Comparison of shear pile force and moment in slippage reinforced with shear pile

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Abstract: High importance of landslide and notable loss of cost and life in various country, leads extensive research in soil mechanics for this problem. Soil stability increases by several methods. The methods work as the factor of causing decrease active pressure or increase passive pressure. One of these is using of shear or soldier pile as single or wall system. Piles by increasing of passive force against landslide will cause the increase of slope stability. Also piles in this manner can operate as deep foundation for structures founded up the slope. In these situations using of them will be lead to economic construction. To use piles for slope control, both structural and geotechnical resistance of piles, must be considered. As the piles in slope are subjected to large axial and shear force, also bending moment, their design needs specific attention. In this research, shear pile response studied with limit equilibrium method, LPILE software and finite differential method approach using FLAC, for two piles with different elasticity modules. Shear and axial force and bending moment diagram for structural designing of piles, from these methods will be presented. Results with emphasis of suitable effect of pile on slope instability control, shows that, location of pile in the slope and elasticity module has significant effect on the forces and bending moment of pile.

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Keyword: Slope stability, landslide, shear pile, LPILE, FLAC

1. Introduction

Each slippage, rolling or block motion of soil, stone or combination of both is called landslide. Assessment of probable danger of failure is caused to accurate recognition of hillside and so suitable methods can be selected for hillside retrofit. Decision on the suitable method needs following cases:

a- type and shape of failure
b- Relation between geology condition and potential shape of failure
c- Importance of hillside activity or size and velocity of it
d- Effective element in instability
e- Shape and characteristic of failure
f- Value of movement and displacement of hillside
g- Possibility of mathematical analysis usage

Terzaghi divided Landslide reason in two group: external cause and internal cause. Increase of active shear stress is cause of external cause that is occurred result of geometric change, loading and uploading of hillside, Shocks and vibration, Drawdown and etc. decrease of shear strength is cause of internal cause that is occurred result of Progressive Failure, erosion, water seepage and etc.

Reinforced concrete pile can be designed for stability of landslide. Making of shear pile is rather simple and don't need special contractor. These piles can be installing during of landslide and are less trouble than other methods.

Commonly, shear piles in geotechnical culture is used as a structural member for transmittal of axial load to underside resistant layers or resistance of lateral load and bending moment on top of pile cab and in low references, shear piles was considered in landslides control. In this paper, piles role is studied in landslide control and its design under distributed and point shear force and moment in pile length.

In last studies, diagrams were presented for determination of suitable distance between shear pile because of interaction of soil and pile, effect of soil arching phenomenon for shift of lateral load and in result decrease of lateral load on piles and negative effect of adjacency piles on use of maximum pile capacity.

Using of pile can increased coefficient of slope stability that value of this increase depend to pile geometry, it's location, distances of piles together, soil type and slope of geometry. Too , piles is introduced as a suitable and certain solution in stability with time limitation, limitation in shape in end of work, limitation in access, high depth of slide sheet, without creation of risk for slope in during of installation.

For increasing of pile effect on soil slope stability, it is necessary that pile pass from slide sheet and then continue with enough length.

2- Boundary equations on the base of load-deformation curve

One of the methods for study of pile behavior in soil trench is boundary equations on the base of load-deformation (P-Y) curve. In this study assumed that pile obtained its strength against shear from earth bearing capacity in touch to itself.

This problem is an interaction between soil and structure and has similar behavior to beam on the elastic bed that was solved by Hetenyi (1946).

$$EI\frac{d^4y}{dx^4}+Q\frac{d^2y}{dx^2}-P+w=0 \qquad (1)$$

That Q= axial load on the pile (if exist), x= length coordinate, y= lateral displacement of pile in point x, P= lateral reaction of soil per length, EI=bending severity of pile and w=load distribution in pile

This differential equation is solved by using soil load-deformation (P-Y) curves. Drawing plan of it is shown in Fig (1).

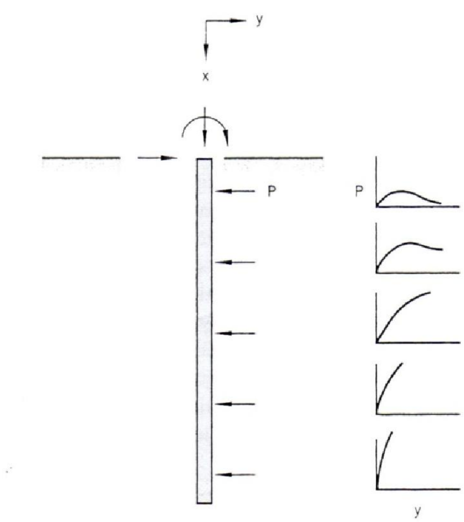

Figure 1. P-Y curve with depth for buried pile under lateral loading (Reese et al 1989 [24])

Reese & Wang (1989) [25] write LPILE program for solve of differential equation. P-Y curve changes with alteration of soil properties, depth, load condition (statically, periodic, temporary and etc). LPILE program permit to geotechnical designer to:

1-Intern soil properties on the base of P-Y curve.

2-Intern real P-Y curve resulted of insitu pile test.

3-Draw P-Y curve from several models of soil and stone.

3- Study of pile behavior in soil trench

3-1- Study of pile behavior by LPILE program

In this paper, LPILE program is used for P-Y analysis and comparison with results of other methods model. This program can presented P-Y curve, shear, and moment and displacement diagrams n length of pile.

P-Y analysis is on the base of modules of bed reaction and considers soil as Winkler elastic-plastic environment (Fig (2)). In this method, soil is modeled by separate nonlinear springs that are set in length of pile and in various depth of soil.

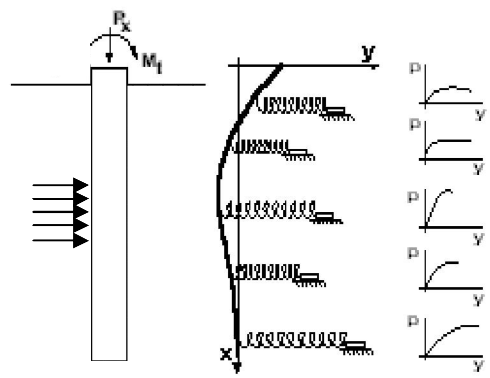

Figure 2. pile modeling under the lateral loading by separate nonlinear springs

Independent of spring behavior is fault of this method, because soil properties in each depth are biased from top and bottom soil. P-Y curves are resulted of P-Y analysis that is independent of shapes and hardenings of pile. P-Y curves show ratio of lateral pressure of soil to pile displacement. Spring behavior is elastic-plastic so P-Y curve in specific depth with increasing of soil deformation change from zero to ultimate lateral strength of soil.

This program has suitable ability for identifying of pile behavior under lateral distributed and point loading. Program inputs are soil properties, subterranean water level, geometry and material of pile, condition of pile cap and distributed and point loads and moment on the pill and its output such as diagrams of shear and moment, pile displacement, P-Y curves and etc.

LPILE program can't consider finite trench and can't model of suitable slope, so only one example modeled with this program according to following properties (Table1).

Resulted of write program according to Ito& Matsui (1975) equation was used as input load of pile. Obtained results of analysis by this software are presented in Fig (3-4)

Table 1.properties of various parts of model

Soil	
Unit weight(KN/m^3)	20
Cohesion(KN/m^2)	10
Internal friction angle	20
Elasticity module(kpa)	2e5
Poisson's ratio	0.25
pile I	
Unit weight(KN/m^3)	78.5
Elasticity module(kpa)	2e8
Poisson's ratio	0.2
Diameter(m)	0.5
pile II	
Unit weight(KN/m^3)	23.5
Elasticity module(kpa)	2e7
Poisson's ratio	0.15
Diameter(m)	0.5
Boundary element	
Elasticity module(kpa)	2e5
Poisson's ratio	0.25
Cohesion(KN/m^2)	10
Internal friction angle	20

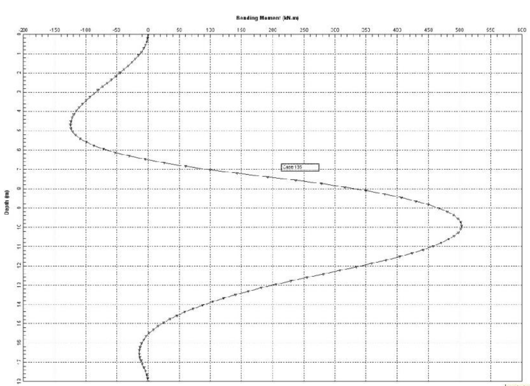

Figure 3- bending moment of pile under lateral load by using finite equation inputs

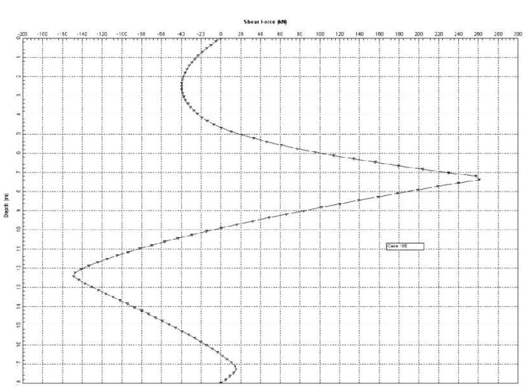

figure 4- shear force of pile under lateral load by using finite equation inputs

3-2- Study of pile behavior by FLAC software

3-2-1- study of axial force, bending moment and shear force in two pile with different elasticity modules and in maximum increase of stability coefficient

One of the parameters that can be effective on the pile force in soil slope is elasticity module of pile. So two pile with same properties but with main difference in elasticity module ($E_1 = 10 \times E2 = 2 \times 10^8 Kpa$) were studied in slope with angle=30 degree and in position with 80% of slope distance from toe. Other geometry and geotechnical properties of soil and pile were same.

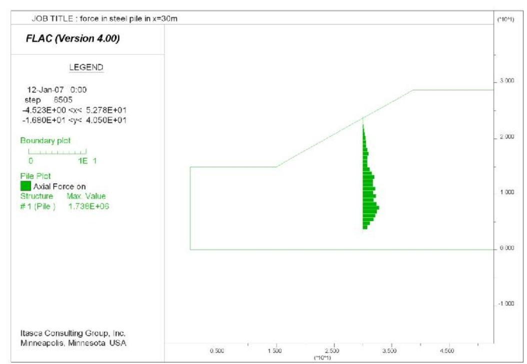

Figure 5- axial force in pile I, maximum value is 1738 KN

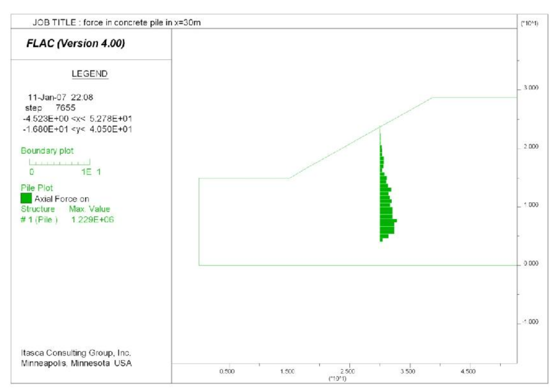

Figure 6- axial force in pile II, maximum value is 1229 KN

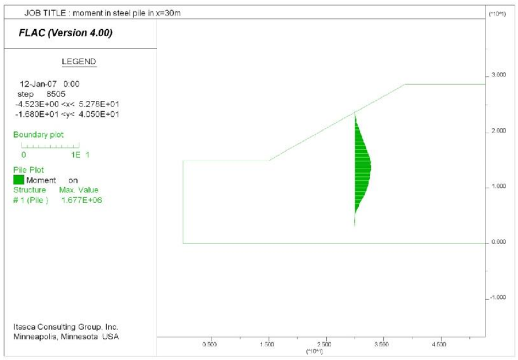

Figure7- bending moment in pile I, maximum value is 1677 KN-m

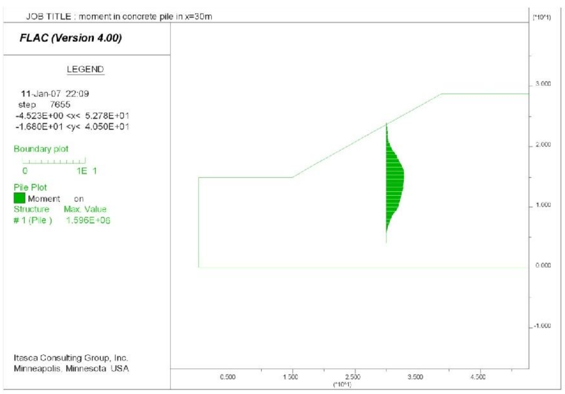

Figure 8-bending moment in pile II, maximum value is 1596 KN-m

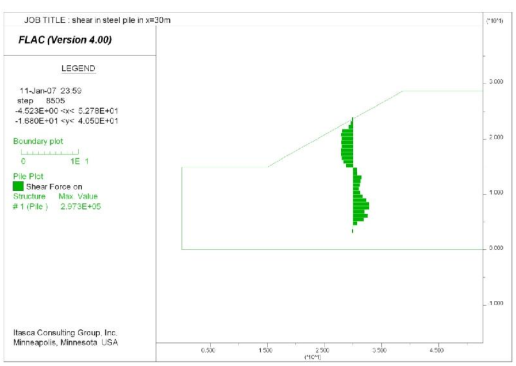

Figure 9-shear force in pile I, maximum value is 297 KN

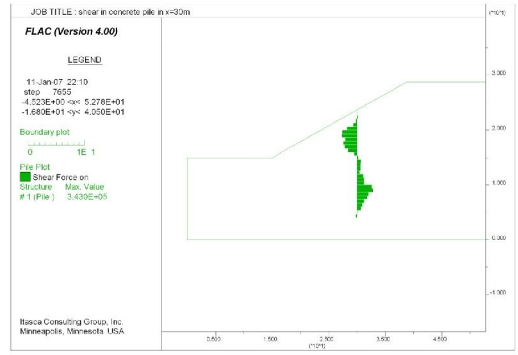

Figure 10-shear force in pile II, maximum value is 43 KN

Following diagrams were obtained for shear and moment from output of FLAC software.

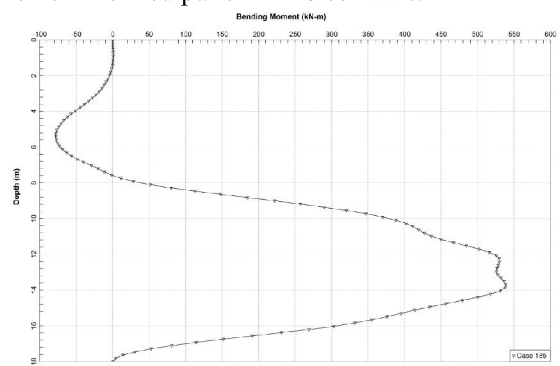

Figure 11-bending moment in pile under lateral load by using FLAC input

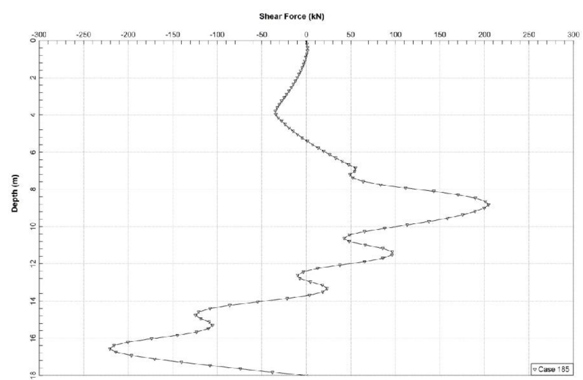

Figure 12-shear force in pile under lateral load by using FLAC input

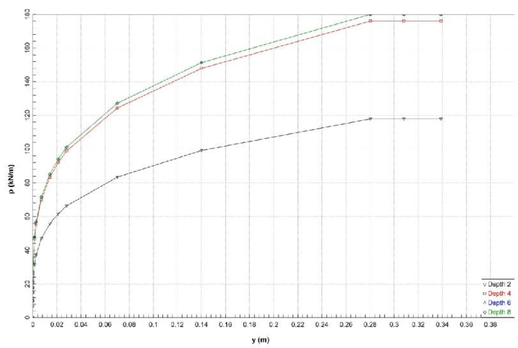

Figure 13- P-Y curve for pile under lateral load

3-2-2- comparison of forces in pile with different elasticity modules and in different distance from slope heel

Change of axial force, shear, bending moment and displacement according distance from toe is presented in Fig (14-17).

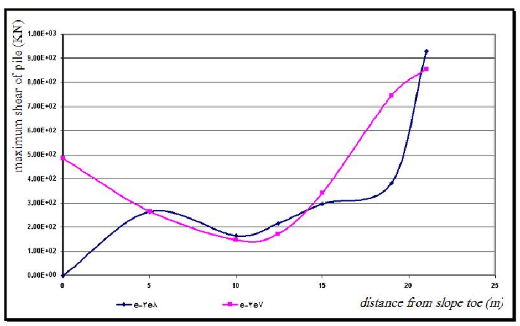

Figure14- comparison of maximum shear of pile in two pile with different elasticity modules and in different distance from slope heel

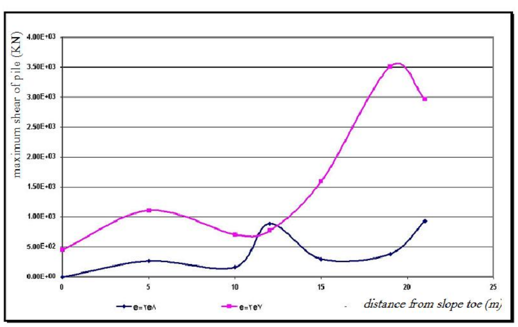

Figure15- comparison of maximum moment of pile in two pile with different elasticity modules and in different distance from slope heel

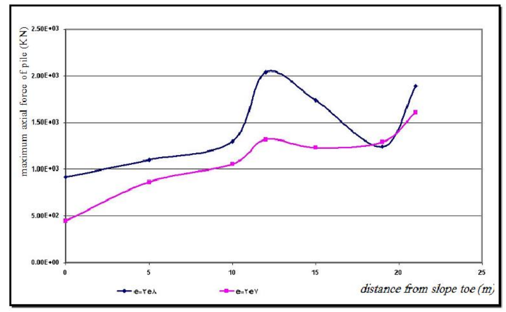

Figure 16-comparison of maximum axial force of pile in two pile with different elasticity modules and in different distance from slope heel

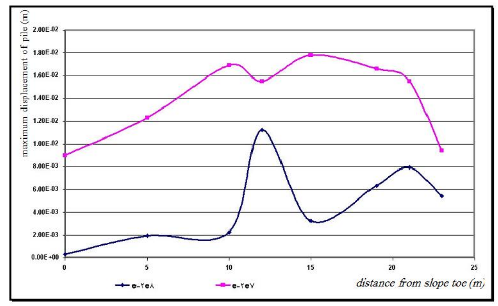

Figure 17-comparison of maximum displacement of pile in two pile with different elasticity modules and in different distance from slope toe

As shown in Figures, with locating of pile in 80-85 percent of slope heel, safety coefficient is increased largely and maximum shear and moment are bigger value in this zone. Also maximum moment in pile with lower elasticity module is strongly bigger than pile with higher elasticity module. This point is correct in maximum displacement and shear.

3-2- Study of pile behavior in soil trench by using wrote program on the base of finite equation of Matsui & Ito (1975)

this equation calculate pile force by using of geometry and geotechnical inputs such as internal friction angle, coherence, specific gravity, pile diagonal, distance of piles (ax to ax) and pile height. This equation is solved on the based of table 2 information.

Table 2- input of program on the base of Ito & Matsui (1975)[13] equation

	Soil 1	**Soil 2**
Unit weight(KN/m^3)	19.8	19.2
Cohesion(KN/m^2)	10	40
Internal friction angle	20	0
Pile diameter	0.5	0.5
Distance of pile (m)	2	2
Pile height in slip circle(m)	8	8

Results of program for determination of lateral load on the pile are in the following figures:

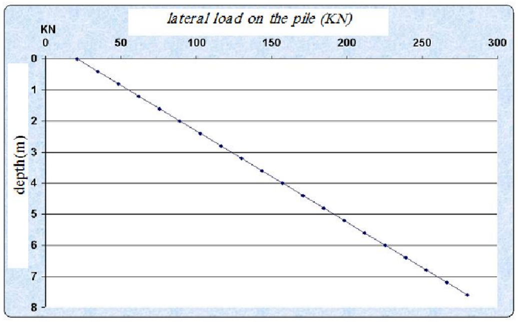

Fig 18- lateral load on the pile with soil 1 by using of Ito & Matsui (1975)equation

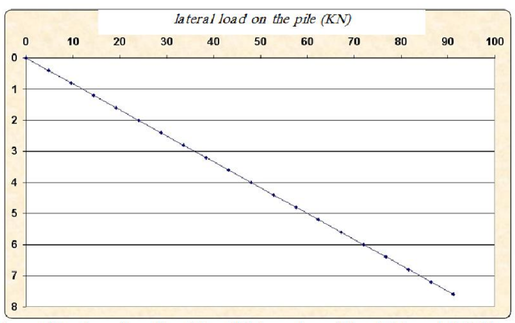

Fig 19- lateral load on the pile with soil 2 by using of Ito & Matsui (1975) equation

This equation can be used only to infinite slops and don't consider other significant parameters such as location of pile in slope, elasticity module of pile and angle of slope on the lateral load of pile.

4- Results

In comparison of finite equation methods on the base of Ito & Matsui formula, displacement-force curves method with using of LPILE software and FLAC as finite element software, it can be seen obviously that two initial method don't consider significant parameters on determination of lateral load of pile. According to figures of FLAC software modeling, location of pile in the slope and elasticity module has significant effect on the forces and bending moment of pile.

By downward movement of soil, significant axial force is load to pile specially in top part of slope. With attention to strength of pile in axial force bearing, it hasn't determinant role in pile design, but if there is vertical load on the pile, this force should be considered in calculations.

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5- References

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