Soil Nailing – A Review

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Abstract - *Slope failure is a natural disaster and is a big catastrophe that our environment usually deals with. This calamity occurs mainly due instability of either slopes or soil. To overcome which soil nailing technique is the safest and the most economical way which leads to stabilization of the structures and therefore, prevention of this calamity. In this review, I tried to gather and study most valid research papers for proper analysis of application of in-situ soil nailing and properties of soil nailing during actual loading. Outcomes of this review brought about the following results:*

Soil nailed slopes shows less deformation than slopes without nailing as inclusions increase shear strength in soil nailing slopes, and reduce horizontal deformation. Also, inclination of soil nails affects the stability of slopes directly. FHWA provides the safe design of the soil nailing and soil nailing method is found to be more economical than other classical method for improvement and repairing of old slopes, and can reduce cost up to 30%.

Flexible type of facing is more economical than rigid facing but it allows more horizontal and vertical deformation and its use should be restricted only to soils with high strengths and less deformations.

***Key Words*: Soil nails, Facing of soil nails, Stability of slopes, Inclination of slopes, Vertical inclusions**

1. INTRODUCTION

Soil nailing is a technique to stabilize ground and usage of this technique could be effective to bring more stability to structure and reduce chances of failure. Its developed from New Austrian Tunneling method. The first round of this technique was applied in 1972 railroad widening project near Versailles, France in 1975 and 1976 Germany and USA used this technique respectively.

The existing slope is reinforced and strengthened by embedding steel bars called soil nails into the slope. In this technique, the construction proceeds from top to bottom which is useful where the ground is excavated in lifts of limited height.

Soil nail walls are generally used as permanent earth-retaining structures in most roadway projects. However, soil nail walls can also be used as temporary structures in roadway works when used to accompany the temporary excavations. The tensile impact is induced in the soil nails by the frictional interaction between the soil nails and the soil. Facing is an element of the soil nailing system used to prevent the soil from raveling out between the rows of reinforcement. Generally, facings used are made up of pre-cast concrete panels, metal sheets, shotcrete, geosynthetics, etc.

Soil nailing is in-situ soil reinforcement technique and the procedure is installing nails to the particular excavated soil, this technique used more than 30 years and vast investigation of researchers shows soil nailing is economical procedure to stabilize soil slopes.

1.1 Advantages of Soil Nailing

The existing data according to preformed projects and investigations on building of slopes defines following advantages of soil nailing:

a. It has little damage to the environment and is environmentally friendly
b. Its use requires little construction materials
c. It is more economical than other methods
d. It is more stable than other techniques against seismic load
e. Nails angle, size and location can be adjusted easily in soil Nailing structure
f. Needs less space for installation

1.2 Limitations of Soil Nailing

a. Can't use soil nailing Technique in every location
b. Soil nailing technique needs experienced labor
c. In the areas with high level of water it's not compatible
d. Gravel and Sand may not be compatible with this method
e. The metal nail is rotten after long term
f. Soil nail may not be good option for permanent adjustment

1.3 Components of Soil Nailing

Soil nailing comprises of following components:

a. Tendons
b. Grout
c. Centralizers
d. Facing
e. Drainage
f. Connection components

2. SOIL NAILING FACING

The soil nailing technique use to stabilize the slopes, and the process of installation carried out by using facing to our structure, soil nailing technique is usually used for new construction although can use for old structures.

Facing control erosion of nails and reduce undermining forces, it typically divided into, hard facing, flexible facing and soft facing.

2.1 Soil Nailing Hard Facing

The main aim of providing facing along with the soil nails is to stabilize the slope and thus to fulfill it, facing used should be dimensioned properly in order to achieve the desired maximum stabilizing forces. Hard facing thus allows lesser deformation and can be used for permanent facing. E.g. Reinforced concrete facing.

2.2 Soil Nailing Flexible Facing

In order to control erosion as well as to attain adequate restrain to the face of the slope, flexible facing is used. Various factors influencing the selection of the flexible facing involves: angle and height of the slope, friction angle of the soil. E.g. geosynthetics, geonets, geogrids etc.

2.3 Soil Nailing Soft Facing

The main purpose of soft facing is to control erosion and is usually used in cases where vegetation cover is provided. They mainly aim at retaining soil and not stabilizing it.

3. LITERATURE REVIEW

Kouji Tei, R. Neil Taylor, George W.E. Milligan (1998) A series of centrifuge model test of soil nail slopes with vertical and near vertical faces were conducted. The resultant 200mm high wall was exposed to 30g acceleration. If it did not result into failure, acceleration was increased to a maximum of 80g. Pullout of nails resulted into failure in all the cases rather than breakage and significant bending of nails occurred only after failure of slope. Measured earth pressure on back of the wall facing prior to failure was similar to that calculated by coulomb's method but the resulting pressure post failure was lower than the calculated value. Also, line of action of resultant force was somewhat high.

G.L. Sivakumar Babu, Vikas Pratap Singh (2009) A study was conducted regarding soil nail walls designed on basis of conventional procedure given by FHWA (2003). Various design parameters were compared which were obtained from conventional design and numerical simulation. Appraisal of all this was done based on close monitoring of in-situ numerical simulation and full scale laboratory study. It's derived that conventional design method provided the safe design.

Sanat Pokharel, Robert L. Parsons, Jie Han, Isaac Willems (2011) Reinforced concrete facing was compared to reinforced flexible facing using 3D finite difference modelling. Physical testing of a 1.5m*1.5 m unit cell of a soil nail wall in clay was done. When a surcharge of 5Psi was applied, it was noted that flexible facing performed well strength wise but showed commendable horizontal and vertical deformation along with significant settlement in surface. So, it was recommended that flexible facing in clay as a substitute to reinforced concrete should not be extended to the areas other than the ones where large deformations are acceptable.

Jian-Hua Yin, Cheng Yu Hong, Wan Huan Zhou (2012) the motive of this research is calculation of maximum shear stress at soil nail interface, a parametrical study was conducted which took whole radius, overburden pressure, dilation angle and grouting pressure into consideration for analysis of their effects. It was observed that in the absence of grouting pressure, maximum shear stress increased with increasing overburden pressure, dilation angle or decreased drill hole radius Also, larger grouting pressure values resulted in greater influence of overburden pressure and consequently, larger was the maximum shear stress at soil nail interface.

Siavash Zamiran, Hadi Ghojavand, Hamidreza Saba (2012) With the help of FLAC3D, models were built to perform seismic analysis and also static and dynamic analysis were performed on the same model. It was found out that side long displacement of wall in seismic condition was 60-95% larger than the lateral displacement of wall in ordinary condition. Whereas in case of static and dynamic analysis, it was found that nearest value of static and dynamic maximum nail force occurs in the mid nail row at mid of wall (53%).

Sanvilate N. Simonini P, Bisson A,Cola S. (2013) Soil nails of different types of facings, stiffness variations and continuity were made to undergo some test which resulted into a conclusion that if facing lacks continuity during excavation, its flexural stiffness gets hindered. Horizontal displacement of front can be controlled if facing is characterized by low axial deformability, though is flexurally deformable.

Veerabhadra M. Rotte, Bhamidipati V.S Viswanadham (2014) Studies on centrifuge model regarding the necessity of slope facing and its effect on performance of soil nailed slopes subjected to seepage were indicated in this paper. Soil nail slope without facing and those with flexible, stiff facing had a maximum crest settlement at 1.63m and 0.145m respectively. Local failure at edges was shown by slope reinforced with flexible facing whereas stability for seepage time more than 21 days was observed for slope reinforced with rigid facing.

S.Rawat, A.K.Gupta (2016) Finite element method was used to experimentally study the response of unreinforced and soil nailed slope when gradually increasing surcharge load is applied on sand soil slopes of angles 45° and 60°, the soil nails were installed at different inclinations of 0°, 15° and 30°. It was concluded that out of unreinforced and reinforced slope for both 45° and 60° slope inclination, the reinforced slope undergo rotational failure. Increase in load carrying capacity: a) was maximum for 0°nail inclination for both 45° and 60° slope. b) was maximum for 60° slope than 45° slope (i.e. soil nailing is more effective in greater slopes) .

W.R. Azzam, A. Basha (2017) Unconfined compression test along with direct shear test were conducted to deduce the relationship between stress and strain. Due to mobilized vertical angle of shear stress, 12° and 19° for number of inclusions N=2,9, shear tests made it clear that vertical inclusions can increase the shear strength. Horizontal deformation was also reduced. 0.85 embedment depth ratio lead to increase of 231% in shear strength and therefore, to eliminate shear failure optimally, vertical inclusions should be extended to a depth zone in sufficient numbers.

Marek Kulczykowski, Jaroslaw Przewlocki, Boguslawa Konarzewska (2017) Slope stabilizing technique was being studied in two cases via soil nailing in Poland which closely worked at the stabilization of slopes beneath old buildings. In first case, the retaining walls supporting base of the dam at hydroelectric power plant in Rutki was being repaired and the second case involved improvement of Castle Hill slope in Sandomierz. Soil nailing in both the cases quite evidently lead to cost reduction of about 30% as compare to classical method and also ensured long run stability without the need for demolition and rebuilding cost. So, soil nailing was found to be an excellent technique for protection of buildings of historic importance.

S. Loghu Prasath, P. Malini, Mohanchandru, N. Nataraj, M. Mohanraj (2019) The aim of this research was to observe the stability and behavior of less cohesive soil with and without Nails. Soil Nails of 10mm diameter were embedded at 10° and 20° inclination with horizontal in (2H:1V) slopes. It was observed that the slope model sustained at any force not more than 6.7 KN and the same model with nails installed at 20° couldn't withstand force >11.2 KN and that inclined at 20° failed at 20.22 KN. With this it was clearly concluded that nails embedded at 10° can withstand higher loads.

3. CONCLUSIONS

a. Slopes with soil nails are more stable and have less deformation than slopes without nailing, and according to many performed projects soil nailing provides well stability to slopes.

b. Inclination of nails in soil nailing technique can affect directly the stability of slopes, and 10° inclination can sustain more loads.

c. The previous projects in conventional method that conventional design of soil nailing through FHWA provides safe design.

d. Soil nailing method is more economical than other classical method for improvement and repairing of old slopes, and can reduce cost up to 30%.

e. Flexible facing performs well against loads and has acceptable strength, but has commendable horizontal and vertical deformation. It's better to use Rigid facing in comparison to flexible facing in areas with large deformations specially in clay soil.

f. Finite element method shows soil nailing is more effective in greater slopes, and slopes with 60° inclination has more load carrying capacity than 45°.

g. Inclusions can increase shear strength in soil nailing slopes, and reduce horizontal deformation. Vertical inclusion should be extended to a depth zone in sufficient numbers.

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