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Stabilization of Landslide: A Case Study

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ABSTRACT

Background: Pursuant to construction of the Qazvin–Rasht freeway and creation of trenches at the foot of the slope in Dashtegan-Rudbar in Gilan Province, the huge landslide of Dashtegan-Rudbar, with 1.5 million m3 in size, blocked the route and caused a long interval in the execution process. **Objective:** Construction material - a combination of rock and soil - in the upper part of mass was lying on a layer of silt and clay settled on the bedrock. **Results:** The studies carried out through back analysis showed the saturated mode before landslide stability of the mass; however, the Dashtegan-Rudbar landslide happened during constructing the freeway. The present paper discusses a series of stabilization methods before and after mass slide to prevent a long interval in project execution process. **Conclusion:** Technical, economic and executive evaluations before and after mass slide confirm superiority of cantilever retaining wall supported by guard piles as compared with other methods.

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INTRODUCTION

Natural disasters, as the greatest natural enemy of humans, cause loss of life and injury of hundred thousand people and homelessness of millions of people all over the world every year. Studying available trenches on a freeway is of the major cases that should be considered at the time a freeway is constructed. On freeways, with respect to the high speed of vehicles, minor collapses along the route may also be very dangerous. Therefore, with respect to this issue and life safety of drivers, it is essential to consider stability of trenches using the methods in proportion to project conditions.

Most natural phenomena act in the opposite direction of human tendency in ever-increasing development of land. In most cases in which they were ignored and where a correct managerial system was not dominant, they appeared as natural disasters. One of the phenomena is landslide, or in a broader term ‘slope instabilities’. Simply, these phenomena include movement of materials down the slope under the influence of gravity. Many factors, such as torrential rains, seismic-caused stresses, and stresses caused by artificial excavation involve in exciting slopes instability. With respect to the geological, physiographic, meteorological characteristics and social condition of Gilan Province, landslide hazard is considered as one of the geological disasters and we face major landslide-caused damages. Several huge landslides have occurred in this province, some led to the burial of some areas or all the villages; burial of the whole Fatlak village in June 1990 was among them. Seymareh (Saidmarreh) landslide in Zagros Mountain Range is one of the greatest and rarest landslides in the world that occurred in prehistoric times. Landslides caused by heavy rainfall in 1993 in Gilan in which 6 people died and 16 houses damaged, are among the major landslides in Iran (Hafeziet et al ,1993, Laskkaripour,1999)

RESULTS AND DISCUSSION

Dashtegan-Rudbar Landslide:

The area under study (Dashtegan-Rudbar) is part of the heights of Western Alborz in north of Iran and one of the mountainous regions along the Rasht-Qazvin freeway. After constructing trenches, landslide occurred in the area under the influence of different factors and due to seismic activity and various geological conditions. The landslide occurred in the eastern part of the old landslide of Dashtegan, between 29+550 and 29+800 kilometrage of the Rasht-Qazvin freeway. Dashtegan landslide is a mixture of soil and rock. Its rock material is made of tuff, green and gray agglomerate, ignimbrite and red and brown ignimbrite tuffs. The upper part the slope consists of flood drain deposits and top soils. High level of weathering and alteration in the region had a

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considerable impact on providing appropriate conditions for landslide. The route was completely stable before trench excavation. Excavation was performed at the level of the slope and in fact, by removing anchor of fine-grained section of mass. Some cracks were formed in the upper part of landslide near the area of high voltage tower as shown in Figure 11. Over time and under the effects of some factors such as excavation at the toe level of the slope, the great Dashtegan landslide occurred in June 2005 (Khosrow Tehrani, KH. 2010)

Due to the landslide, about 1.5 million m^3 soil and rock moved downward in only a few minutes, which accompanied by loud noises. As an unstable mass, it blocked the freeway in this area, displaced agriculture lands, and olive gardens, disturbance of agriculture task, and collapse of high voltage towers in the region. As a great challenge, the landslide hindered construction procedure of the Rasht-Qazvin freeway.

Fig. 1: Landslide near high-voltage power pylons

Causes of Dashtegan-Rudbar Landslide:

According to the studies (Mortazavi *et al*., 2006), with respect to the experiments and excavations, the major causes of landslide on the freeway were categorized into three general groups including, natural, geological, climatic conditions and artificial factors related to human activity. These factors are briefly explained as follows (Mortazavi *et al*., 2006):

- Unique structural and tectonic impacts, 45 degree slope of land topography, known faults (Herzevil fault, Rudbar fault, and Sefidrood fault)
- The effect of mass weight, material and components of its mass volume
- Over 30 m height Trenches with side slope of 8 vertical and 1 horizontal
- Temperate to slightly arid climate of the region
- Surface waters of the Sefidrood river, rain and snow
- Trenches construction, explosion and change in slopes

Stabilization Methods of Dashtegan-Rudbar Landslide

After examining the major causes of landslide incident in Dashtegan-Rudbar, two methods were studied; they include 1-Construction of retaining wall that is anchored to the bedrock by tendons 2- Cantilever retaining wall supported by guard piles in the upper part of the Dashtegan landslide (Cornforth, 2005)

Method 1: Construction of Retaining Wall Anchored to the Bedrock by Tendons

The main objective of the above method is reduction of a considerable amount of excavation and embankment. To reduce height of wall and access an executable height, part of the soil was removed in the retaining wall construction and the retaining wall was constructed. To complete construction of the freeway, we need to remove the soil in front of the wall. This reduces resisting forces and increase displacement of the upper end wall. In order to control the impermissible displacements of the upper end wall and wall collapse in some sections, we need to anchor the wall by tendons. Figure 2 and Figure 1 show the results of the numerical analyses of this method for mass stabilization, respectively.

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Based on this, the average height of the wall to reach stabilization before slide was between 16 and 18 meters. After slide and with the increase of about 25 percent, it reached 20 to 22 meters. Wall thickness is 1.5 meters. One of the major problems of this method is the long anchors, 35 to 50 meters. With further instabilities of a mass after slide, we will encounter some more serious problems to erect them. By studying this method, we aimed to reduce excavation and embankment operations considerably, as volume of excavation and embankment was reduced to half. As Figures 3 and 4 show, deformations of internal mass and upper end wall in the quasi-static mode exceeds the static model. However, by bracing the upper end wall, its displacement was controlled to one percent of the wall height.

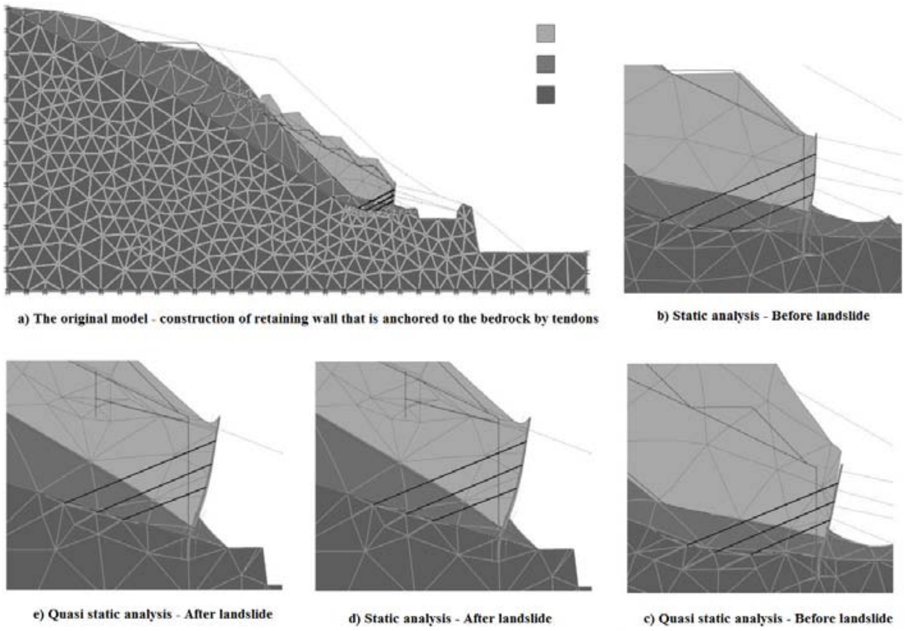

Fig. 2: The deformed mesh after stability analysis

Table 1: The output of numerical analysis - construction of retaining wall that is anchored to the bedrock by tendons

Parameter	After landslide		Before landslide	
	Quasi static analysis	Static analysis	Quasi static analysis	Static analysis
The maximum displacement of the soil mass	934 mm	66 mm	445 mm	59 mm
The maximum displacement at Pile tip	169 mm	66 mm	69 mm	31 mm
Pile axial force	208 ton	363 ton	105 ton	235 ton
Pile Shear force	247 ton	217 ton	239 ton	171 ton
Pile bending moment	767 ton-m	653 ton-m	562 ton-m	452 ton-m
Tendons axial force	142.2 ton	81.9 ton	82.9 ton	62.4 ton
The maximum displacement of the soil mass	1.51	1.52	1.32	1.65

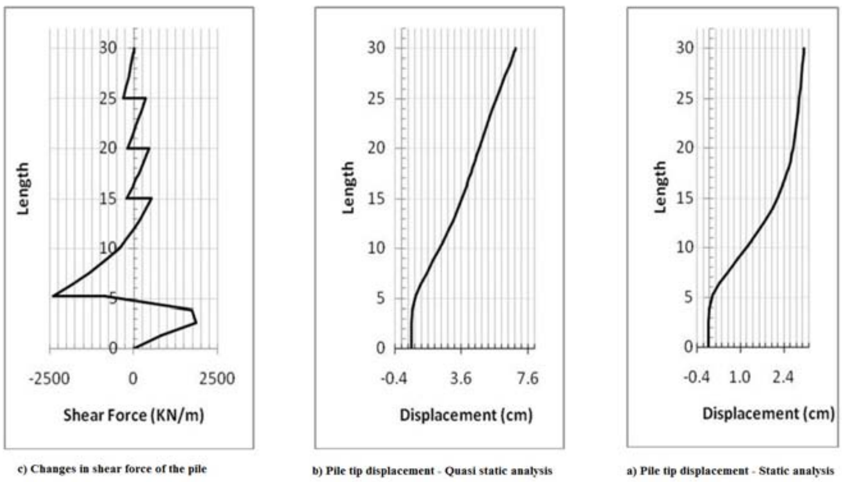

Fig. 3: Deformation and shear force diagrams for retaining wall (pile) - Before landslide

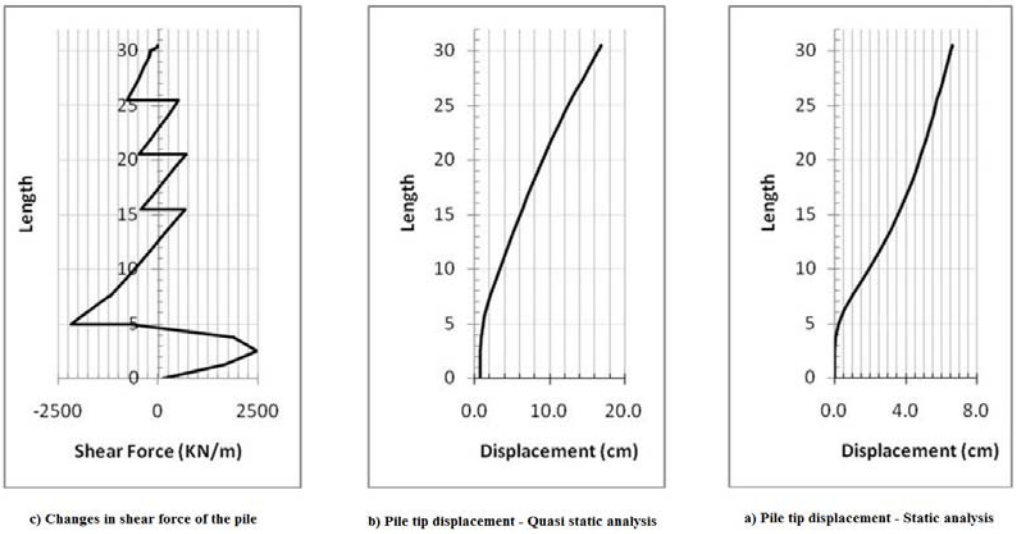

Fig. 4: Deformation and shear force diagrams for retaining wall (pile) - After landslide

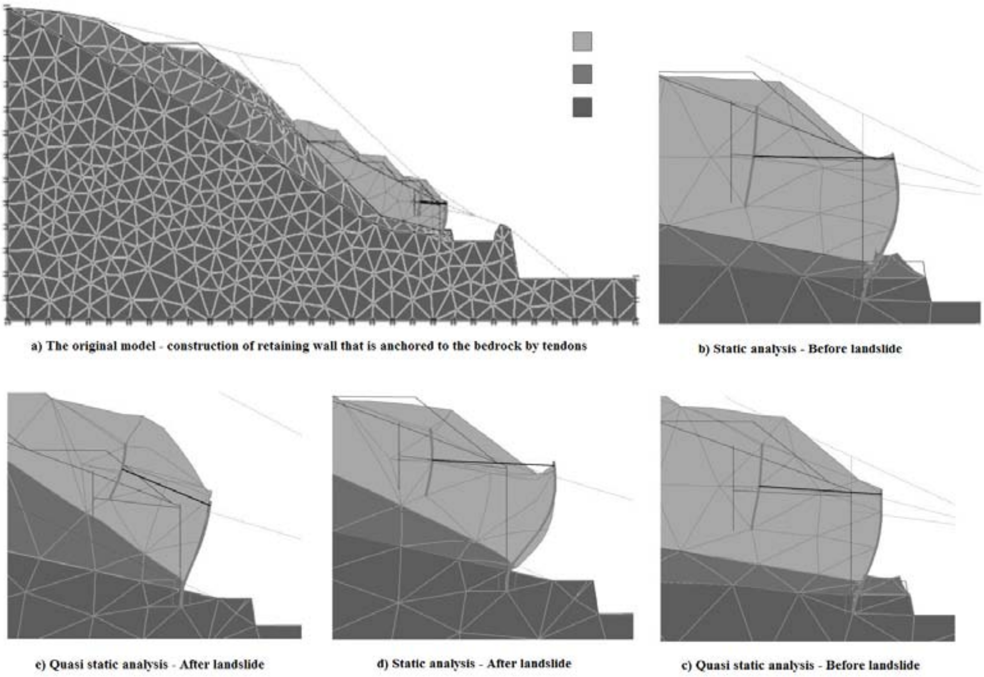

Fig. 5: The deformed mesh after stability analysis

Method 2: 2- Cantilever Retaining Wall Supported by Guard Piles in the Upper Part:

Guard piles in the upper part of the mass were used for overcoming the problem of installing long tendons inside a weakened mass. In this method, again, part of the soil above the mass was removed to access the executive length of the wall. The retaining wall was constructed after excavation. To prevent impermissible displacements of the upper end wall, one series of short piles were placed in the upper part of Dashtegan landslide and the main retaining wall was anchored to it by tendons. To examine stability of each execution steps, cross section modeling was performed by dividing it into different execution phases. After examining stability of each execution process at static mode, quasi-static stability analysis was carried out by applying horizontal acceleration coefficients equal to 0.175 g. Figure 5 shows the results of deformations caused by stability analyses. Table 2 shows output of piles .

In this state, as shown by Figures 6 and 7, deformations of internal mass and the upper end wall at quasi-static mode exceed the static mode; however, by bracing the upper end wall, its displacement was controlled to one percent of the wall height. On the other hand, with respect to the forward mass movement after sliding and damaging soil cement tissue, displacement of upper end wall, internal forces, and anchors of piles increased. In

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this analysis, average length of the wall - before and after the slide - and volume of the excavation and embankment were remained fixed to stabilize the mass. However, bracing method was changed, as the average lengths of the secondary piles – for bracing the retaining wall before slide and after Dashtegan slide were determined as 6.5 meters and 6 to 8 meters, respectively. The average height of the braces between the retaining wall and the secondary piles – before and after slide – were determined as about 7 and 8.5 meters.

Table 2: The output of numerical analysis - cantilever retaining wall supported by guard piles

Parameter	After landslide		Before landslide	
	Quasi static analysis	Static analysis	Quasi static analysis	Static analysis
The maximum displacement of the soil mass	930 mm	93 mm	448 mm	67 mm
The maximum displacement at Pile tip	230 mm	90 mm	122 mm	64 mm
Pile axial force	444 ton	241 ton	150 ton	169 ton
Pile Shear force	370 ton	324 ton	256 ton	191 ton
Pile bending moment	1414 ton-m	1044 ton-m	620 ton-m	493 ton-m
Tendons axial force	163.8 ton	57.9 ton	59.5 ton	58.4 ton
Safety factor against mass stability	1.40	1.45	1.21	1.60

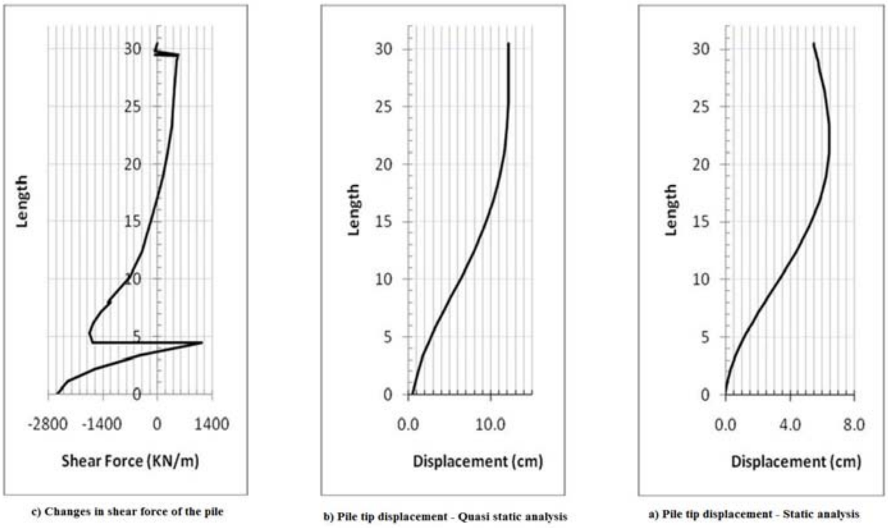

Fig. 6: Deformation and shear force diagrams for retaining wall (pile) - Before landslide

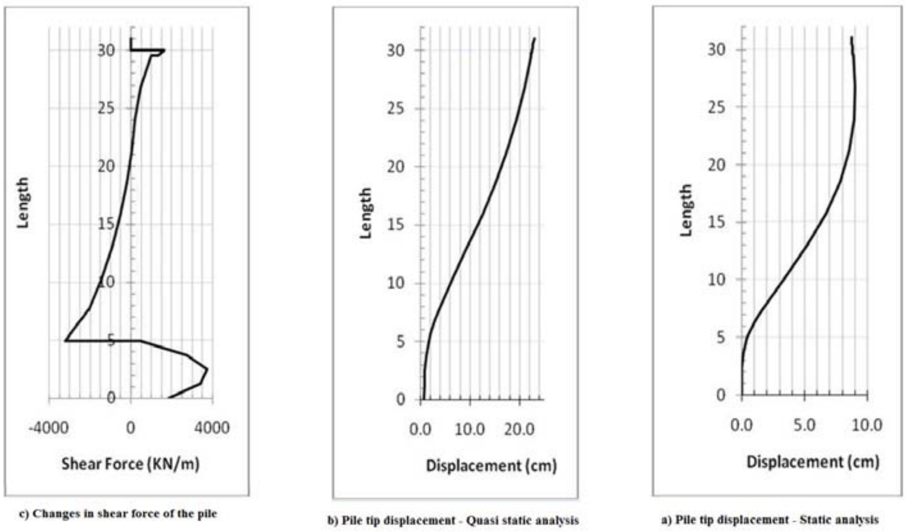

Fig. 7: Deformation and shear force diagrams for retaining wall (pile) - After landslide

Discussion and Conclusion:

Excavation and stepwise excavation can be one of the options for mass stabilization. With respect to the specific conditions of the profile of soil mass layers, volume of the excavation operation before and after slide

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were respectively 65 and 75 percent of soil on bedrock. Due to the high volume of excavation operation, mass stabilization methods were studied by the structural rigid retaining systems. To control displacements and make them cost-effective, bracing was evaluated by anchoring tendons to bedrock and secondary guard piles on the upper part of the mass. Bracing by anchoring tendons to bedrock faced many executive problems concerning installing long braces. Anchoring retaining wall to the secondary piles on the upper part of the mass was proposed for resolving this problem.

Constructing rigid retaining wall supported by the shorter piles on the upper part of the mass (tied-back wall) was proposed as a superior option for stabilizing the mass. Employing this method involves half of the earthwork and convey needed for excavation and embankment. Moreover, deep drillings, especially in bedrock, prevent executing 35 to 50 meter braces and are highly cost saving. Height of rigid retaining walls before slide is between 16-18 meters. After slide, the height is 20-22 meters – with approximately a 25 percent increase. Volume of earthwork operation is also reduced to half. The best time for mass stabilization was before constructing the freeway and before mass slide, as it considerably prevented long interval in constructing the freeway, exploiting it, and the additional expenditures incurred.

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