Advances in Environmental Biology, 8(9) Special 2014, Pages: 865-878

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/aeb.html

Study of Stability and Dynamic Analysis of Trenches in Road of Elam - Kermanshah by Nailing Method

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ARTICLE INFO

Article history:
Received 15 April 2014
Received in revised form 22 May 2014
Accepted 25 May 2014
Available online 15 June 2014

Key words:
Soil nailing, ditches, Plaxis, reinforcement of soil.

ABSTRACT

Soil nailing is a new method for protecting and establishing of the slopes and ditches. Considering the road and railway construction needs in difficult to pass and mountainous areas, numerous problems are created for engineers; while the existent establishing methods for solving the problems are expensive and they are not economic. In order to solve this problem, engineers attempt to employ suitable methods including in situ reinforcement of soil. Accordingly, soil reinforcing by nailing method is considered by geotechnical engineers, due to flexibility, speed, easy performance and cheapness. The basis of this system is using materials to reinforce the soil in order to support high tensile strength, in which, increases the soil mass stability. Considering the widespread use of this system in the stabilization of slopes, borrow-pit and excavations, evaluation and complete analysis of forces is necessary in the static and dynamic point of view. Supposing the rigid condition for the soil, theoretical studies and laboratory models are examined in the static and para-static condition; while, the soil is not rigid and the dynamic behavior of soil is deterministic. Using plaxis finite element software in main road of Elam- Kermanshah, the studied slopes are modeled and the effects of different parameters including angle of repose, length and distribution of nails on axial forces and occurred displacements are inspected and finally the optimum dimensions of nails are presented in the economic and executive aspects.

To Cite This Article: Saied Hassan Jaffari, Haji Karimi, Study of stability and Dynamic analysis of trenches in road of Elam -Kermanshah by nailing method. ***Adv. Environ. Biol., 8(9),*** *865-878, 2014*

INTRODUCTION

The soil as one of the important materials in foundation of civil structures performs as a support. Hence, engineers have been try to use different methods in order to improve soil reinforcement, one of these methods which are attracted attention of engineers in last year is to reinforce soil. So far, in order to soil reinforcement have been used of different material such as fiberglass or metals including aluminum or polymer as geotextile and geo-grade that has high power to tolerance of tensile stress [2].

Nowadays, to improve resistance parameters of soil and stability of slope, trenches and ditch are used of nailing methods that is cheap, efficient and fast method. Soil Nailing method have been derived from New Austrian tunneling method. This method is introduced by Prof. Rabsavich about tunnel building in 1995, and between 1957 to 1977 by Rabsavich and his colleagues such as Salzburg and Putcher is completed and developed. Whatever, NATM is called is the sets of implementation must be conducted meanwhile and after tunnel digging based on exact recognition of stone properties in the location and timely usage and appropriate maintenance along with site measuring. That stability of tunnel is determined by using the capacity of stone as a main parameter of tunnel maintenance. This method is a combination method generated by bolts steel and shot-create that will be used for maintaining armed-walled tunnels and underground spaces [1]. The first nailing wall was built in France by Bouygues Company that this wall is about 70 degree on slope and 18 meters on height. The first research project was carried out on soil nailing in German [5].

According to this new method for stability in various following projects and supplies can be used [3] such as slip stability (landslides), Excavation stability sustainable in urban areas and the vicinity of high structure that is used as safeguard structure, high slope stabilize, abutment of bridge in problematic geographical conditions and ect. Furthermore, this method is utilized in various soils such as sand, clay, rocks as marl and heterogeneous soils. Of course this method is not being recommended due to having the capability of drainage problem in soft-plastic clay.

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In this article in terms of retrofitting of this method in slopes and excavations with assumption of soil nature, studies of theory and modeling in conditions of static and mid static in finite element software is surveyed. By using this software is conducted modeling on slopes in the road of Kermanshah-Elam and the effect of different parameters such as angle, length and distribution of nail and displacement are evaluated and finally the optimum dimensions of nails with consider Executive and economic aspects is presented.

Methods of determining nail forces:

The available methods to determine the created forces in nails can be categorized into following five general groups [2]:

- Experimental diagram methods for lateral soil pressure
- method of force-displacement (P-Y)
- finite element method
- limit equilibrium method
- discrete elements methods

Terzaghi in 1948, is presented non-linear elastic plastic reaction model for retaining walls. His model is relevant lateral pressure of soil with the relative displacement of wall. Many researchers such as Baguelin *et al*, 1978, Briaud *et al*, 1983 have been presented different experimental techniques for extraction k values by using the results of pressure meter test. Fister *et al*. in 1982 is provided diagram based on field tests that it can be achieved K value by having shear strength parameters of soil. Unterreiner and *et al* in 1997 are presented a two-dimensional finite element model for one of the walls of Clouter project called C.E.B.T. P. The simulation results of construction stage and stretching forces in nails with observed and measured values have a good accordance together.

Smith and Su in 1997 by providing a three dimensional finite element analysis on nailed wall with arched shape has to be concluded that the location maximum tensile force in each nail is closed to slip surface and the greatest tensile force is created in forth nail(total number of nails is 6).

Yang and Drumm in 2000 are implemented three dimensional finite element analyses for the stability of a slope of mine waste storage by using nailing system. According to the results of the study, under the terms of the gravity loading, created stretching forces in nails was small but with increasing burden this value will be increased more.

Plumelle and *et al*. have studied the obtained results of investment tool of C.E.B.T. P wall from Clouter projects by using finite element method and TALREN method (a limit equilibrium method based on the multi proposed method by Schlosser). The results of this study suggest that the maximum tensile force and bending moment of nails are adapted with the observed failure level in the wall.

Franken berge *et al*., 1996, Ste and wart et.al 1994, Barar, 1990, Felio *et al*., (1990)

According to seismic observation of nailed bulkhead structures by Franken berge et.al in 1996, Ste and wart *et al*. in 1994, Barar in 1990, Felio *et al*. in 1990 that were realized these type of structures have high resistance against structures. As a result, these methods are useful and economical for geotechnical works in earthquake zones. During the past 20 years, conducted lots of studies on models and finite element methods in order to evaluations of seismic response of soil reinforcement and nailed walls.

Field Information and Recognition the Location of Implement System:

The place of study for the implementation of system is the main road between Kermanshah and Elam province with geographical coordinates 46 34 21 and 34 23 67. Given that the route was in mountain and impassable areas in which trenches are there with long height. Therefore, it should be raise the degree of safety due to the heavy traffic load of the trenches with viewpoint of local and general slip will be controlled.

For stabilizing of these trenches Has been suggested that different ways such as retaining wall, a deep channel besides the road and constructed protective Gallery and etc. that it seems that these methods in terms of both Executive and economic and also work's progress, which has a heavy cost is unjustified, and that in the meantime the project employer (administration of Elam transportation province) has been decided to use new methods such as using soil nailing.

Soil Mechanics Characteristic Of The Case Studied Road:

• Trench km 62 + 150

Table I: Soil characteristics of trench 62+150.

ϕ	$c\left(\frac{kn}{m^2}\right)$	$\gamma\left(\frac{kn}{m^3}\right)$	φ	$E\left(\frac{kn}{m^2}\right)$	υ
43	16	17	0	$3*10^4$	0.3

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• Trench km 68 + 300

The soil mechanics characteristic of this layer with 9 meters height is in following table: this trench is composed of two layers.

Table II: Soil characteristics of trench 68 + 300.

ϕ	$c\left(\frac{kn}{m^2}\right)$	$\gamma\left(\frac{kn}{m^3}\right)$	φ	$E\left(\frac{kn}{m^2}\right)$	υ
33	15	18	0	$2.85 * 10^4$	0.3

• Trench km 71 + 00

The soil mechanics characteristic of this layer with 9 meters height is in following table:

Table III: Soil characteristics of trench *71 + 00*.

layer	H (m)	ϕ	$c\left(\frac{kn}{m^2}\right)$	$\gamma\left(\frac{kn}{m^3}\right)$	φ	$E\left(\frac{kn}{m^2}\right)$	υ
first	9	32	15	17	0	$3*10^4$	0.3
second	9	30	10	17	0	$3*10^4$	0.3

In the above occasion the angle of over load is 4 degree.

Choosing the most critical condition:

Comparison of soil mechanics characteristic in the path length that seems the tranche with km 71 + 00 has most critical state.

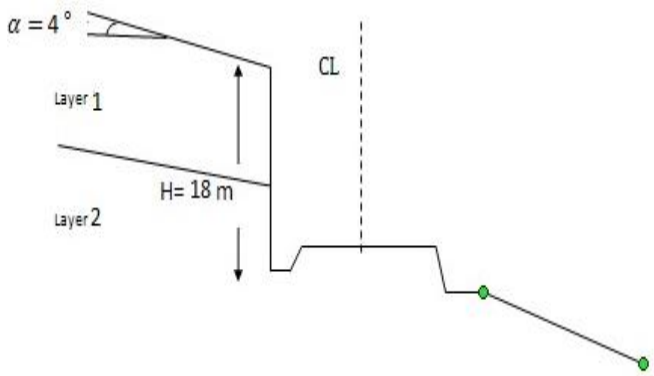

Fig. 1: cross-section of trench.

Of course, need to explain that for materials specifications modeling in plaxis software must be used intact examples. And for preparation of the test sample should be used direct shear test. That, unfortunately, due to the heavy costs have been used the results of transferred sample to the laboratory.

Iv. Modeling:

First step:

The first step of modeling is choosing a model, introduction the dimensions of models, size of element, materials of trench and nails and applied initial stress to the model.

The selected model is in accordance with Moher-culomb theory.

In the input of software the dimensions of model is adjusted in case of that model boundaries are not effective on the results of output, to do this must:

- boundaries will be considered farther from the trenches
- Using catchy boundaries that tension waves don't return at boundaries.

Table IV: Soil profile information.

layer	H(m)	ϕ	$c\left(\frac{kn}{m^2}\right)$	$\gamma\left(\frac{kn}{m^3}\right)$	φ	$E\left(\frac{kn}{m^2}\right)$	υ
first	9	32	15	17	0	$3*10^4$	0.3
second	9	30	10	17	0	$3*10^4$	0.3

Second step of modeling contains selecting damping of absorbent boundaries.

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Due to internal friction of materials as well as slip and energy dissipation is created martial damping between the surface and common section and. According to the type of materials is selected damping coefficient. In this modeling considered $\alpha = 0.001, \beta = 0.01$.

Absorbent boundaries:

As shown in Fig 2, Absorbing boundaries considered to avoid from boundary effecting due to return of stress waves and also for preventing of results with error.

V. Stability study of available situation of static state:

After modeling by using software, slip wedge is formed in accordance with program output in Fig 3.

In this case, the safety factor is extracted from program calculation.

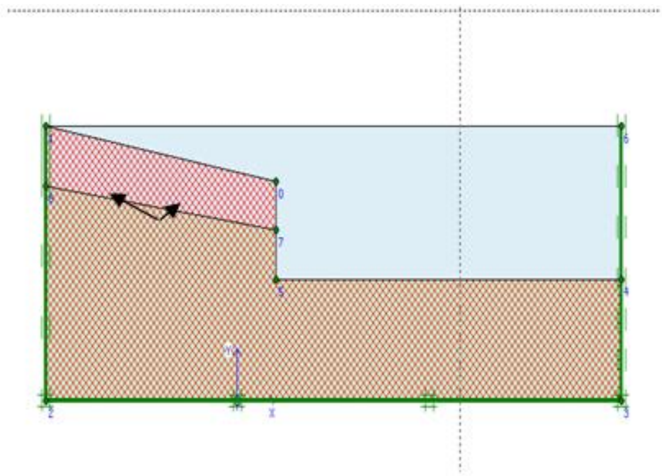

Fig. 2: catchy boundaries creating in mode of geometry.

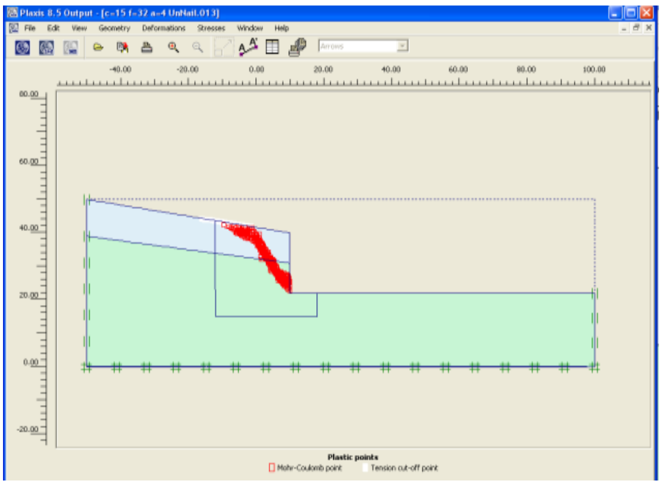

Fig. 3: slip wedge formation in static state.

The value of Safety factor is 0.918 as it can be observed most of slopes are falling.

We have changed the model for the following reason:

- According to the top height of the trench is so difficult to nail implement.
- An executive operation of shotcrete (cover of surface) is not possible.
- Concrete splurge is too much.
- It’s not economic.

So for Executive operations must be performed stairs with width of 8 meters between the two layers. In this situation the stability analysis can be done as well:

Failure wedge is created in accordance with fig 4 .

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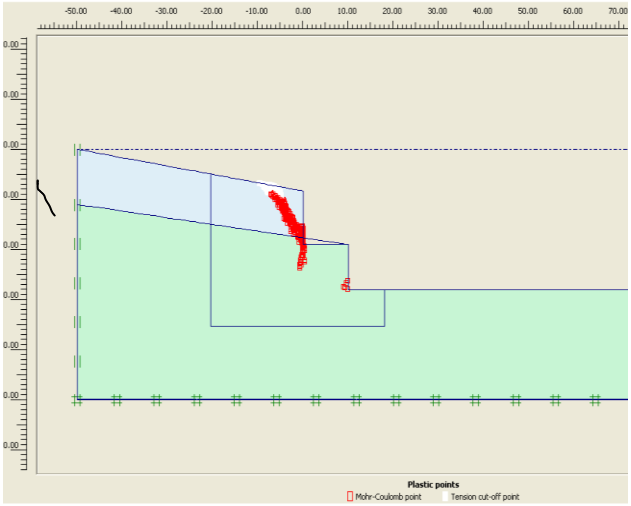

Fig. 4: formation of failure wedge with Berm.

In this case, safety factor is 1.00. So according to survey former study must be nailed both bodies of stairs. For this purpose the steel nails with diameters of 25 and 28 mm with concrete slurry with drilled holes (with 76 mm diameter standard of drilling drill) is used. For initial design of nailing length in upper part of stair is 12 m and for lower stairs is 15 m and also installation arrangement is considered 1m*1m.

For nails modeling is used geo-grade element that has only axial force. The axial stiffness of nails is $9.8*10^4$ kn/m .and angle placement of nails in initial statues is 4 degree compared to horizontal.

The above modeling is shown in fig5.

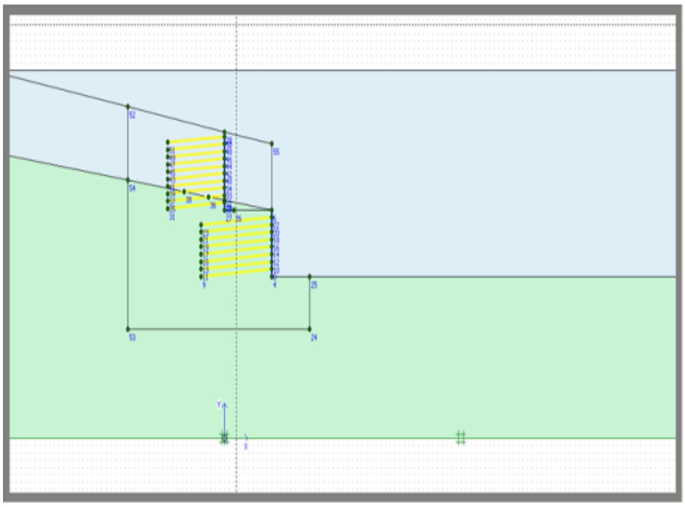

Fig. 5: nailed modeling of wall studied.

In accordance with table 5 the related parameters and characteristics of nails are entered.

Table V: characteristics of nails.

ϕ	EA	Material type
25	$9.81*10^{4}$	Elastic

With attention to this state the static stability analysis is conducted:

In the case of reinforced wall Observed that slip wedge is formed in accordance with the fig6 wedge. In this statues safety factor is 1.41.

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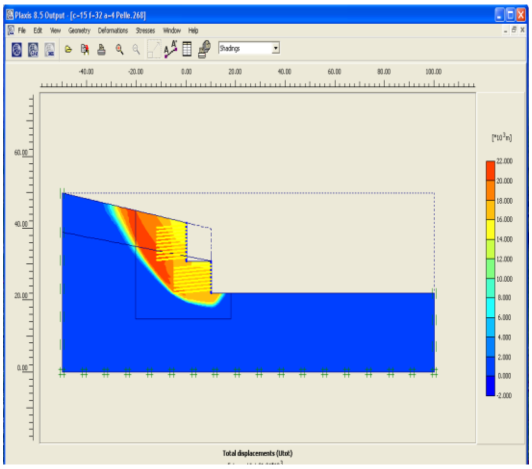

Fig. 6: Slip wedges in state of reinforced.

VI. Applying the dynamic loading:

In order to dynamic analyzing of nailed wall, an accelerogram was entered in according to fig 7 to the base model. This acceleration is propagated on difference time in height. This accelerate gram is a good match with area because the peak acceleration is 239.90 cm/s^2, which is equal to 0.24 (g) design based acceleration of region.

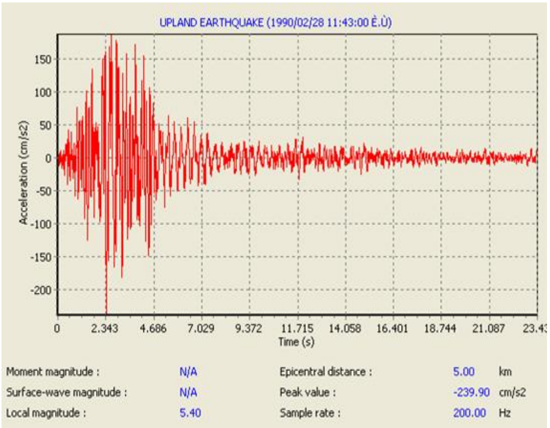

Fig. 7: exerted acceleration to model.

With dynamic analysis is observed that the existence of nails is caused to not create failure wedge. in fig8. the maximum created displacement is equal to 37 $*10^{-3}$ m.

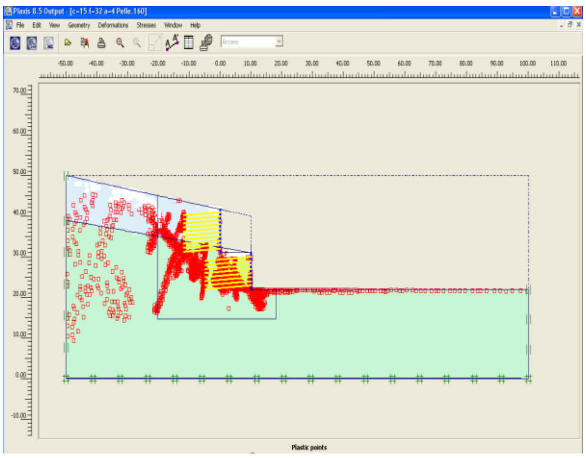

Fig. 8: plastic point in reinforced statues.

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Slip wedge in dynamic state is accordance with fig9, and in this case safety factor is equal to 1.1.

By studying the axial forces is observed that nails have different forces, for example, the axial force of last nail (eighth nail) is shown in dynamic and static state in fig10 and 11 as it's expected.

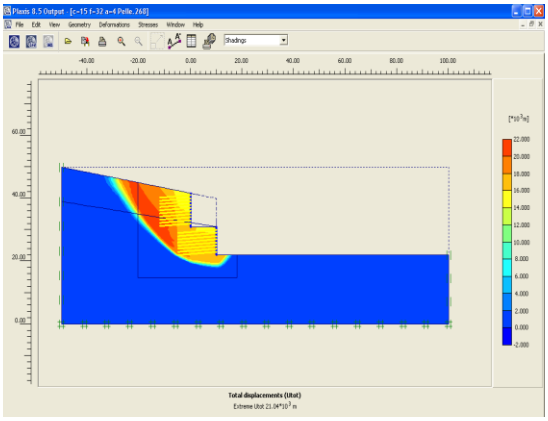

Fig. 9: dynamic slip wedge in the state of reinforced wall.

The geometric location of maximum axial force is at the place of slip line passed from the nail.

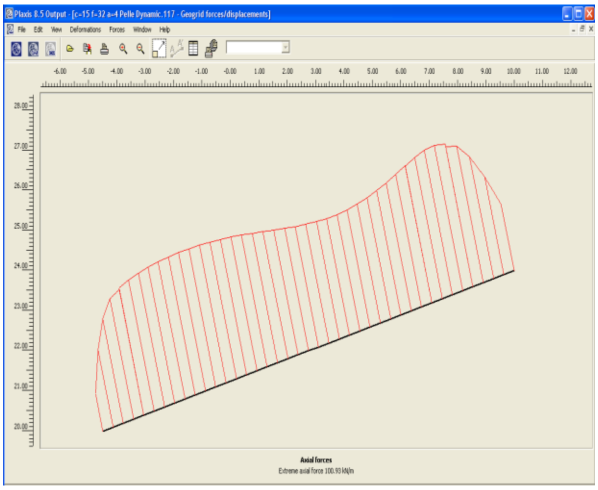

Fig. 10: diagram of axial force in static condition (in 8 nail).

Axial force on static state of 8 nail is 100.93 kn/m.

Axial force of eighth nail in dynamic state is 139.51 kn/m. So for designing of nails in dynamic state is used axial forces. The maximum of created horizontal displacement in the above state is $35.7*10^{-3}$ m (Fig 12).

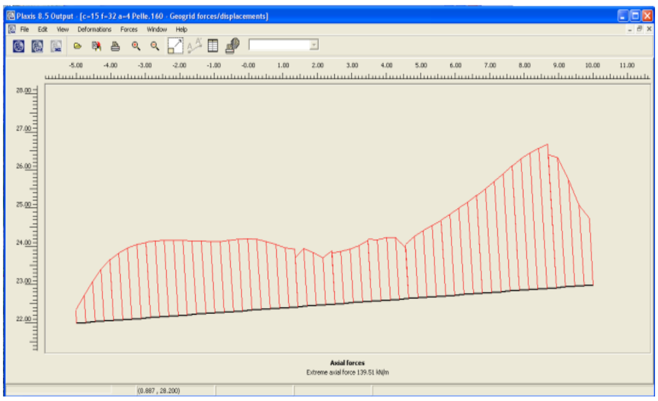

Fig. 11: diagram of axial force in dynamic state (in 8 nail).

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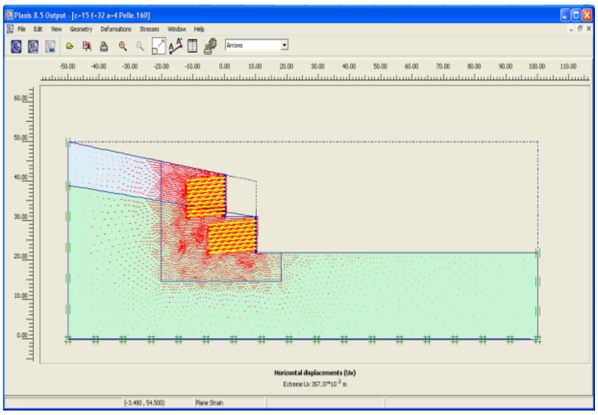

Fig. 12: Maximum vertical displacement that is created in vertical surface of trench.

The axial forces changing of in the nails of upper stair are accordance with the diagram of Fig13.

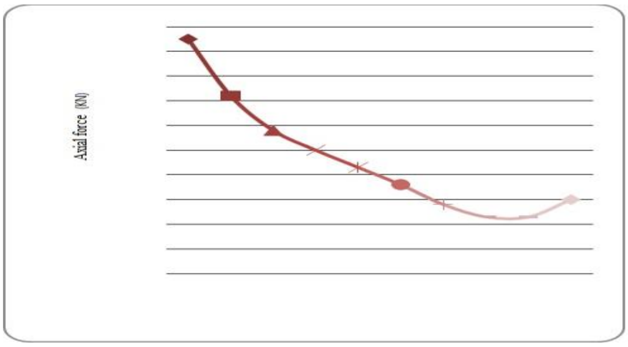

Fig. 13: axial force changes in elevation alignment.

As it is expected and is shown in diagram, the created axial force in bottom nails to above nails is reduced. And this is due to become more the time interval from the sources of dynamic force.

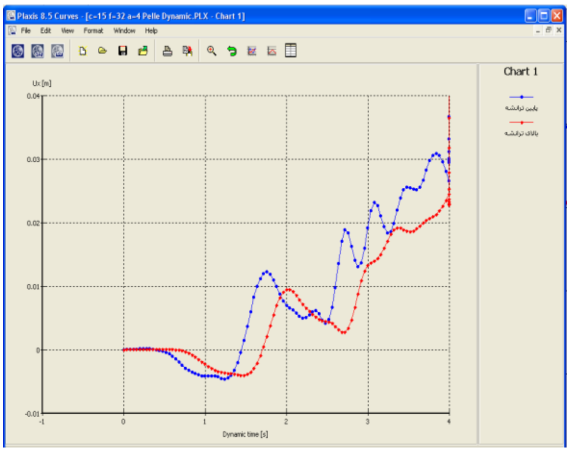

Fig. 14: Comparison chart of created displacement at the time of applying dynamic force on the top and bottom of trench

With applying dynamic force at the base of model, the maximum displacement of two points at the top and the bottom of trench is shown in fig 14,15.

As expected the displacement at the bottom of trench is more than top of trench. As well as a comparison between the maximum acceleration at the bottom and the top of the trench is shown in Fig16, that maximum acceleration at the bottom of trench is happened at 2.72 seconds.

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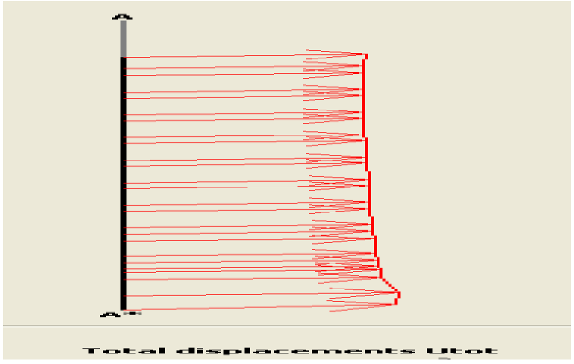

Fig. 15: total maximum displacement at the top and bottom of trench.

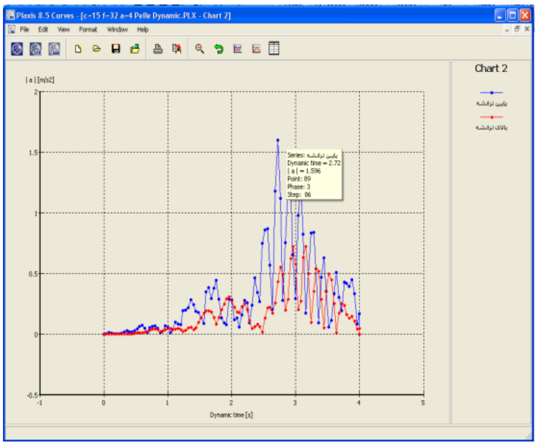

Fig. 16: compare the maximum horizontal acceleration at the top and bottom of trench.

vii. Studying the effEct of Different Parmeters on Trench Stability:

According to previous studies, the discussion is continuing with comparing of different statues in terms of angle placement, length the diameter of nails.

It should be noted the access to Executive and economic design it has been considered. That in this regard in the first stage the placement angles is changed 4 to 6 and then 8 and so on up to 16 degree.

And results in seven States on the axial forces safety factor through the graph is compared together.

Then in the next stage by changing the diameter of nail from 25 to 28 and finally to 32 mm and also the effect of nail length are evaluated.

Finally a proper combination of length, diameter and placement angles is presented to achieve the Executive, safe and economic design in the place of study.

Study Of The Effect Of Placement Angle In Nail:

At first, the effects of changing the angle of nails (α) comparative to horizon of 4 to 16 with 2 degree progression is studied on the displacement of wall location (Fig 17).

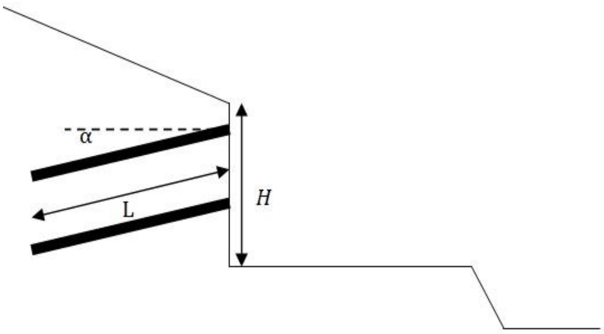

Fig. 17: introduction of length and angle of nailed.

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As the output of the program shows the lowest displacement corresponds to the angle of 8 ° with is 26 * 10^{-3} m. It should be noted in terms of Executive this right angle is also appropriate because also can be used the nails as a drain.

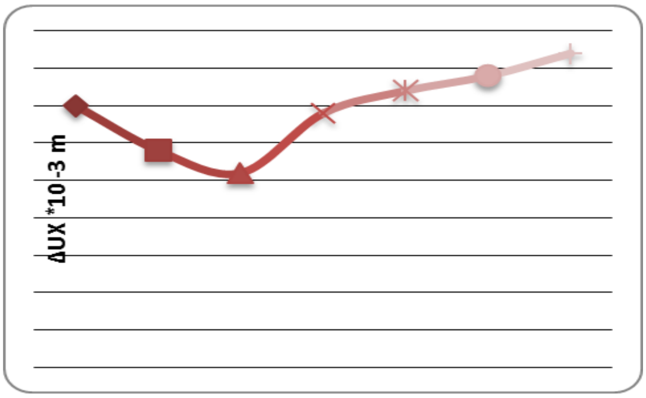

Fig. 18: the influence of nails angle changing on the maximum displacement in dynamic state.

Calculation Of Safety Factor For Static And Dynamic State:

In the next and important stage is calculated safety factor in static and dynamic state

Following diagram are shown changes of safety factor in front of change of angle in static and dynamic state

For this state the safety factor in static is 1.45 and dynamic state is 1.18. And this factors in nails with of angle 8-degree is observable

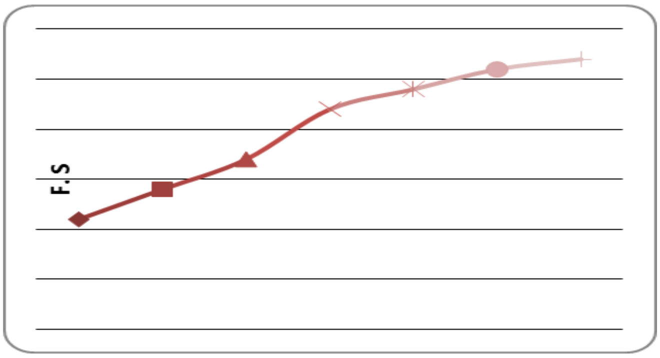

Fig. 19: changes of static safety factor versus the placement angle of nails.

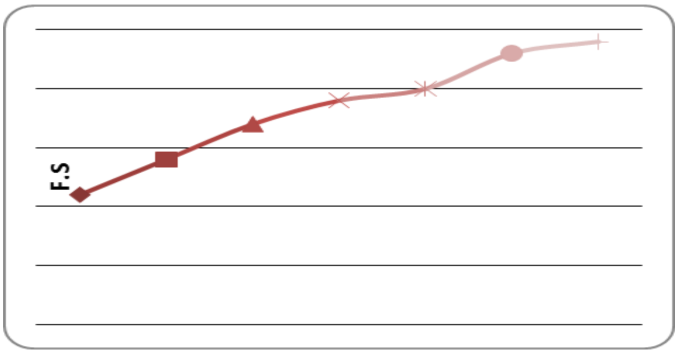

Fig. 20: Changes of dynamic safety factor versus the placement angle of nails.

Changes Of Axial Force In Height Elevation Of Trench:

Fig 21 shows the changes of created axial force in above 10 nails with angle of 8 degree. By increasing elevation level from bottom to top of stored axial force in nails is reduced.

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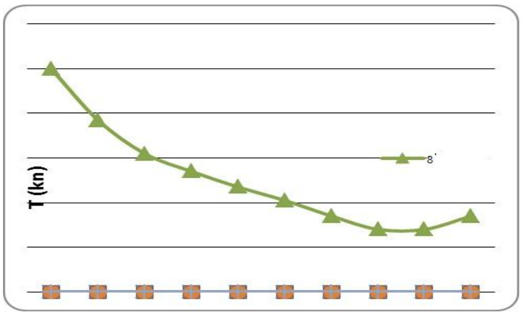

Fig. 21: the changes of axial force in nails at placement angle of 8 degree.

Fig 22 shows the changes of axial force in different placement angle.
In overall look is cleared that the changes of axial force are almost identical for all placement angle.
But in higher angle is shown the more stored of force value.

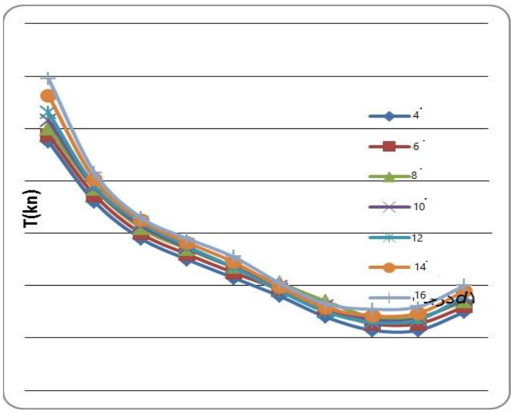

Fig. 22: Axial force changes at different placement angle.

From the above figures is deducted the minimum irritability of axial force of nailing within the scope of placement angle is 4 to 8 degrees.

Studying The Effect Of Nail Length On Axial Force:

Other important parameter in the implementation of the system is length of nail.

For this purpose is used L/H ratio that L and h are the length and height of trench respectively (Fig 23). For different proportions to a nail for example for eighth nail is drowned in figure 24.

Observed that whatever the L/H ratio is increased or in other words the length of nail become longer, the created forces in nails is reduced.

In the case of L/H ratio lower than 0.5 the program doesn’t work. Because the length of nails in this state are placed inside the failure wedge and doesn’t have any performance.

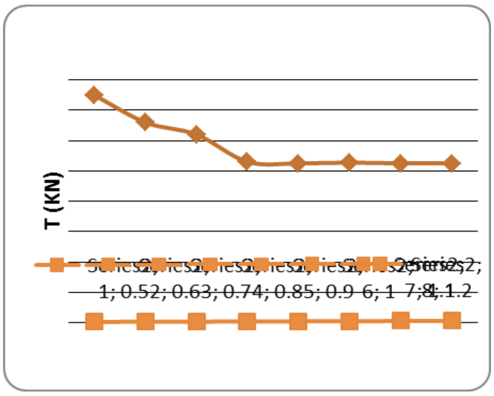

Fig. 23: Influence of L/H parameter on axial one axial force of nails.

And in L/H state more than 0.8 the axial force is almost constant due to supply clamping. And it doesn't need to longer length.

Studying Effect Of Nail Diameter On Tensile Forces:

Since there nail diameter is a direct impact on the amount of stored axial force.

Therefore, has been trying to study the influence of placement angle and diameter on stored force. In fig 25 is drawn the effect of diameters of $\phi 25, \phi 28, \phi 32$ in front of stored force.

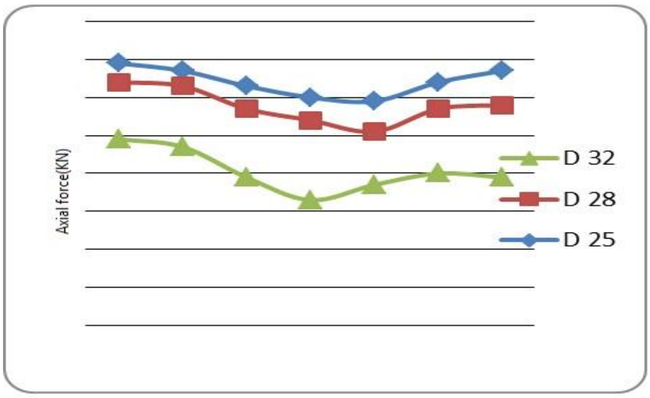

Fig. 24: changes of axial force with different diameter of nails.

Observed due to changes of nails diameter is also changed irritability of axial force.So that any increasing of nail diagonal is caused to reduce a created axial force

Studying The Effect Of Nail Scattering On Tensile Forces:

Number of nails per unit area is other important and influencing parameters on stored force.

In fig25 is shown created tensile force in nails for different values of nails scattering.

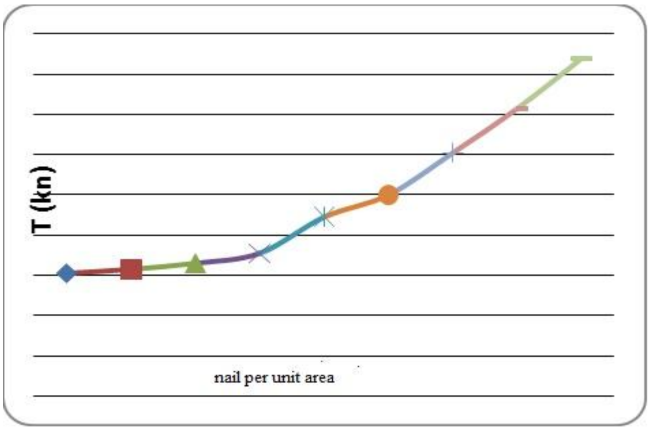

Fig. 25: Influence of changes of nails scattering on tensile forces.

According to the diagram, it has been shown that tensile force increased by reducing the number of nails in per unit of area. With executive and economic aspects, the best option is one nail per unit area.

Viii. Conclusion and recommendations:

Study of this system in Plaxis software makes it possible to check all different parameters such as changes of slope, diameter, nail length and layering and angle of trench overhead and even changes of soil mechanical characteristics such as internal friction angle and cohesion. According to the previous results of modeling it can be said that:

- The highest forces are focused on downside of trenches.
- In designing, we must pay attention to bottom section of walls.
- In order to be easiness of implementation and appropriate drainage is better that nail certainly conducted with negative angle.

Surface Cover:

Shotcrete is cover of nailed structures by using mesh reinforcement and concrete spraying with pressure and is not the main component of structural or bearing part. This cover is surface continued and flexible layer that can fill the cracks and caps appeared while nailing the trenches and also protect the local stability of soil against surface corrosion and weathering. Usually its thickness is between 5 to 10 cm is executively implemented from top to bottom. Maybe, It's not generated required quality and beauty. Drainage between soil and shotcrete doesn't implement well.

Select The Best Parameters To Performance:

Using the results of analyses and study of last parts is offered the article summary and conclusions and finally presented some Executive suggestion for safe, economy, performance and durable designing. So in this project and this kind of materials in current situation for stability of the trench is proposed:
-implementing a Berm with 8 meters in width, in the trenches with height of 15 to 18 m.

- Nails diameter is from the type of $\phi 28$.
- Nails length implement 0.8 H (H is height of the walls of trench).
- nail angle implement -8 degree into horizon
- In the number of one nail to be considered in a square meters of the trenches.

Ix. General Suggestions:

So in order to implement the system in road-building following general recommendations are presented;
- In some parts that trench has been implemented:

According to much height and impossibility of implementation the system should be created stairs with width of 8 meters. And for any square meters put the nails on two created surface from bottom to top. Nails dimensions, length, diameter and the number of them in the previous sections were calculated. Shotcrete cover is implementing with mesh by numbers of 8 and 10 cm intervals (prefabricated). in a few parts of the trenches path to the height of over 35 meters is observed that in terms lack of access to above trench the possibility of implementing the system is not prepared. Ineluctability is used in situ reinforced conservation Gallery with sagital section and charge of more than 5 times of discussed system for sustainability. Means that if at first phase the excavation operations and then nailed. The charge of it is 35% other charge of stability techniques. In parts that trenches has not still been created:

For this purpose in steps after excavation to the height of 2 meters, then is implement nailing and shotcrete and so on up to the bottom of trenches executive operation is repeated (fig26).

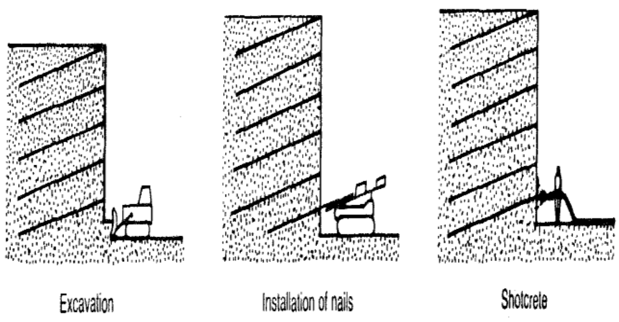

Fig. 26: sequential stages of system implementation.

Due to the high altitude (h = 18 m) is requirement to reach static safety factor 1.45 and dynamic safety factor 1.2 as a surface after software analysis. Nail diameter with dimensions of $\phi 36$ and number of 2 nail per square meter is needed. Nail length or ratio of L/H are applied 0.8. The most suitable angle of nailing is $\theta = -8$.

Conclusion:

According to previous researches on capability of Plaxis software is considerable in nailing simulation technique. The result of software validation is shown its high-precision in analysis of geotechnical structures.

According to focus of conducted research in this project on soil reinforcement by using nailing method can be expressed the following results of obtained analysis data:

- With attention to exert acceleration to mode in the state of available one stair is happen at the bottom of trench in the middle of trench, the maximum displacement.
- The maximum horizontal acceleration at the bottom of the trench is occurred.

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- Maximum tensile force is stored at the lowest nail.
- the obtained results from analysis and evaluation of the above paragraph illustrates that the critical parts in nailing operation is the bottom areas of trench and more consideration should be focused on these areas.
- However the stored forces in nails are different in various heights, but in an angle alignment of nail placement, have not effect on the amount of force in that place.
- By increasing the L/H ratio (ratio of the nail length to height trench), the axial force is reduced and this factor is remained constant for values of more than 0.8.

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