Study of Stress-Strain Behaviour in Soil Nail Wall Using Flexible Facing

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Abstract: Soil nailing is a process used to strengthen the existing fill of soil. It is a cost-effective way to reinforce soil. A number of steel bars are put up into a slope during the top-down excavation. The excavation support is a very effective as well as economical way to build a retention wall to support hilltop, bridge abutments and highways. In this research, a physical model was prepared for performing experiments on various flexible materials. The nail arrangement used was of rectangular pattern consisting of six nails. The flexible materials used in the research were Jute gunny bag, bamboo fibre, and Drainage geonet. In the present study behaviour of stress and strain was studied so as to find the material suitable for flexible facing. In the present study it was found that among the three materials Bamboo fibre was able to absorb maximum stresses before its failure.

Keywords: Flexible facing flexible materials Reinforcement soil nail wall

1. Introduction

Soil nailing is a type of soil reinforcement in which the reinforcement is installed into the slope creating a mass stabilised of ground either natural soil or an existing fill [1]. Soil Nailing is a technique used for stabilization of either natural or excavated slope. In this process, we drill the holes for inserting steel bars which are then grouted. Therefore, a mesh is attached to ends of bar to hold face of slope in the position. Soil nailing process is used for slopes, retaining walls, excavations etc., to stabilize them [2]. The steel bars are installed at an inclination of 10-20 degrees to the vertical on the excavation face [3]. Shotcrete or other material could be used for grouting to grout the nails. Major applications of soil nailing include the landslide redemption, stabilization of highway and roadway embankments, stabilizing the steep cutting and stabilizing the retaining walls. In the present time soil nailing is being used in various areas like for railway construction work for strengthening of side slopes in existing track road or laying of new tracks near the existing track [4][5].

Soil as we know is a heterogeneous material with strong compressibility but weak in tension [6]. Therefore the strength of soil could be improved by utilizing a material that is having considerable tensile strength [7]. Soil nailing technology is used to offer reinforcement for natural and steep slopes on site [8][9]. So the utilization of soil nailing provides stability for permanent support structures and temporary construction and is also helpful to take appropriate measures to decrease ground movement [10][11].

2. Literature review

Soil nail innovation was first utilized in France to assemble a perpetual holding divider cut in delicate shake. Thetask, attempted in 1961, was where steel nails were utilized to fortify a holding divider. The main soil nail divider to utilize current soil nailing procedure was worked close Versailles in 1972. The
method included introducing high-thickness, grouted soil nails into a 60-feet-high divider and confronting it with strengthened system [12]. Chow Chee-Meng and Tan, Yean-Chin, (2006) studied that soil nailing is one of the popular methods of soil stabilization nowadays. Soil nailing is popular due to many reasons as soil nail is an economical method of stabilization of slopes, constructional work is also easy, no skilled labor is required for it and also there is not as such any requirement of maintenance in future. In this paper, the author deals with the soil slope of 25m in the country of Malaysia. 25m slope is stabilized by the method of soil nailing in Kuala Lumpur. The author used a design which is taken as per the recommendations of the Federal Highway Administration (FHWA, 1998). Shotcrete is used in the whole constructional work of this slope or way may say that soil nailed wall [13].

G.L. Sivakumar Babu (2009) have studied that soil nailing is being utilized in various geotechnical utilizations to improve the dependability of unearthed steep cuts and current leanings. The document shows a few circumstantial analyses on the regulation of steep cut and enhancement of incline security utilizing soil-nailing strategy. The author observed that the steep cut soundness/slant dependability intensifies because of the fortifying jolt of nails. In this paper, a few contextual analyses on soil nailing are displayed showing its points of interest. There is a need to utilize this strategy on a vast scale in India in numerous frameworks extends wherever materials to understand the specialized and monetary favourable circumstances related to the procedure [14].

SeyhanFırat, (2009) studied that Installing piles in a line is a good technique to enhance the stability of slope especially when the sliding surface for the un-reinforced slope is relatively shallow. The author studied that both slope stability and pile stability are influenced by the lateral force. This effect of lateral force makes it essential for the analysis of stability, so it's very important to estimate the lateral forces very precisely and accurately which helps in finding a pile slope system that is best and as well as stable. In this paper two methods for calculating lateral forces are adopted which are named plastic deformation and visco-plastic flow. Eight various mechanisms of the study were administered to determine the factor of safety values of a slope reinforced by a line of nails. Eight methods are the method of Fellenius's, Method of Bishop, Method of Janbu Simplified, Method of Janbu general, Method of Morgenstern Price, Method of Spencer, Method of Samra, or also Fredlund and Krahn Method [15].

S.N.L. Taib, (2010) soil nailing is a moderately new strategy, which has been utilized for more than thirty years for soil support purposes. It is in-situ earth strengthening strategy, in which the essential applications are to hold excavation or slices and to balance out slants. The chief strengthening materials, the nails, are embedded into the earth as aloof considerations giving fortification to the earth that helps the earth structure to pick up its general quality. A factor, which makes soil nailing procedure more alluring than other earth strengthening techniques when performed on cuttings or excavation, is its simple and adaptable top-down construction. All strategies utilize the restricting harmony examination and in certain techniques, utilization of fractional wellbeing factors is clear. In the restricting balance investigation, worry on the suspicion made on the concurrent assembly of protections ought to be tended to [16].

Zhou et al., (2012) prepared a model which is a three-dimensional finite element model to affect the soil nail pullout behavior in a special type of box that is prepared for testing of soil nail pullout with different values of loads or stress. With the help of a modified model of the Drucker-Cap model, a stress-strain curve or you may be able to say the behavior of stress-strain is characterized for decomposed granite soil and the characterization of soil-nail coordinate is done by a different type of model which is a Coulomb friction model. Experimental pullout data of soil nail is when revised in a reverse manner then parameters of coordinate or interface are to get determined. In the model of soil constitutive, the data of the triaxial
test are used to determine the parameters of soil [17].

Rawat et al., (2017) presented a model to determine the failure of soil slope under various load conditions. In this research, the authors have inserted nails at different angle such as 10-degree, 15 degree and 30 degree respectively. Homogeneous soil slope has been prepared and subjected to various loads. The resistive as well as driving forces are taken into account for the calculation of safety. From the test it has been analysed that the safety factor has been lessen by increasing the seismic acceleration [18].

Truc T T Phan and M W Gui, (2019) studied regarding maintainable arrangements of bone slants with the dirt nailing arrangements, the input plan boundaries. For a typical anchor, the powers created in the anchors differed along its length; secures in the base 5 layers have a bigger anchor power than the best 4 layers of the anchor. Once more, it demonstrates that the base portion of the slant is going through more development than the top portion of the incline [7].

3. Materials and Methodology

The soil used in the present study was collected from Chandigarh University and then soil properties were studied on the basis of code (IS2720). Various properties such as moisture content, specific gravity, compaction characteristics and unconfined compression strength were calculated and are mentioned in the table 1.

| Properties                          | Values |
|-------------------------------------|--------|
| Moisture Content (%)                | 11     |
| Specific Gravity                    | 2.56   |
| Optimum Moisture Content (OMC) (%)  | 7.3    |
| Maximum Dry Density (MDD) (g/cc)    | 1.98   |
| Coefficient of Uniformity           | 5.6    |
| Coefficient of Curvature            | 0.64   |
| UCS (Kg/cm2)                        | 0.118  |

From the above table 1, the soil can be categorized as poorly graded sand.

Various flexible materials used in this research work are Bamboo, Jute gunny bag and Geo net. These materials are chosen for the research work as these materials have tensile strength which is required to balance the tensile stresses that are acting on the slope.

3.1 Physical Model: A physical model that was used in the present study was prepared with the Perspex sheet (acrylic sheet) of thickness 8mm. The dimensions of the model were taken as 60 cm, 40 cm and 50 cm (L*B*H). The model drawing is shown is figure below
Various Nails are placed in the model according to position shown in the above figure. The diameter of nail was taken as 10 mm and the length of the nail was 45 cm.

The various components used in the physical model are described below.

3.2 Pressure hydraulic jack (bottle jack): Pressure hydraulic jack of bottle jack having weight 5 ton is used and placed in between the Perspex sheet. It is used to lift heavy loads and works on the principle of screw action.
During the research, hydraulic jack is placed in between the Perspex sheet of 8mm thick as shown in above figure.

3.3 Pressure dial gauge: It is mainly utilized to damp the vibration and pressure spikes. As it is filled with fluid therefore, it also works as a lubricant and guards the gauge. As it is sealed properly, therefore, helps to work effectively in a corrosion environment.

3.4 Steel Bar: Six numbers of steel bar of diameter 10mm and length of 45cm is used in this research work.

3.5 Flex sensor: The flexible sensor is just like a variable resistor. As the nails bend, the resistance of the flexible sensor increases. Flex sensors are installed on the nails and extended to interconnect with the four copper wires to the main electric board. In order to calculate the strain a multi-meter is attached to switch and following formula is used to calculate strain

$$Strain = \frac{\Delta R / R}{\Sigma_c}$$

Here $\Sigma_c$ stands for gauge factor, its value lies between 2 to 2.5 and for 200 KΩ, the value of gauge factor is 2.1.

The other components such as copper wire, bearing plate and hexagonal washer with digital multi-meter and switch were used. As the load is applied there is a change in resistance value which could be calculated from Digital multi-meter and thereafter by using the above formula, strain could be calculated.

At last, the design model is tested, the tested setup of the proposed model. Copper wire is attached with each nail and resistance is measured using digital multi meter.

4. Results and Discussions

Facing material are required so as to hinder deformation thus limiting the mobilization of shear stress along nails. Flexible facing for soil nails is designed to provide the necessary restraints to slope between the bearing plates as well as erosion control. The approach for using the flexible materials can be used for environmental benefits as they allow the vegetation growth which can provide the significant changes. Soil nails as an entire system distribute the stresses on the adjoining nails when some nail become overstressed and due to this it would not cause the failure of whole system.

Following are the Results of 6 nail arrangement by using various materials.
Table 2 Stress and Strain reading by using bamboo as facing material

| Stress N/mm² | Strain in N1 | Strain in N2 | Strain in N3 | Strain in N4 | Strain in N5 | Strain in N6 |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 0.98         | 0.049        | 0.103        | 0.024        | 0.002        | 0.017        | 0.021        |
| 1.96         | 0.069        | 0.123        | 0.015        | 0.009        | 0.033        | 0.060        |
| 2.94         | 0.069        | 0.120        | 0.055        | 0.061        | 0.057        | 0.096        |
| 3.92         | 0.097        | 0.186        | 0.074        | 0.067        | 0.071        | 0.118        |
| 4.9          | 0.125        | 0.189        | 0.158        | 0.106        | 0.126        | 0.148        |
| 5.88         | 0.179        | 0.263        | 0.220        | 0.200        | 0.212        | 0.201        |
| 6.86         | 0.247        | 0.306        | 0.305        | 0.241        | 0.284        | 0.271        |
| 7.644        | 0.293        | 0.378        | 0.334        | 0.282        | 0.284        | 0.316        |
| 8.82         | 0.383        | 0.511        | 0.487        | 0.334        | 0.327        | 0.363        |
| 9.4          | 0.449        | 0.511        | 0.501        | 0.388        | 0.382        | 0.414        |

Table 3 Stress and Strain reading by using jute gunny bag as facing material

| Stress N/mm² | Strain in N1 | Strain in N2 | Strain in N3 | Strain in N4 | Strain in N5 | Strain in N6 |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 0.000        | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        | 0.000        |
| 0.980        | 0.048        | 0.130        | 0.019        | 0.026        | 0.055        | 0.098        |
| 1.960        | 0.088        | 0.148        | 0.033        | 0.062        | 0.103        | 0.161        |
| 2.94         | 0.091        | 0.151        | 0.057        | 0.089        | 0.129        | 0.184        |
| 3.92         | 0.116        | 0.200        | 0.083        | 0.123        | 0.166        | 0.224        |
| 4.9          | 0.182        | 0.244        | 0.138        | 0.186        | 0.199        | 0.198        |
| 5.88         | 0.243        | 0.284        | 0.174        | 0.220        | 0.353        | 0.224        |
| 6.86         | 0.337        | 0.385        | 0.205        | 0.224        | 0.353        | 0.194        |
| 7.644        | 0.391        | 0.527        | 0.294        | 0.378        | 0.733        | 0.366        |

Table 4 Stress and Strain reading by using Geo net as facing material

| Stress N/mm² | Strain in N1 | Strain in N2 | Strain in N3 | Strain in N4 | Strain in N5 | Strain in N6 |
|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 0            | 0            | 0            | 0            | 0            | 0            | 0            |
| 0.98         | 0.039        | 0.019        | 0.002        | 0.016        | 0.044        | 0.041        |
| 1.96         | 0.044        | 0.006        | 0.005        | 0.021        | 0.060        | 0.041        |
| 2.94         | 0.077        | 0.019        | 0.005        | 0.029        | 0.062        | 0.136        |
3.92 0.103 0.024 0.003 0.031 0.177 0.142
4.9 0.130 0.049 0.019 0.067 0.224 0.179
5.88 0.282 0.093 0.096 0.132 0.329 0.260
6.566 0.442 0.095 0.098 0.132 0.342 0.308

| Flexible Material        | Stress (N/mm²) |
|--------------------------|----------------|
| Bamboo                   | 9.4            |
| Jute Gunny Bag           | 7.644          |
| Drainage Geo Net         | 6.56           |

From the above Table no.5, it is found that bamboo have taken up maximum stresses as compared to the other materials because bamboo had maximum stiffness as compared with the other ones. In general both the flexional and axial stiffness of facing controls the deformation. In the present study maximum stresses are taken by bamboo as compared to other materials and this is due to the bamboo having stiffness higher as compared to other materials.

5. Conclusions

- In the present study the experiments were performed on physical model using different material and it can be concluded that use of flexible facing in soil nail walls will lead to an increase in the soil slopes load handling and slope stability.
- This research can be the beginning of learning guides for a construction technique that even reflects to be cost-effective and less environmental impact.
- In the present study bamboo has taken up higher stresses as compared to other materials for rectangular nail arrangement.
- Drainage Geo net has taken up minimum stresses for rectangular nail arrangement.

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