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GEOTECHNICAL SCHEMES FOR CONSTRUCTING LIGHT STRUCTURES ON INSTABLE SLOPES

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ABSTRACT

Slopes in soils and rocks are natural or man-made structures. Landslide and slope failure are responsible for millions of dollars of damage to public and private property every year. The great variety of slope movements reflects the diversity of conditions that cause the slope to become unstable and the processes that trigger the movement.

The stability of a slope can be threatened by erosion due to surface water runoff, or more severe erosive forces associated with water. In this paper the geotechnical schemes which were done for constructing light structure (aviculture) in Noabad (Mazandaran-Iran) by regarding to the movement of site in previous years are described.

In the first part of this paper the authors present bases of slope stability and safety factor of instable slope in case study area before geotechnical scheme then the reason of instability in case study area is described. In second part the geotechnical schemes were done and safety factor after geotechnical schemes is calculated.

The factor of safety is calculated before geotechnical scheme which shows instability risk in study area and after geotechnical scheme the factor of safety is calculated for same sections again. And finally the result is checked. In general the authors believed that the schemes can provide useful and successful procedure for stabilization similar cases.

INTRODUCTION

This paper deals application of methodology for constructing, seismic strengthening, and stabilization of slope of Noabad's aviculture (Mazandaran, Iran). First in 2004 an aviculture was constructed without any remediatial options. In 2005 instability of slope induced sever damage and the structure (aviculture) which was constructed in 2004 was completely destroyed. The experiences gained from first project (2004) including geotechnical engineering and structure engineering, is used for new project (2005) *Fig. 1*.

In the first part of this paper the authors present bases of slope stability and safety factor of instable slope in case study area before geotechnical scheme, then the reasons of instability in case study area is described. In second part the geotechnical schemes which were done and safety factor after geotechnical schemes is shown.

Fig. 1. Study area after instability

Reinforcement of soil structure such as slopes has become an accepted engineering practice in the last 20 years.

Distributions of slope angels in tectonically active mountain belts point to the development of threshold conditions, where hillslopes attain a critical inclination or height at which they fail readily because of limitation in material strength [1,2].

SLOPE STABILITY

Although slope instability and landslide has been recognized as a wide phenomenon in the world, having a great social, economic and geomorphological impact. Seismic behavior of study area, high annual rainfall, steep slopes, deforestation, high weathering rates and slope material with a low shear strength or high clay content are considered the preparatory casual factors for mass movements. Increasing population pressure, with slope disturbance, inconsiderate irrigation and deforestation as consequences and such triggering factors as earthquakes and extreme rainfall are the reasons of instability.

The field of slope stability encompasses the analysis of static and dynamic stability of slopes of excavated slopes, natural slopes in soil and soft rock and earth and rock-fill dams, slopes of other types of embankments.

Earthen slopes can develop a cut-spherical weakness zone. The probability of this happening can be calculated with using a simple 2-D circular analysis package. A primary difficulty with analysis is locating the most-probable slip plane for any given situation[3,4].

CASE STUDY

Noabad has been located in north of Iran, Mazandaran province. The annual mean temperature of the terrain is 12.5 ‘c and the annual mean precipitation is estimate 800 (mm). The area climate from dommartan method is humid. From geological point of view, the most of geologic units are related to senozoaek era that for reason of the existence of marl, shiel silty stone are susceptible to landslide occurrence *Fig. 2*.

From the physical point of view, it is better to visualize slopes existing in one of following three stages: stable, marginally stable and actively unstable. Marginally stable slopes are those which will fail at some time in response to the destabilizing forces attaining a certain level of activity. Actively unstable slopes are those in which destabilization forces produce continuous or intermittent movement. Case study area is in third group (actively unstable) *Fig. 3*.

Fig. 2. Map of Mazandaran

Fig. 3. Previous instability

For calculating factor of safety following tasks were done.

Ground Investigation

Before any further examination of an existing slope, essential borehole information was obtained. This information gave details of the strata, moisture content and the standing water level. Also, the presence of any particular plastic layer along which shear could more easily take place, was noted.

Piezometer tubes were installed into the ground to measure changes in water level over a period of time.

Ground investigations also include: in-situ and laboratory tests, area photographs *Fig. 3*, study of geological maps and memoirs to indicate probable soil conditions, visiting and observing the slope, previous instability which happened *Fig. 3* and plotting topography plan *Fig. 4*.

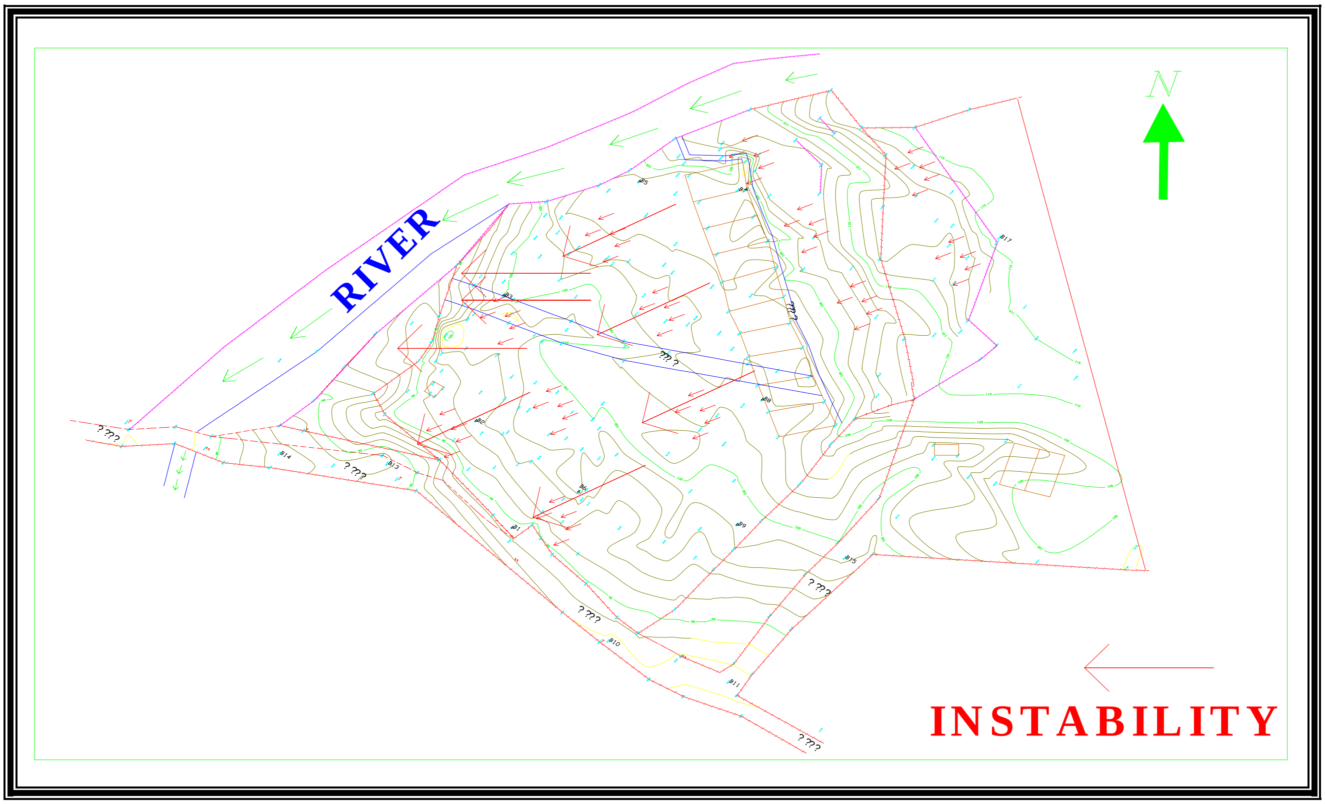

Fig. 4. Topography

Tension Cracks

A tension crack at the head of a slide suggests strongly that instability is imminent. Tension cracks are sometimes used in slope stability calculations, and sometimes they are considered to be full of water *Fig .5*.

Tension cracks are not usually important in stability analysis, but can become so in some special cases *Fig. 6*.

Slip or failure zone is a thin zone of soil that reaches the critical state or residual state and results in movement of the upper soil mass and failure surface is the surface of sliding.

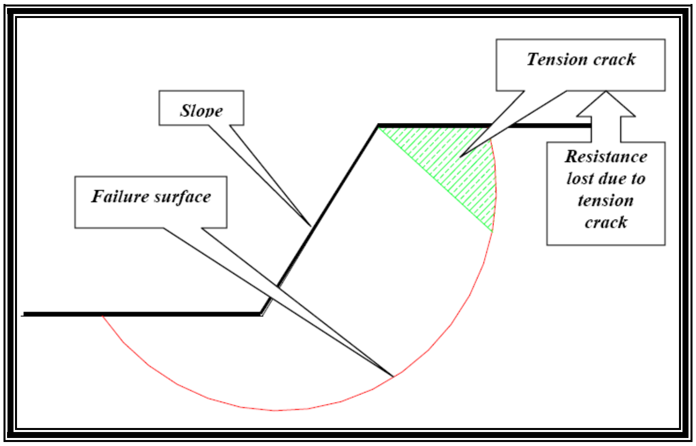

Fig. 5. Tension cracks

Fig. 6. Tension cracks in case study area

FACTOR OF SAFETY (FOS)

In slope design, and in fact generally in the area of geotechnical engineering, the factor which is very often in doubt is the shear strength of the soil. The loading is known more accurately because usually it merely consists of the self-weight of the slope.

The FoS is therefore chosen as a ratio of the available shear strength to that required to keep the slope stable.

Table 1. Factor of Safety & Type of Slope.

FACTOR OF SAFETY	DETAILS OF SLOPE
<1.0	Unsafe
1.0-1.25	Questionable safety
1.0-1.25	Satisfactory for routine cuts and fills, Questionable for dams, or where failure would be catastrophic
>1.4	Satisfactory for dams

<u>Parameter Selection</u>

It is important to identify the most dangerous condition in a practical problem so the appropriate shear strength parameters are used in design.

We used undrained assumption here as a long time will elapse before there is significant dissipation of porewater pressure. At the end of construction the soil as almost still undrained. Hence we use a total stress analysis, making use of the undrained shear strength, Cu.

For long term analysis after a relatively long period of time, the fully drained stage will have been reached, therefore only the effective stress parameters, C' and ϕ' was used.

<u>Limit Equilibrium and Assumptions</u>

We need to make certain assumptions in analyzing slopes using limit equilibrium.

For assumption of a Failure Mechanism We assume the shape and location of a failure surface rather then determining it by analysis.

For assumption of Plane-Strain (2-D): We ignore 3-D effects (although of course in reality slopes are in three dimensions). We are being conservative by neglecting these effects. we would achieve higher FoS's by taking them into account.

For assumption of rigid block movement we assume the soil mass to move as a rigid block, with the movement only taking place on the failure surface itself.

Method of Slice

The soil mass above a trial failure surface is divided into slices by vertical planes. Each slice is taken as having a straight line base.

The Factor of Safety of each slice is assumed to be the same, implying mutual support between the slices, ie. There must be forces acting between the slices.

Janbu's Method

Janbo (1973) assumed a noncircular slip surface and considered equilibrium of horizontal forces. He made similar assumption to bishop (1955), expect that a correction factor is applied to replace the interface shear. The difficulty in analyzing a non-circular failure surface is that it is difficult to find a single point through which many of the force components act. So, the moment equilibrium method used for circular surfaces is no longer the most appropriate.

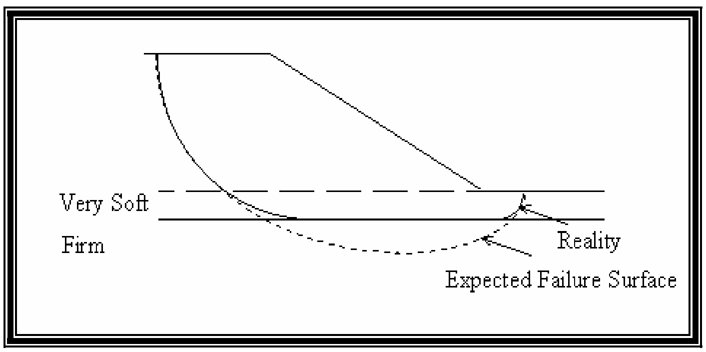

Fig. 7. Janbo's method & non-circular failure surface.

ANALYSIS & FACTOR of SAFETY *(BEFOR GEOTECHNICAL SCHEME IN STUDY AREA)*

The computed value of the factor of safety is a clear and simple distinction between stable and unstable slopes.

Five sections in study area were selected for analyzing which is shown in *Fig.8.*

The factor of safety is calculated by Janbo's method and the result is shown in Table 2.

The factor of safety is calculated before geotechnical scheme which shows instability risk in study area and after geotechnical scheme the factor of safety is calculated for same sections again. And finally the result is checked.

Factor of Safety (before geotechnical scheme calculated by Janbo's method)

Table 2. Safety factor before geotechnical scheme

Section	A	B	C	D	E
Factor of Safety	0.84	0.89	0.90	0.86	0.82

Factor of safety shows instability which failure occurred in study area Before geotechnical scheme. Therefore, first the reasons of instability should be known then the reasons should be covered by geotechnical scheme for making slope stable and finally the factor of safety should be calculated for checking the procedure which is done[5].

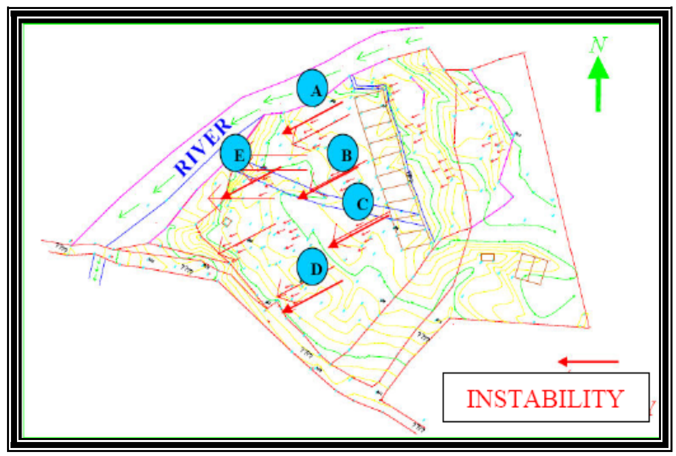

Fig. 8.Section selected for analysis.

REASONS OF INSTABILITY

When preparing a landslide report for a particular site, of primary impotence is the recognition of the conditions which caused the slope to become unstable and the processes which triggered that movement. Only an accurate diagnosis makes it possible to properly understand the landslide mechanisms and thence to propose effective remedial measures.

More recently, significant relationships have been found between the raining water and instability because during construction of first aviculture and damages there wasn't any seismic loading and no earthquake were occurred but the precipitation increases in spring and autumn. There is high value of rainfall, 8 months per year. In winter there is rain and snowfall because of low temperature and runoff from snowmelt is obvious in summer. Long period of rainfall saturate, soften, and erode soils. Water enters into existing cracks and may weaken underlying soil layers, leading to failure *Fig. 9.*

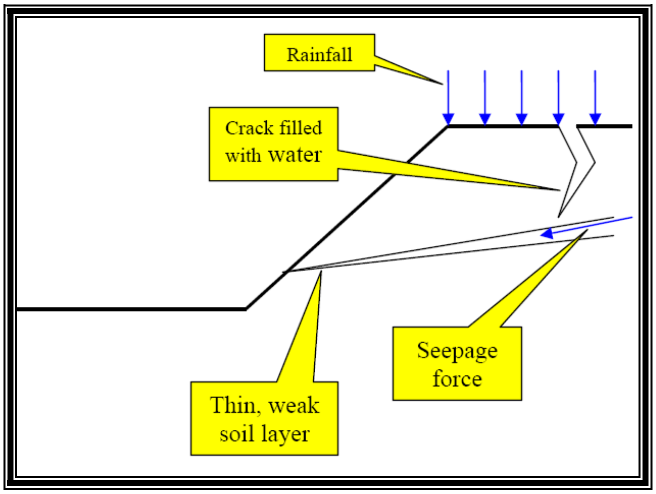

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Fig. 9. Runoff influence on slope stability.

Earthquakes induce dynamic forces, especially dynamic shear forces that reduce the shear strength and stiffness of the soil. The project should be guarantee against seismic loads so seismic load is counted in calculations[6,7].

GEOTECHNICAL SCHEMES

Runoff assessed the main reason of instability. Rain falls from the sky it enters the topsoil. Topsoil consists of small pieces of soil, rock particles, organic matter, water and air. Topsoil thickness varies widely.

As the rainwater enters the topsoil, it begins to fill the space in the soil that just moments before held air. In periods of heavy rainfall all or most of the air is expelled from the soil. Hundreds of thousands of gallons of water can be stored in the topsoil layer. This water begins to move under the force of gravity and the weight of the water within the soil. Water, as most things, desires to take the path of least resistance. As it moves sideways through most soils, we intercept it and re-direct it to a low spot on our property (drain).

Drainage is often a crucial remedial measure due to the important role played by pore water pressure in reducing shear strength. Because of its high stabilization efficiency in relation to coast drainage of surface water is the most widely used, and generally the most successful stabilization method.
(Bromhead, 1992).

The drain system we used in this project consists of a 0.5 (m) wide by 1 (m) deep trench that works like a moat to protect study area from subsurface water attack. Perforated drain pipes were placed in the bottom of the trench. The pipe is then covered with 3(cm) and larger washed gravel to within 20 (cm) of the top of the trench *Fig. 10.* As the water passes sideways through the soil it contacts the gravel. The water decides that it is much easier to drop down through the gravel and into the perforated pipe rather than push its way through the soil.

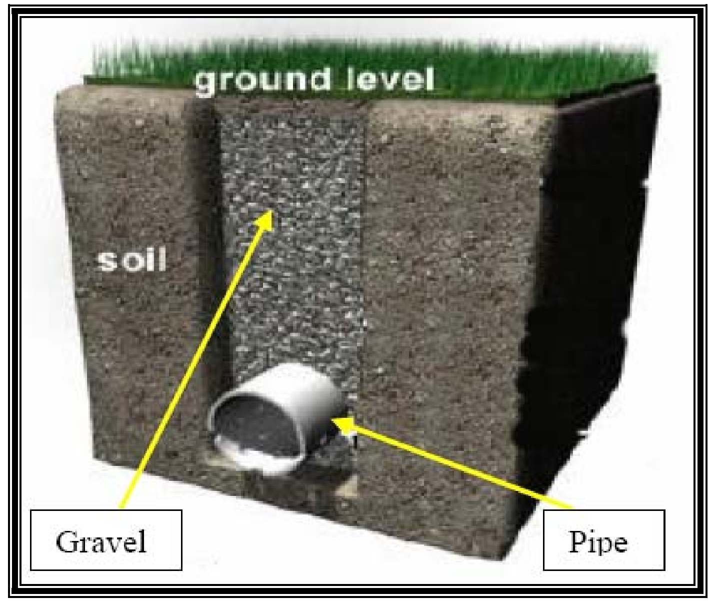

Fig. 10. Drain system

The trick to trench placement is simple. We want the trench in a location so that it intercepts the water before it hits the slope and study area. Because of slope in study area, we placed the trenches on the high side of your property. This way we collected all of the water flowing through the soil uphill from your lot.

The depth of the trench can remain a constant 1 (m) as it passes by and around slope. Because of slope, the constant trench depth will create a natural slope to the perforated pipe in the bottom of the trench. Once the trench system passes aviculture, we can start to make the grade at the bottom of the trench less or even level.

Before installing this system we were sure to check for underground utilities. Digging by hand or with a power ditching device can result in serious injury or death if it strikes electric or natural gas lines (used for heating machines and lights in aviculture placed in study area) *Fig. 11.*

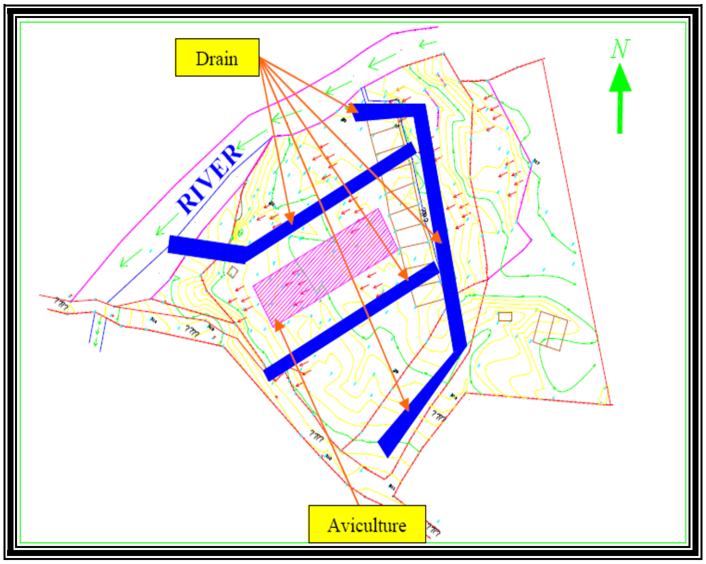

Fig. 11. Plan of drainage

Designing berms is a most efficient method particularly in deep seated landslides.

However, the success of corrective slope regarding (fill or cut) is determined not merely by size or shape of the alteration, but also by position on the slope *Fig. 12.*

Designing berms was another scheme we used in this project. A berm is a mound of earth with sloping sides that is located between areas of different elevation. Berms may serve following functions: (a) protecting the slope against instability (b)Separate areas of conflicting uses (c) Screen undesirable views (d) Provide wind protection.

Fig. 12. Modification of slope geometry and designing berm.

Vegetation plays an important role in improving slope stability and preventing mass movement. Therefore in the study area in extra places we planted trees for increasing the factor of safety.

FACTOR OF SAFETY (after geotechnical scheme calculated by Janbo's method)

Table 3.Factor of safety after geotechnical schemes.

Section	A	B	C	D	E
Factor of Safety	1.10	1.21	1.17	1.06	1.09

CONCLUSION

Groundwater infiltration of surface runoff can cause saturation of the soil that will significantly reduce soil strength .Because of some limitations retaining wall was not designed. If the wall was not designed with extra reinforcement to handle these reduced strengths, then a drainage system is necessary to be provided to prevent the fill from becoming saturated.

In study area it is shown that using balanced cut and fill construction cause to minimize earthwork and helps to stability.

Placing construction slash and rocks along the toe of fill increase the factor of safety.

Drainage and modification of slope geometry was used in order to repair of landslides. These are also generally the least costly repair solution which is obviously why they are the most used.

Geometrical changes, unloading the slope toe and loading the slope crest was man-made reasons of instability in this case(in destroyed aviculture), which was obvious in value of safety factor before geotechnical schemes.

This report intended to discuss some problems related to landslide causes and landslide remedial measures.

The versatility of schemes and the parsimonious time and money requirement are the success of the scheme reported here. It is hoped that the outcomes such comprehensive modeling could contribute to improved management through planning regulation.

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