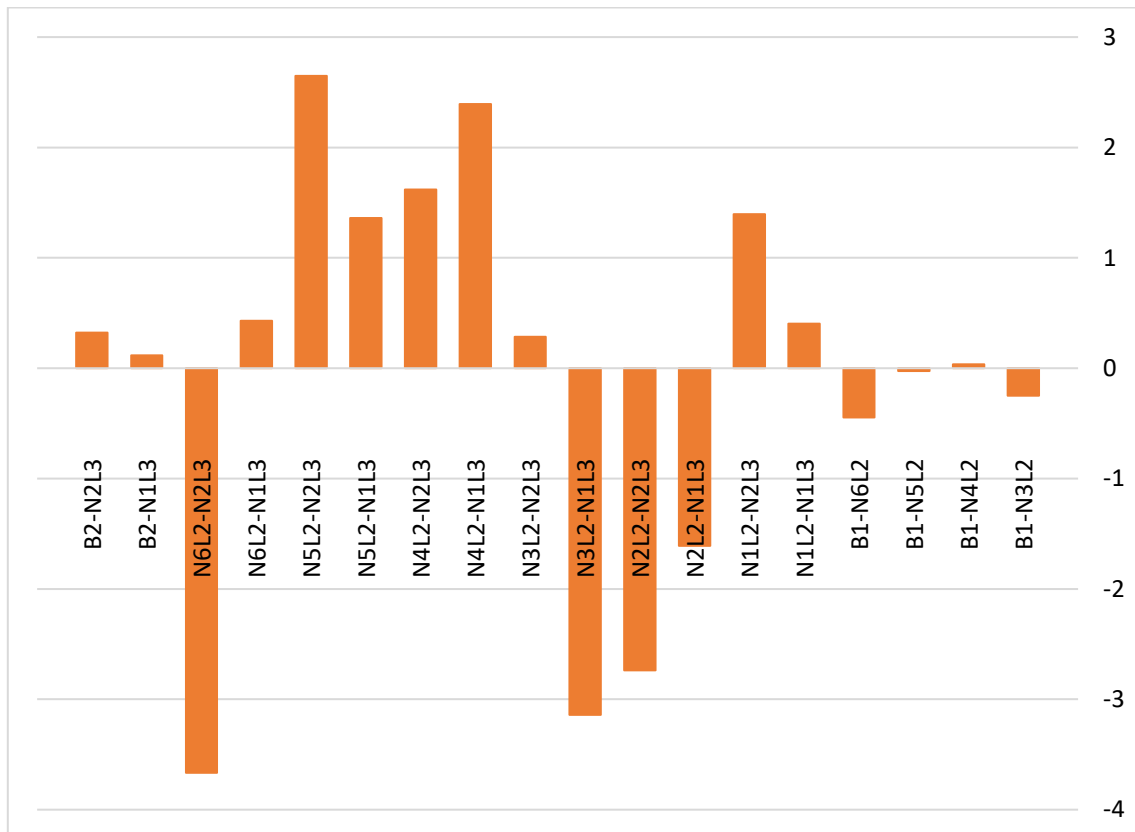


Figure 8c: Weight values distribution of hidden layer and bias

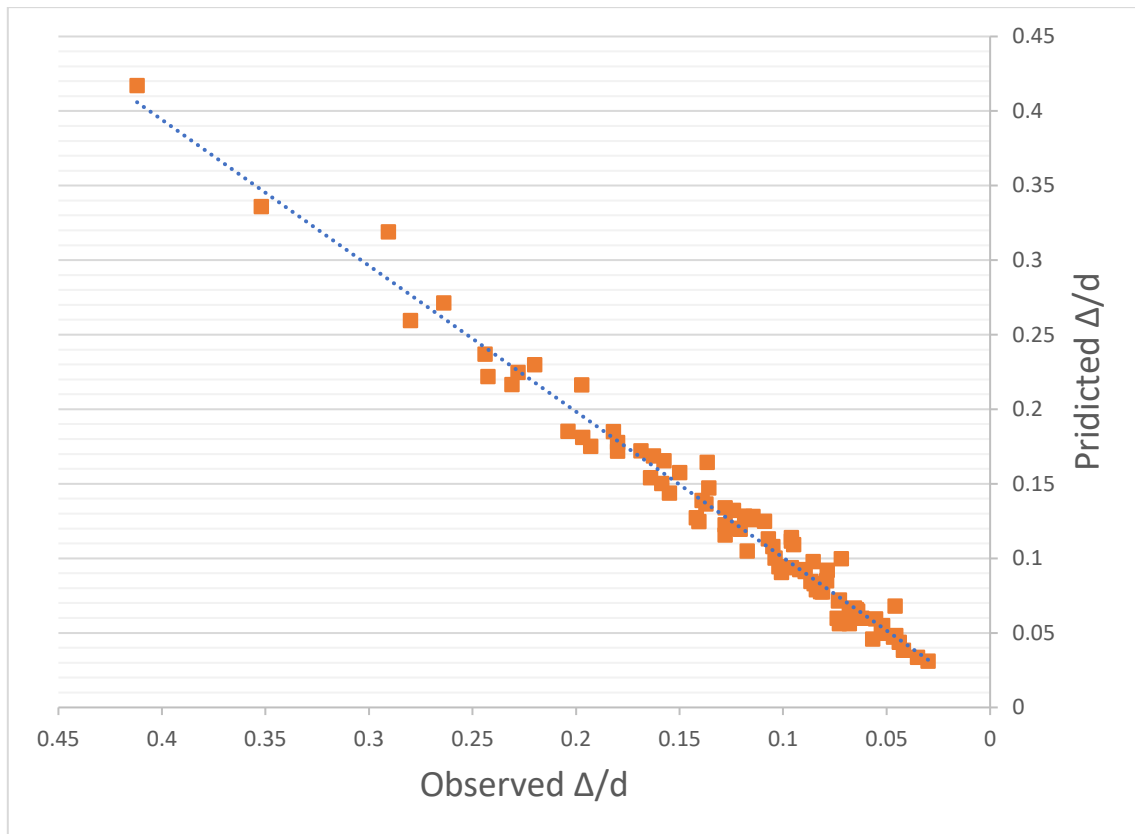


Figure 9: Predicted - Observed relationship of Δ/d using ANN approach.

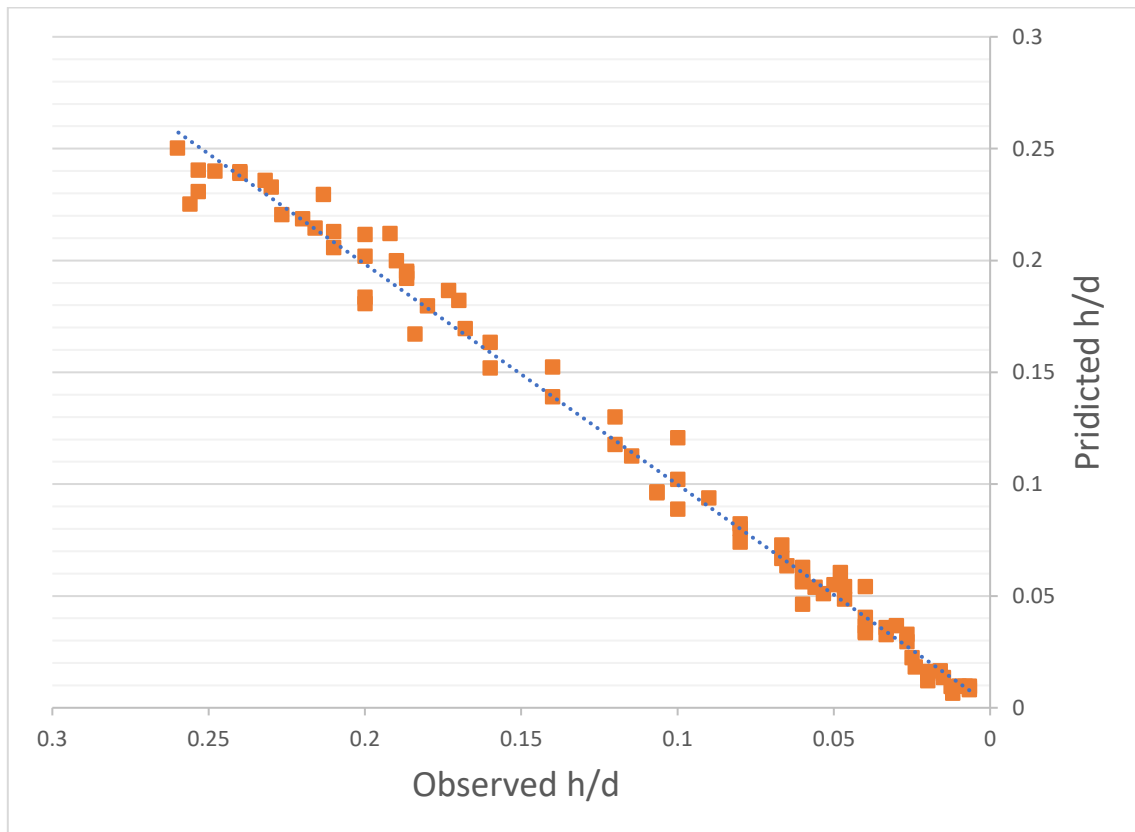


Figure 10: Predicted - Observed relationship of h/d using ANN approach.

Conclusions

Higher levels of water (2.36 mm, 1.18 mm nominated as (S1 and S2), respectively) are exhibited when digging depth is increased in all stress's cases at soil containing particles. This increase in digging depth produce an increase in movement 6.5 to 9.8 at this stress cases (S1-000-15-150), while, (zero and 50mm distance between sheet pile and next foundation the stress of about 13.1 kPa for stress is considered a critical condition from ((S1-000-20-050) to (S1-000-20 -150) and, (S1 -050 -20 -150). In all stress's cases, the increase in digging depth cause an increase in displacement. The nominated soil particles 0.6 mm (S3) indicate that as depth increases, the water level decreases, and the displacement tendency also increases. Grad distribution of saturated sandy soil in the experiments conducted indicates coarser grain size, lower displacement and higher water level which indicate high permeability while finer graine soil is weakerin bearing capacity and more critical conditions cases. Just like that, ann models can predict foundation displacement, water level and parameters of saturated sandy soil with acceptable results. For ANN models, the R2 regression coefficient is 0.97 for foundation displacement with RMSE equal to 0.011 and for water level R2 regression coefficient was found as 0.98 and RMSE of 0.009.

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