Application Loess Soils in Establishment of Small Embankment Dams

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Abstract

Construction of Debris control structures have important role on the protection of watershed basins as well as aquiferous basins. It also had a great influence on preventing the movement of sediment deposits from upstream to downstream of these basins. Of these watershed basins, more attention should be given to GOLESTAN watershed province and its different basins.

These types of watershed with special characters and high flood– water areas should also get special attention and precise planning. In such basins, varieties of deposits are transported from upstream to downstream. Since the residential areas and access roads are located on the flood-channels and downstream of these basins, remarkable damages are usually expected to take place on the infrastructures as well as on the installations (or industrial plants). Therefore, it is very important to control the movement of the upstream sediment deposits by reducing the slope of the existing channels or constructing sediment control structures as well as Debris control structures for trapping the debris and sediments. One example of these Debris control structures are the small earth dams at the height of 6-10 m that are built in different areas of GOLESTAN province.

It is essential to construct earth dams with sediment control structures in the upstream channels of the basins due to the existence of high erodible soils in the region. Geologically, MALEK ALI TAPPEH basins are located in loess covered regions. Since loess soils are weak with high settlement potential, construction of structures should be carried out with special plan.

Also due to the lack of suitable construction materials in the region as well as economic reasons for transporting these materials, the construction of the earth dams was carried out from the in situ materials in the region.

Key words: Stability analysis, loess, debris control structure, earth dams.

1. Introduction

Collapsible soils are subject to changes in volume or break down in response to wetting or water absorption. This will dramatically reduce the shear strength of the soil and cause settlement.

Loess is one of these types of soils which are formed by wind. Its layers are deposited by wind which makes its structure to be porous and spongy. Due to these characteristics, loess existence in foundation of the structures has become problematic. Also the problems become more severe for dams and their reservoirs located in loess formations which are subject to soil saturation. In addition, using loess as construction materials for earth dams will create some problems.

In this article, after presentation of geographic or site location, engineering behavior of loess is investigated. Then, some cases of earth dams design constructed with such materials are explained. Stability analysis under different stages such as, end of construction phase and steady seepage, are presented afterwards. Finally, the utilization of loess materials in construction of the earth–dams will be presented.

2. Data and Material

2.1. Case study

The study area named Malek Ali Tappeh watershed basin with 8664 hectare area is located in the north east of Gonbad city with longitude 55° 19′ 39″ to 55° 26′ 39″ east and latitude 37° 20′ 39″ to 37° 37′ 57″ north in Tamran village witch in central part of Calaleh city.This area bounded by Atrac village of Dashilyboroun subprovince of Gonbad Kavoos from the west. Fig.1 showing the location of studied area.

2.2. General Geology of study area

Case study is located between two sedimentary basins: Kopehdagh formation Gorgan-Rasht tectonic sheet zone, north–eastern of Gonbad Kavoos and Malek Ali Tappeh basin. Vast highly thick loess deposit makes the region to have sloping, uneven and rough topography. Generally the wind sediment deposits or loess form the hill and mountain peaks of the region. Since eolian deposits relevant to Quarternary era typically outcrop in the study region, therefore, brief description of these types of deposits will be presented in this article.

Loess deposits in Iran typically consist of fine grain, powder like and unstratified or unlayered. They consolidate under the rainfall with little erosion.

Loess in Iran mostly found in Mazandaran land and eastern Alborz Mountains and part of Hezarmasjed – Kopehdagh Mountains. Loess deposit can get to 50 meters thickness in northern region especially eastern Alborz.

In western part of Kopehdagh and north – east of Gorgan plain, Upper Pliocene deposits of Caspian sea with angular disconformity's, cover different Cretaceous rock horizons. This indicates that the region was out of water during Paleogene era. Quarternary eolian deposits include loess deposits and sandy hills or sand dune shoreline.

Sediment deposits observed in the area are eolian deposits of Pliocene – Quarternary era that were formed as the result of loess deposits in the peak region.

Figure 2 showing the geology map of studied area. This map shows that outcrop formations mostly are from glacial deposits of Pliocene-Quarternary age. This formations be shaped by loess deposited in high lands.

Most importan of geology units discuss bellow:

Q^{v}: This unit forms by fluvio lacustrine deposited that are collection of valley floor complexes under alternation.

Q^{gel}: This unit forms by glacial eolian deposits that consist of low land loess.

Q^{ff}: Deposits of this unit are from fluvial tips that consist of sand, silt and debris materials. This formation erosion by water stream and dissected.

Q^{fe}: Litology of this eolian and fluvial deposits, sand, silt and accessory clay.

Q^{ff1}: This unit forms by fluvial and local oxbow deposits that not dissected.

Figure 1. Geographical location of case study

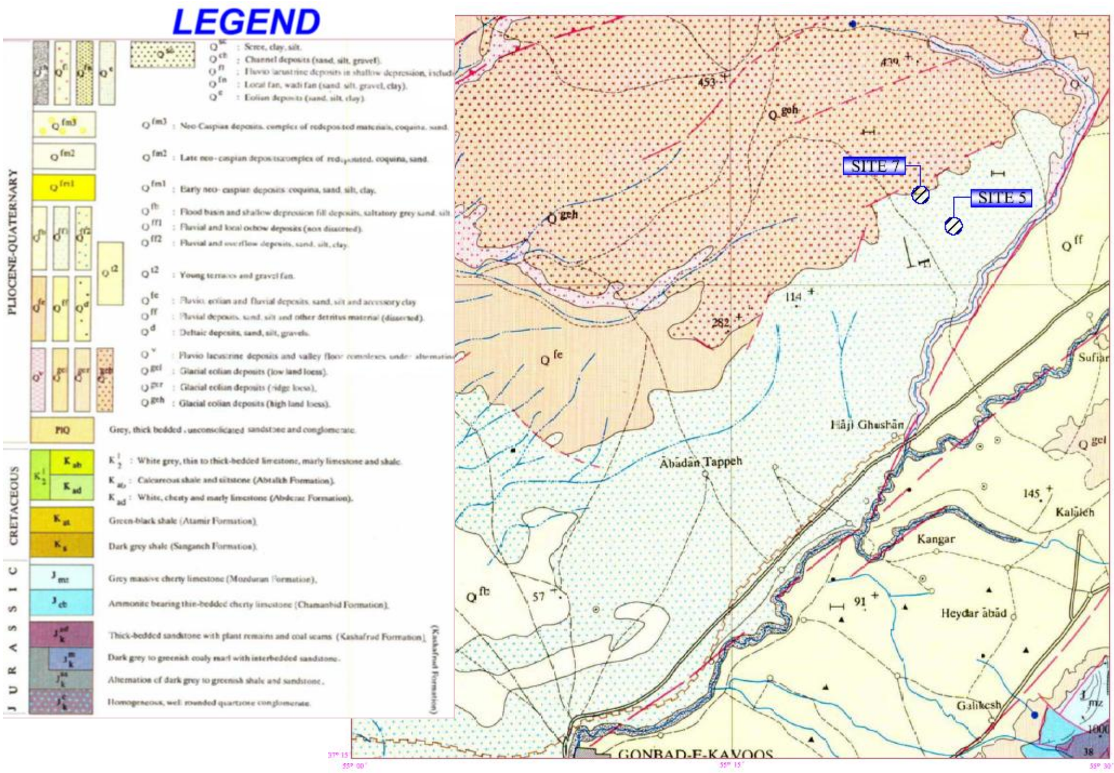

Figure 2. Geology map of case study (Derivation of Gonbad-e-kavoos Geology Sheet-1:250,000)

3. Research Methodology

There are different opinions about slope stability of hillside. However, it has been suggested that the upstream slope should be lower than the downstream slope.

Of course, selection of suitable slope for upstream and downstream of the dam depend on many factors such as type of materials constructed in body structure, foundation, materials, structural importance, type of installations and lands downstream of the dam as well as dam utilization. Table 1 illustrates the stable slope in variable materials.

Type of dam	Upstream Slope	Downstream slope
Silt- homogeneous	2.5 :1	2 :1
Clay or Salty Clay- homogeneous	3 :1	2.5 :1
Sand or Sandy Gravel-heterogeneous with Clay Core	3 :1	2.5 :1
Height<15 Meters	2.5 :1	2 :1
Height>15 Meters	3 :1	2.5 :1

Table 1. Slope of hillside (Terzaghi)

In this research, due to type of Materials in dam body (CL-ML) and its loess foundation, upstream slope of 1: 3.5 and downstream slope of 1: 3 are selected. The stability analysis will be described later.

Strength behaviors of dam and foundation materials determine the shear strength of the failure plane. Therefore, to control the stability of the dam, Geotechnical specifications were determined based on study of engineering geology and borrow materials. Table 2 illustrates the material characteristics of dam body and foundation based on laboratory results of soil mechanic tests on coarse and fine grains borrow materials.

Materials	Saturated Density (KN/m3)	Strength Parameters	
		Internal Friction Angle ϕ_{deg}	Cohesion (KN/m2)
Dam Body	16.6	9 = ϕ_{uu}	45 =Cuu
		20 = ϕ_{cu}	19 = Ccu
Filter	22	36	0
Drainage	25	38	0
Alluvial Foundation	14.9	6.1	37

Table 2. Physical and mechanical parameters of dam materials

4. Results and Analysis

The software Slope/w from Geoslope office programs is used to determine the stability analysis of the earth dam in Malek Ali Tappeh is a software product that uses limit equilibrium theory to compute the factor of earth and rock slopes.

The software is able to calculate the safety factors within different rupture plane such as circular, wedge or any plane in static and pseudo static according to Bishop, Morgenstern Price, Janbu and Spencer methods. Table 3 shows the allowable safety factor in static / pseudo static analysis based on recommendations of valid references such as US. Army corps of engineers.

Loading Condition	Minimum of safety factor			
	Downstream Slope		Upstream Slope	
	Pseudo Static	Static	Pseudo Static	Static
End of Construction	1.00	1.25	1.00	1.25
Steady Seepage	1.25	1.50	-	-

Table 3 –Minimum safety facto for earth dams

It should be noted that due to low reservoir volume and low height of the dam in study area, the stability analysis was determined only at the end of dam construction. Steady seepage also was carried out with full reservoir.

4.1. Stability analysis at end of construction condition:

Stability analysis of the upstream and downstream of the dams should be determined at end of construction and before filling the reservoir. Stability analysis calculations are determined at end of construction using drained strengths in permeable materials and undrained strengths in materials with low permeability.

The materials with permeability more then 10-4 cm/s usually drain completely and materials with permeability less than 10-7 cm/s are undrained.

Undrain conditions are usually determined by total stress analysis. To assess the behavior of fine grain and non-permeable portion of the earth dam at the end construction phase under the condition in which that embankment rate is more than consolidation rate undrained-unconsolidated test (UU) is used. Since the materials are unsaturated under this condition, the internal friction angel of the soil (ϕ) can be assumed to be above zero. In this research, stability analysis is performed according to UU parameters. Table 4 illustrates this analysis

Loading state	Method	Slope	Analysis Type	Safety Factor
End of construction	Limit Equilibrium-Comprehensive Stress	Upstream	Static	2.29
			Pseudo Static a=0.22g	1.15
		Downstream	Static	2.31
			Pseudo Static a=0.22g	1.19

Table 4 –safety factors obtained from stability analysis at the end of construction condition

4.2. Stability analysis under steady seepage condition:

Up/downstream slopes may be ruptured during the operation of the dam. This is due to water seepage forces from dam body and foundation.

Calculations and stability control during water seepage through the dam and foundation is performed under the conditions that allow sufficient time for water flow to be in steady state.

In such condition, stability control is determined based on drained strength and effective stress analysis. In steady seepage condition, it is assumed that the whole materials building the dam have sufficient time for drainage regardless of their permeability. For this reason, effective stress parameters (C′,ϕ′) are used in the analysis.

Loading conditions	Method	Slope	Analysis Type	Safety Factor
Normal Level	Limit Equilibrium-Effective Stress	Downstream	Static	2.34
			Pseudo Static a=0.22g	1.3

Table 5 –Result of stability analysis in steady seepage

5. Conclusions

Materials type, their physical and mechanical properties are the most effective parameters which determine the stability of the embankment. From engineering point of view construction of the earth dams with weak materials such as loess soils is not recommended except under special circumstances. Under these conditions, construction of the earth dams with loess materials should be approached with special considerations as well as speculations.

In this research due to unsuitable mechanical parameters of existing materials, mild slope design was considered. Following the result of stability analysis, upstream slope of 1:3.5 and downstream slope of 1:3 were considered satisfactory and suitable. The calculated safety factors in different states are more than the recommended safety factors under such conditions.

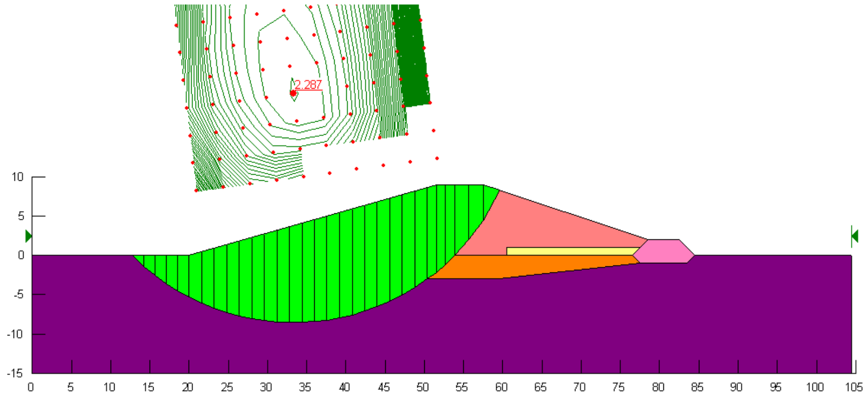

Figure 3. End of construction-Static-Upstream

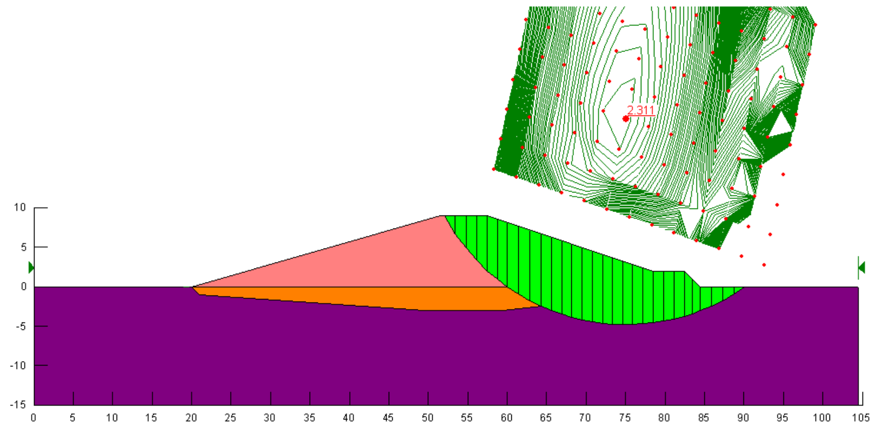

Figure 4. End of construction-Static-Downstream

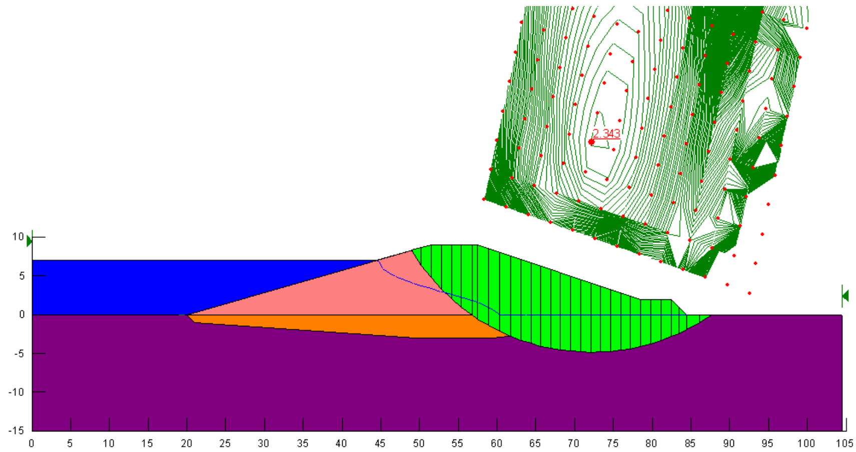

Figure 5. Normal level-Steady Seepage-Static-Downstream

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