ICENS International Conference on Engineering and Natural Science
May 15 - 19 Skopje

SLOPE STABILITY ANALYSIS METHOD OF ACCOUNT BACK AND EXAMINATION OF TEKKE LANDSLIDE WITH BACK ANALYSIS METHOD

Mümin FILIZ
Suleyman Demirel University, Isparta and 32000, Turkey.
mfiliz@tef.sdu.edu.tr

Semiha GÖKCAN
Bilecik Seyh Edebali University, Bilecik and 11000, Turkey.
semiha.gokcan@bilecik.edu.tr

Abstract
One of the methods used in slope stability analysis is the method of back accounts. In the method provides the detection of unknown parameters from the parameters are known. In this study, which is one of slope stability methods back calculation method by including information about the method applied Tekke Landslide was investigated. There are the characteristics of the soil profile among the factors that control the slope stability. İn addition; there are additional loads can be located on the slope with topographic, geological, hydrological, climatic conditions and vibration forces. Ground material condition of Tekke Landslide on Antalya-Burdur highway were investigated and improvement works were carried out for path to enhance the existing standards. As a result of the assessment and accounts; the most appropriate solution is found to be the fore-piling applications for area available protect from landslides an increasing size. This situation has been deducted around the landslide areaso as to be properly drained. This situation was designed and implemented will not be allowedto the water inlets the bottom of the slope in landslide area.

Keywords: ***Slope, Stability, Tekke Landslide***

1. INTRODUCTION

The loss due to the mass movements (landslides) in Turkey, because of which the number of the dead and premises is numerous, are of great significance. Champer movements cause to the champer corruptions on highways as well as constructional damage in urban areas and harvest losses in rural regions on accountt of rippled surface sructure of our country. These movements might occur due to human acts however they might as well come out by themselves. The measurements to be applied for these movements in Turkey are practised by various ways, one of which is Back Measurement Method. This method provides to determine the way that the earth would conduct in future, and thus designate proper precautions to be taken.

On the highway between Antalya and Burdur, in Tekke passage, a landslide occured as a result of a stability problem due to the weakness of geological units and existence of underground water. For this reason on this route were drillings constracted in order to gain data for back measurement method to get a local betterment by means of geological-geotechnical studies. The data obtained from Tekke Landslide has been analysed through PLAXIS, an alaysisprgram with an ending element, and thus attempted to strenghten the earth to realize precautions not to have a future occurance of the same event.

2. EXPERIMENTAL

On the highway between Antalya and Burdur, in Tekke passage, a champer movement occured resulting in the deformity of existing quality of the highwa. The higway route is shown in Pic. 5.1. In order to meet the increasing traffic current due to the develoment of our country the Burdur-Antalya highway has been resconstrated by warm mixture method. In this betterment project the starting point is the existing champer movement and thus the reasons for the corruption is analysed. The surface parameters analysed and for that the scurity factor is taken as. By means of the usage od Back Measurement Method the model is applied in Plaxis program and parameters giving the slide conditioon are determied. These parameters are used in the betterment project applied later on.

Within these the studies, in order to determine the geometrics of the landslide geological-geotechnical surveys are realized by means of several drilling applications on the highway between Antalya and Burdur, in Tekke passage. Several essential tests are applied then on the samples taken from these drillings, which are then used for geological and geotechnical mapping of the route. The findings are put into the usage for proper betterment process in case of a repetition of the landslide.

2.1.Materials

The place of 2.1.1. Landslide: Highway between Antalya and Burdur, Tekkekoy region.

The geology of 2.1.2. Survey Area: The structure of the land of the city area has a complex texture because of the combinations occured in various geological eras. Prior to the second geological era the region was within TETIS geocenklinal era, and through second, third and fouth eras the land have passed the Alpine orogeny having its shape today.

The formations commonly seen in the region belong to vairouspeoriods of mesozoic and tesierpeirods. Quaternary storages take place in the lower areas of the region. (Figure. 1)

Figure 1. 1/25000 scale Geology Map of the project area and the environment

2.1.3. Tectonical Evolution

Burdur city and its environment is within 1st degree earthquake zone, and in the past century numerous earthquakes occured, 11 of which were either medium or high level earthquakes. As a result becuse of the numerous deads and loss of land premises people started to abondon the place, which then affected the theeconomical and social life blocking the development of the whole area.

The city of Burdur is located over Burdur plate zone which is one of the most active plates in the West Anatolia. (Figure 2).Within the years of 1914, 1957 and 1971 various major earthquakes between the sizes of 6.1 – 7.1occured in the area. The distance of the underground water from the surface is of a great importance within the areas enjoying first degree earthquake risk because of the difluation of the surface.

Figure 2. The costructional map of the area

2.1.4. Geomorphology

The area has two parts geomorphologically, one of which is Burdurresevoir involving Burdur and Yarışlı Lakes, and the other is Tefenni reservoir in the southwest of Burdurresevoir between Karamanlı-Tefenni and Kemer. These young reservoirs which occured in different durations in lengths and developments connect with a passage.

2.1.5. Seismicity

According to the data obtained from "Turkey Earthquake Regions Map" studied by T.C. BayındırlıkveİskanBakanlığı (Ministry of Public Settlements) the project area is in a first degree earthquake area. The horizontal earthquake acceleration to be used in slope satbility analysis is to be taken as ah ≈ 0.2 g.

2.1.6. Land Studies

As a result of drilling applications organized by Highways 13. Region, on the highway between Antalya and Burdur, in Tekke passage, a landslide occured as a result of a stability problem due to the weakness of geological units and existence of underground water. For this reason on this route were drillings constracted in order to gain data for back measurement method to get a local betterment by means of geological-geotechnical studies. As a consequence of these results the structure of the ground is Silty sand and Clay sand, and this info is then used in the designs.

The sieve analysis results in accordence with the samples obtained from the drillings: The percentage majority of the ground particules goes through sieve 200, and for this reason Attenberg Limits tests are required.

Attenberg Limits tests results for the drillings samples taken from the area involved in the reports are;

Liquid Limit LL (%)=31-44

Plastic Limit PL (%)= 15-17

Plastisite İndex PI (%)= 15,5-27,5

Natural Water content between (%): 10-11

Table 1.Tekke Landslide area Labortuary test results

TEST RESULT TABLE											
SAMPLE				Atterbeng Limits			Sieve Analysis Over %				USCS Ground Class
Drill No	Depth (m)	Sample No	Wa (%)	LL	PL	PI	4 %	10 %	40 %	200 %	
SK-5	9,00-9,07	SPT-6	6,8		N-P		52,0	39,5	24,5	3,2	SP
SK-5	10,50-10,95	SPT-7	19,0	36,3	15,2	21,1	72,5	66,9	55,2	40,0	SC
SK-5	13,50-13,67	SPT-9	9,4	43,7	16,2	27,5	75,5	72,3	61,7	47,8	SC
SK-6	1,50-1,95	SPT-1	7,4		N-P		61,7	51,8	39,2	18,6	SM
SK-6	4,50-4,85	SPT-3	12,0		N-P		76,1	62,5	38,3	23,0	SM
SK-6	9,00-9,28	SPT-6	4,2		N-P		69,8	59,1	45,0	20,9	SM
SK-6	15,00-15,35	SPT-10	10,9	31,8	16,1	15,7	62,1	54,4	45,0	35,1	SC
SK-6	19,50-19,60	SPT-13	13,3		N-P		63,2	49,5	32,4	12,1	SM
SK-7	4,50-4,70	SPT-3	11,2	37,3	17,0	20,3	97,0	88,7	65,4	46,3	SC
SK-7	10,50-10,60	SPT-7	9,5		N-P		65,3	54,3	44,1	25,5	SM

Table 1. Drilling list

No	Dirll No	Depth (m)	YASS. (m)
1	SK-5	34,00	-
2	SK-6	30,00	15,50m
3	SK-7	20,00	-

2.1.7. Research area geology and Tekke Landslide size

During the construction of the existing highway Dutluderelimestones located in a massive and steep slope on the right handside (TRjd) are costructed with mixed filling and some part of the way with filling (Qm). The reason why there is a noncontinuous surface between the old slope (Qc) and the filling is that the cullival (Qc) and Kızılcadağmelange and contact of the filling are not contructed in a squezed way from the bottom towards the top along with its high and steep slope structure.

Besides there is a water canal taken from the small river running towards Tekke village in 1050-1053 elevages, which goes through the landslide area (probably in the area of the filling before the land slide). This water canal is still running without coating and control through the landslide. Some part of t he canal disappears in the landslide. It is thought that this canal weakens the filling and activates the landslide. Moreover the rainfalls leak through the filling+cullivion-surface contact which results in a noncontinuous surface. This, with the addition of gra vity creates stability problem. In a ddition the the upper parts of melanges (Kkzm) in the basis are very weak-non durable, a lot-totally seperated, fragmental and in the form of clay.

In the skirts of t he landslide area is a retaining wall constructed before. The wall itself and the dilatations have lost their stability due to openings towards outside and drawdowns, which depend on two reasons:

First; the wall cannot bear the filling on top of it. Second; the leaking water at the base charges the grounds.

Consequently, Tekke landslide; is a filling landslide with 70 metres in width, and 80-90 metres in length. All told 3 dri llings (SK-5, SK-6 and SK-7 drillings) have been applied in the area. In a ccordence with the drillings the section of the landslide area is shown in Figure. 3

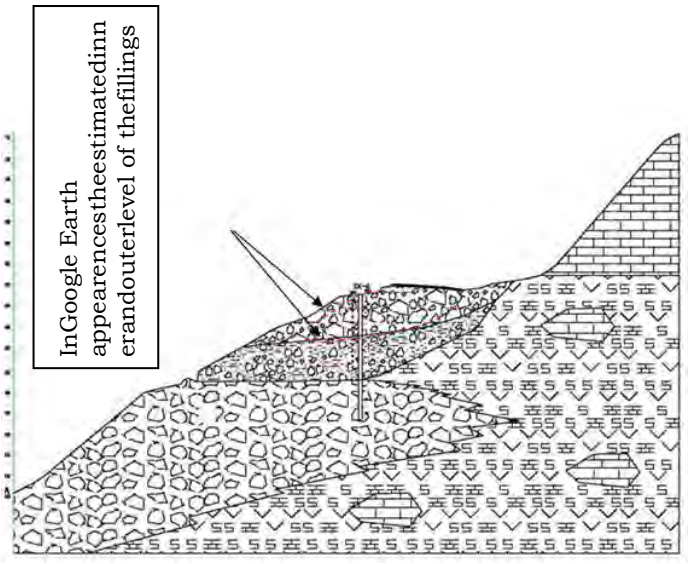


Figure 3.landslide zone section

2.1.8. The Susceptibility of the units against water

When the permeability of the units are taken into consideration the existing way fillings is costructed with sand, blocked pebbles and blocks which are permeable, and colluvials, depending on the pebbles and clay they involve, are permeable and half permeable. The Recristalizedlimestones involved in Dutderelimestones (TRjd) and conglomera and limestone blocks in Kızılcadağmelange (Kkzm) are half permeable and impermeable depending on the leaks and gaps within themselves.

3. GEOMETRICAL PROJECTS

The target of this project studiesis to find a permanent solution for the landslides occured in Turkey Antalya-Burdur Highway km 99+200. In order to have an idea of the occurence and macanism of the landslides for the mentioned solution analysis in the land of the occurence has been done along with several detailed geological and geotechnical researches have been applied concerning the landslide area. In accordence with these studies the tests and assumptions determined some geotechnical parameters which are then used in designing. Google earth provided the existing and past chamfer and highways conditions. This data provided useful info for the design of the landslide along with what kind of stability problems might occur in future.

As a result of the evaluations, the way to protect the existing Antalya-Burdur highway in part 99+200 from a bigger landslide is the fore-pile application. While analysing fore-piles the method used is basic ground mechanics principals. PLAXIS program is for the design. The concrete design of the Fore-piles is applied/resulted according to the The principals of design and Constructions of Concrete Structures (TS500) along with the regulations for the structures to be constructed in disaster areas.

Besides various suggestions have been taken into consideration in order to support the fore-piles and to decrease the amount of the load likely to come on the fore-piles.

3.1. The conditions of the environment during the landslide

Tekke landslide occured in Burdur-Antalya highway KM: 99+200. As it can be seen from the photographs and the section of the landslide champfe slope is about 30 degrees (Figure. 4). The chamfer angles that have

slided and settled on the filling are below 30 degrees. In the geotechnical department these materials have been named as colluvial and way fillings. The angle of the chamfer slopes from the wall that has moved towards the valley grounds go until 35 degrees. This material has been defined as Bresh. On the other side of the highway there is a steep drop-off with 40-45 degrees structured with limestone (Figure.5). The existing chamfer slopes provides useful data about the endurence of the material.

Figure 4. The Landslide and the deformations

Figure5. The steep drop-off on the other side of the landslide

The satellite photographs of the landslide provides important ideas about the shape and the reasons of the landslide. In the photo in year 2003 (Figure 6) we understand that the higway has three lines and there is a landslide in the 15-20 mt of the chamfer towards the walley grounds moving the fillings. In the photograph that belongs to year 2006 (Figure 7) we see that the part that slided has been repaired with a 30 degree filling. The 2010 (Figure8) photograph shows we can see that the repaired filling slipped. In Figure11 the the borders of the estimated filling is shown with red lines. Upon analysing the photographs we can clearly see that the 2-3 mt high wall underneath the chamfer has started to lose its stability in the 2003 landslide. When comparing 2006 and 2010 photographs the filling and the wall side of the filling has moved clearly. All these datas indicate that the sliding mechanism occurred in complex (mix) surface.

Figure 6.*The satellite photo of the landslide in 2003.*

Figure 7.The satellite photo of the landslide in 2006.

Photo 8.The satellite photo of the landslide in 2010.

4. BACK ACCOUNT ANALYSIS

The analysis of Tekke Landslide has been realized by PLAXIS, a program with elements with ends. The model of element with ends is shown in Figure 9. The highway is represented with a 10kPa regular spread load.

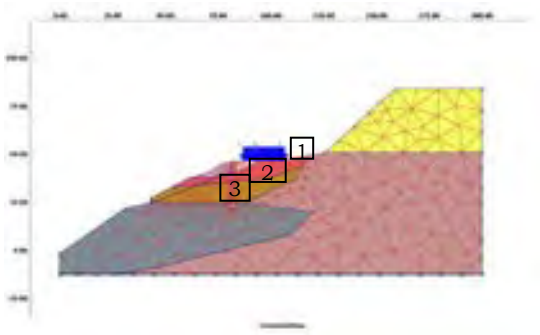


Figure9. The realized PLAXIS model

According to the observations of the landslide area and the labrotary experiment results analysis has been resulted and the model slide surface of the lanslide and the shape of the slide has been drawn. (Figure 10). Table 5.11 shows that the landslide is 60 m long. Accordingly the simplest solution to protect the highway from a growing landslide was to locate piles that are connected with bent cap method 15 mts behind the beginning of the landslide. The piling application has been determined in the duration of construction.

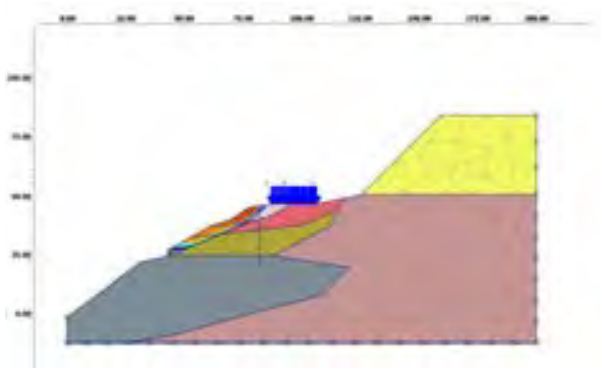


Figure 10. The existing material parameters along with a probable landslide situation in the area

Figure11. The size of the landslide

The Material parameters used in analysis are shown in Table 3.

Table 3.Material parameters used in analysis

ID	Name	Type	γ_{unsat} [kN/m^3]	γ_{sat} [kN/m^3]	k_x [m/day]	k_y [m/day]	υ [-]	E_{ref} [kN/m^2]	c_{ref} [kN/m^2]	Φ (^{o})	Ψ (^{o})	E_{incr} [kN/m^3]	c_{incr} [kN/m^3]	γ_{ref} [m]	T-Strengh [kN/m^2]	R_{inter} [-]
1	RoadFilling	Dranied	19.0	19.0	0.0000	0.0000	0.30	35000.0	4.0	27.0	0.0	0.0	0.0	0.0	0.0	0.60
2	RoadFilling	Dranied	19.0	19.0	0.0000	0.0000	0.30	40000.0	4.0	28.0	0.0	0.0	0.0	0.0	1E10	0.65
3	Colluvial	Dranied	19.0	19.0	0.0000	0.0000	0.30	45000.0	4.0	29.0	0.0	0.0	0.0	0.0	0.0	0.70
4	Bres	Dranied	22.0	22.0	0.0000	0.0000	0.30	2E5	100.0	37.0	0.0	0.0	0.0	0.0	100	0.90
5	Melange	Dranied	22.0	22.0	0.0000	0.0000	0.30	3E5	250.0	38.0	0.0	0.0	0.0	0.0	50	0.90
6	Limestone	Dranied	22.0	22.0	0.0000	0.0000	0.30	4E5	350.0	40.0	0.0	0.0	0.0	0.0	500	0.90
7	Wall	Dranied	24.0	24.0	0.0000	0.0000	0.20	2.8E7	5E3	55.0	0.0	0.0	0.0	0.0	2000	1.00

The 80 cm fore-Piles have been designed to socket to the strong Brash layer by 3 mts, 1 mt away from center to center all told 25 mts in length. When measuring the piles 3 loading methods have been used.

The situation of the filling conducted in 2006 that lost all its passive endurance by sliding totally (Table 2)

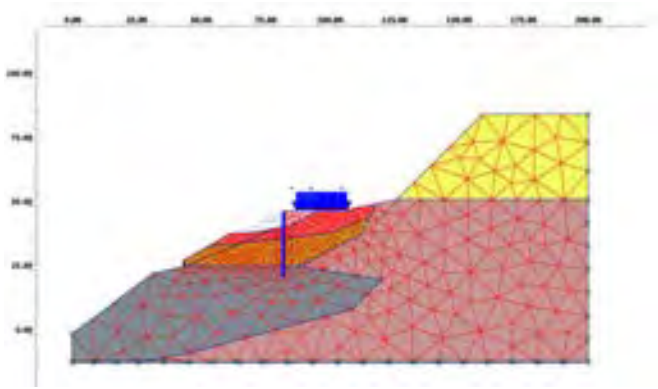


Table 12. First loading situation

The situation of the wall under the chamfer that loses its endurance and falls down (Table13)

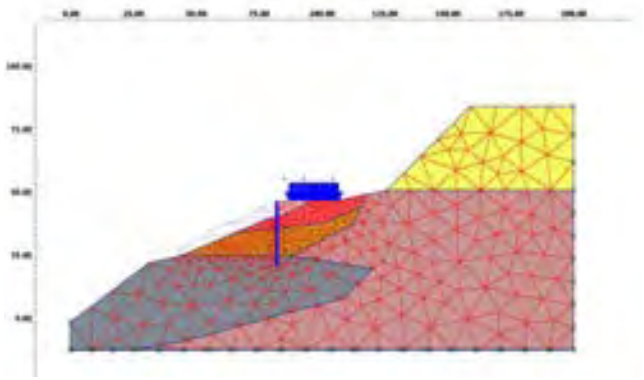


Table 13. Second loading situation

Earthquake situation (horizontal earthquake acceleration taken as 0.2g)

5. Concrete Calculations

The section effect currency obtained from analysis and the currency used in the design are shown in Table 4. The design values for 1st and 2nd situations have been enlarged by 1.6 factor and the design has been realized, and for the earthquake situation the currencies are taken the way they are.

Table 4.*The currency used analysis results and Fore-pile design*

	Analysis Results		
	N (kN/m)	**V(kN/m)**	**M (kN.m/m)**
1. Situation	83	89	290
2. Situation	63	91	335
3. Situation	148	154	364

	Currencies Used in Design		
	N (kN/m)	**V(kN/m)**	**M (kN.m/m)**
1. Situation	132,8	142,4	464
2. Situation	100,8	145,6	536
3. Situation	148	154	364

The concrete design of fore-piles are constructed by taking The Rules of Construction and Design of Concrete Structures (TS500) and The Regulations for Structures to be Built in Disaster Areas into consideration by the Administration of 13. Region.

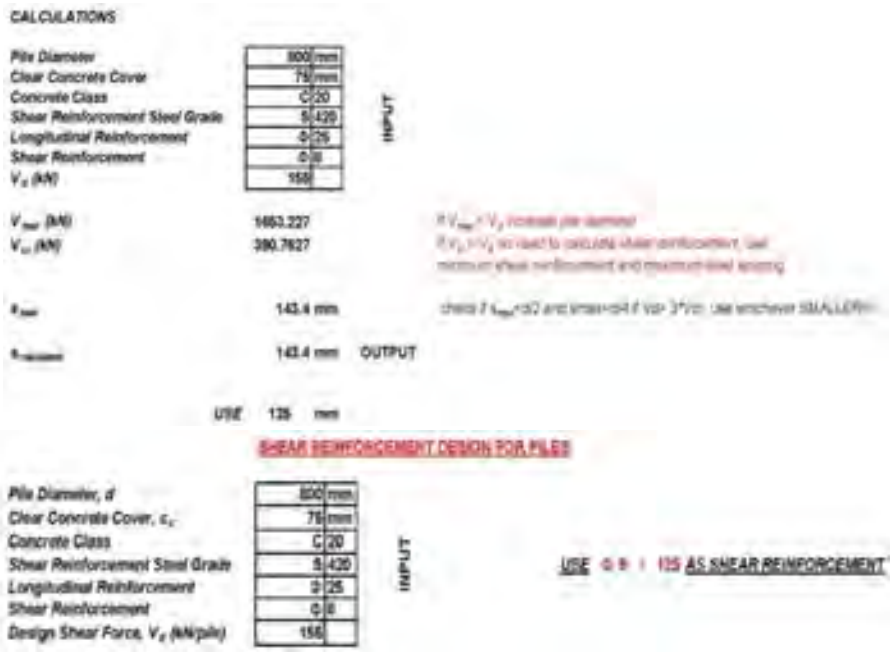
The analysis results conducted in PLAXIS program are as below:

The factor for 1.And 2.Situations is designed as 1.6 in order to keep the situations safe and for the 3. Situation, the earthquake situation, the currencies remain the same.

1.Situation PLAXİS results	 AxialStrength Diagram	 DiscontinuationStrength Diagram	 Moment Diagram
2.Situation PLAXİS results	 AxialStrength Diagram	 DiscontinuationStrength Diagram	 Moment Diagram
3.Situation PLAXİS results	AxialStrength Diagram	 DiscontinuationStrength Diagram	 Moment Diagram

Fore Pile Concrete Analysis Results (The existing factors of fore-piles and beams applied in the landslide area)

Discontinual Outfit Calculation



CALCULATIONS

Pile Diameter	800	mm	INPUT
Clear Concrete Cover	75	mm	
Concrete Class	C	20	
Shear Reinforcement Steel Grade	S	420	
Longitudinal Reinforcement	Φ	25	
Shear Reinforcement	Φ	8	
V_d *(kN)*	156		

V_{max} *(kN)*	1663.227	If $V_{max} < V_d$ increase pile diameter
V_c *(kN)*	390.7627	If $V_c > V_d$ no need to calculate shear reinforcement, use minimum shear reinforcement and maximum steel spacing
s_{max}	143.4 mm	check if s_{max}<d/2 and smax<24 if Vd> 3*Vc: use whichever SMALLER
$s_{recommend}$	143.4 mm	OUTPUT

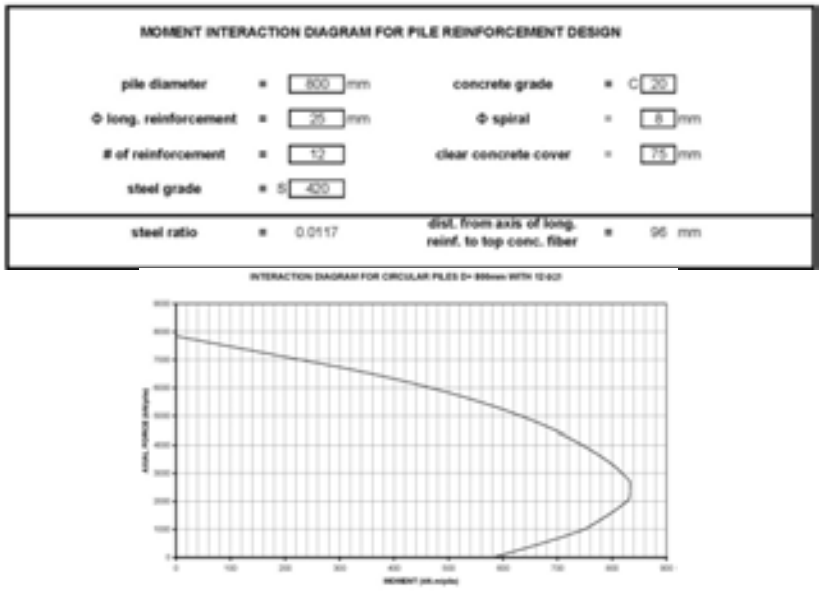
USE 125 mm

SHEAR REINFORCEMENT DESIGN FOR PILES

Pile Diameter, d	800	mm	INPUT
Clear Concrete Cover, c_c	75	mm	
Concrete Class	C	20	
Shear Reinforcement Steel Grade	S	420	
Longitudinal Reinforcement	Φ	25	
Shear Reinforcement	Φ	8	
Design Shear Force, V_d (kN/pile)	156		

USE Φ 8 @ 125 AS SHEAR REINFORCEMENT

Lengthwise outfit Calculation

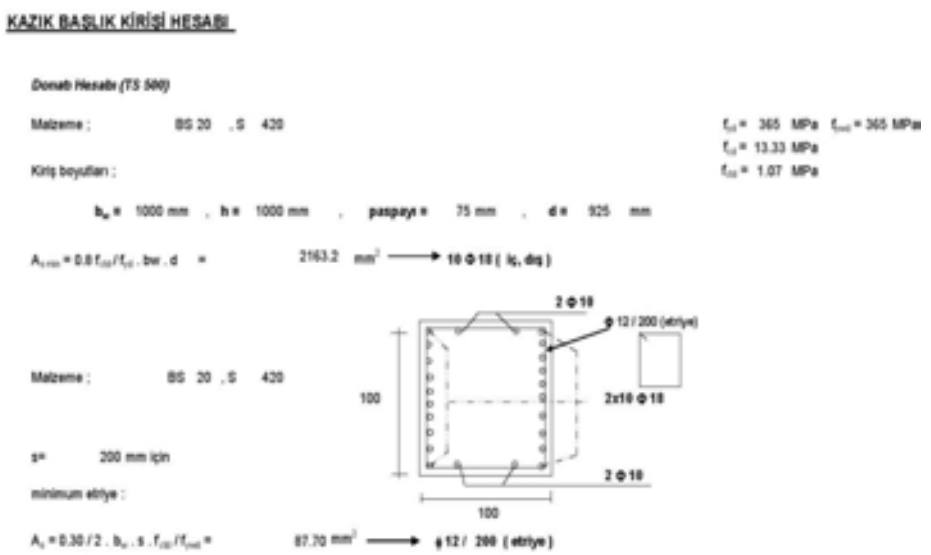


MOMENT INTERACTION DIAGRAM FOR PILE REINFORCEMENT DESIGN

pile diameter	=	800 mm	concrete grade	=	C 20
Φ long. reinforcement	=	25 mm	Φ spiral	=	8 mm
# of reinforcement	=	12	clear concrete cover	=	75 mm
steel grade	=	S 400			
steel ratio	=	0.0117	dist. from axis of long. reinf. to top conc. fiber	=	96 mm

INTERACTION DIAGRAM FOR CIRCULAR PILES D= 800mm WITH 12-ELT

Caping Beam Calculation



6. RESULTS

We determine the conditions in case of a chamfer reconstruction and an appropriate model for chamfer now. Thus upon applying a model, the way to determine an unknown parameter is to enter the known parameters and get a result through it. The back calculation method is one of the most effective methods in our country where it contributes a great deal to complete the betterment projects economically and safely in chamfer conditions in which a landsllide occurred. Also PLAXIS program for which the method make use practically and safely has been a source to apply within this study. PLAXIS prorgram indicates the geometrical madel that it creates within itself appropriate to the real condition in a detailed way.

To be able to examine the landslide occurred on Antalya-Burdur highway in 99+200 and to make use of the highway safely the problem has been approached in a safe way by means of Back Calculation method. Accordingly the area has been examined for several ways like geological, geotechnical and for earthquakes. The geological units determined in the landslide area; Existing road filling (Qm), Cullivion (Qc), Recritalized Limestone Dutdere limestone (TRjd), Serpantit, Limestone and KızılcadagMelange and Olistostrom that constitute Conglomeras (Kkzm). The Tekke landslide is within the 1st degree earthquake zone in Turkey Earthquake Map (1996). Three drills the depth of which vary between 20-30 mt were organized in the area to examine the existing landslide mechanism. As a result of the labrotary examinations and analysis of the samples taken from the drills along with the studies and the examinations applied in the landslide area, the data that determined the size and type of the lanslide has been modelled by means of PLAXIS program. This model has been subject to certain loads within parameters. Upon entering the loads 3 different situations have been defined and these situations have been then analised. The 1st situation is that the filling applied in 2006 loses its passive endurance by sliding totally, the 2nd is the situation that the wall underneath the chamfer looses its endurance and falls down and the 3rd situation is where the loads applied by taking the horizontal earthquake acceleration 0.2 g. As a reslut of the analysis for 1st and 2nd situations the N, V, M values are close, and for 3rdsituation the value is pretty high. The reason for this is tension created by a probable earthquake situation. The values obtained in the designing process according to the results: For 1st and 2nd situations the 1.6 factor is multiplied and obtained, and the 3rd (earthquake situation) is kept the same. All these standarts and the concrete design of the Fore-piles are applied/resulted according to the The principals of design and Constructions of Concrete Structures (TS500) along with the regulations for the structures to be constructed in disaster areas.

The position of the landslide is exactly in 99+175-99+235 km which is determined along with the studies conducted with Higways 15. Region Administration. In order not to give damage during the deep foundation diggings the fore piling system which is one of the chamfer supprting systems has been conducted. Fore piling system presents a high safety preference depending on the depth of the digging, the conditions of the ground and surcharge (environmental) loads as well as economical solutions. Accordingly in order to prevent the landslides in the area the 80 cm fore-Piles have been designed to socket to the strong Brash layer by 3 mts, 1 mt away from center to center all told 25 mts in length. When measuring the piles 3 loading methods have been used. In addition the simplest solution to protect the highway from a growing landslide was to locate piles that are connected with bent cap method 15 mts behind the beginning of the landslide. The piling application has been determined in the duration of construction. The application cot was determined in the duration of construction. The concrete used in the piles is Concrete C20, Steel S420 class, ϕ25iron, and in the entries ϕ 8 iron in addition of spacer 75 mm distance has been left. The concrete used in the beams is Concrete C20, Steel S420 class, ϕ25iron, and in the entries ϕ 8 iron in addition of spacer 75 mm distance has been left. In beam connection ϕ 25 iron is used and the links are determined as ϕ 8. The link slope is in 1000x1000 mm measurements. In addition to the fore piling applications for strengthening the broken chamfer some precautions are also planned for the water that has an accelerating effect for the landslides. The surrounding area of the landslide hass been drained properly and the leaking parts underneath the chamfer have been blocked. In order not to have any repetitions of some identical problems several precautions have been taken. As a result of this study we understand how important it is to take precautions for such occasions like preventing from the landslides because of the rough topographical structure of our country and as well as our country being in the earthquake zone. The factors causing landslides (e.g. slope, rain, type of land, gravity, various natural disasters, various construstion activities etc.) according to the place of the region and the condition of it should be analysed, examined and determined one by one, and studies and examinations should be done in order to prevent the repetitions of the same events. In addition to this

Necessary precautions should be taken. The experiments applied and coducted in labrotary and in the land represent the limited part of the region. Also the analysis that the back calculation method provides us indicates more precise data of the section edurence information. Within the application of back calculating method which is applied through the geotechnical data in such occasions, the usage of PLAXIS program (Ended Elements Method) reveals that the betterment of sliding chamfers might as well be provided in a short time.

ACKNOWLEDGMENT

I hereby present my deepest appreciations to 13. Region Highway Administration staff and Civil Engineer Suat Erol.

REFERENCES

[1]. Akçakal, Ö., A C ase Study By Using Back-Calculation Method In Slope Stability Analysis, Istanbul Technical University, Institute of Science, M.Sc., 85S, Istanbul. 2009.

[2]. Durgunoğlu, H. T., Kulaç F., Karadayilar T. veBaştürk, G., 1990. Back calculation method in the stability of the soil behavior: BuğralarEtut, İstanbul.

[3]. Mining Technical Exploration 100 000'lik Geological Map of Antalya. http://www.mta.gov.tr/v2.0/daire-baskanliklari/jed/index.php?id=100cd

[4]. Yıldız, L. (2005). Bearıng Capacıty Of Shallow Foundatıon OnGeogrıd – Reınforced Slope, Department of Civil EngineeringInstitute Of Natural And Applied SciencesUniversty Of Çukurova

[5]. About Construction in Disaster Zones Regulations, 1998. The Ministry of Public Works and Settlement, Ankara.http: //www.mevzuat.gov.tr/metin.aspx? Mevzuatkod = 7.5.11445 &sourcexmlsearch = &mevzuatılis that = 0