

## A CASE STUDY ON A LANDSLIDE: A GEOTECHNICAL INVESTIGATION

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**Abstract** - For centuries human has tried to control the nature for their advantages and to some extent, they have achieved in harnessing the Mother Nature. During the ancient times, human had a little knowledge about the nature and its functioning, but as the time elapsed more innovative technologies developed, population rate increased and the land become scarce, as a result human become greedy for their own needs, a lot of disasters other than natural calamities began to strike – the manmade disasters. The paper mainly aims at studying the geotechnical aspects of a landslide occurred near Muvattupuzha, Ernakulum district, Kerala. The study includes the primary investigations of the site, collection of soil samples, testing of samples, and analysis of test results with scientific theories, conducting slope stability analysis and finally identifying the root cause of the landslide.



Fig- 1: Three storied building before collapse

**Key Words:** Landslide, Slope stability, Factor of safety, Geostudio Software, shear parameters

### 1. INTRODUCTION

The devastating landslide which took place at Muvattupuzha, Ernakulum, Kerala on 27 June 2015 caused severe damages to the public. The catastrophic incident resulted in the complete collapse of a three storied commercial building and the debris got spread to a distance of 200m which affected the traffic flow. Now the main threat was a water tank having capacity 10.5 lac liters (1050 m<sup>3</sup>) which is situated at the top of the collapsed hill. The present slope of the hill cannot withstand the surcharge weight of the water tank. Also cracks were developed along the sides of the road to the water tank. The photograph of the three storied building before and after the collapse is shown in figure 1 and 2.

Presently, there are a lot of unauthorized encroachments occurring in many part of Kerala, particularly in the high range places. These are mainly done for increasing the area of land thereby increasing its cost. Every hill is having its own natural slope. Beyond that slope it cannot withstand the soil on top surface which causes shear failure, ultimately results in landslide.



Fig- 2: Three storied building after collapse

### 2. LITERATURE REVIEW

According to Dai, F.C., and Lee, C.F [10] landslide, also known as landslip, is a geological phenomenon that includes a wide range of ground movements. Landslides occur when the stability of the slope changes from a stable to an unstable condition. Landslides are mainly aggravated by human activities such as deforestation, cultivation and construct, which destabilise the already fragile slope.

Fellenius [2] (1936) introduced the Ordinary or Swedish method of slices. In the mid-1950s Janbu [3] (1954) and

Bishop [4] (1955) developed advances in the method. The advent of electronic computers in the 1960's made it possible to more readily handle the iterative procedures inherent in the method which led to mathematically more rigorous formulations such as those developed by Morgenstern and Price [5] (1965) and by Spencer [6] (1967). One of the reasons the limit equilibrium method was adopted so readily, is that solutions could be obtained by hand-calculations. Simplifying assumption had to be adopted to obtain solutions, but the concept of numerically dividing a larger body into smaller pieces for analysis purposes was rather novel at the time. H. Rahardjo et.al [7](2007) studied on the relative importance of soil properties, rainfall intensity, initial water table location and slope geometry in inducing instability of a homogenous soil slope under different rainfall through a series of parametric studies. B.N Sinha [8] (2008) emphasis that advanced method of slope stability analysis for economical design of earth embankment and discusses on the concept and theory involved in different methods of slope stability analysis of earth embankment. Abdoullah Namdar et al [9] (2010) say that achievement of slope load sustainability using mixed soil technique is considered acceptable method for slope construction technology.

([11] Siddappa G., Shanthakumar M. C. (2014)) To quantitatively assess the stability of a slope in engineering geology, a parameter F known as factor of safety is introduced. The factor of safety is the ratio between the resistive forces and gravity pull.

$$\text{Factor of safety } F = \frac{\text{Resistance forces}}{\text{Gravity force parallel to slope}}$$

$$F = \frac{\tau_{ff}}{\tau}$$

Where  $\tau_{ff}$  is the maximum shear stress the soil can sustain at the value of normal stress of  $\sigma_n$ ,  $\tau$  is the actual shear stress applied to the soil.

A value  $F > 1$  indicates stability, whereas  $F < 1$  implies instability. Thus, the transition between stability to collapse may be envisaged mathematically as a decrease in the factor of safety to values below unity.

### 3.OBJECTIVE

The major objective of the study is to identify the root cause of the landslide by checking the stability of the slope using Geostudio software after determining the shear parameters.

### 4. METHODOLOGY

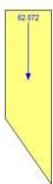
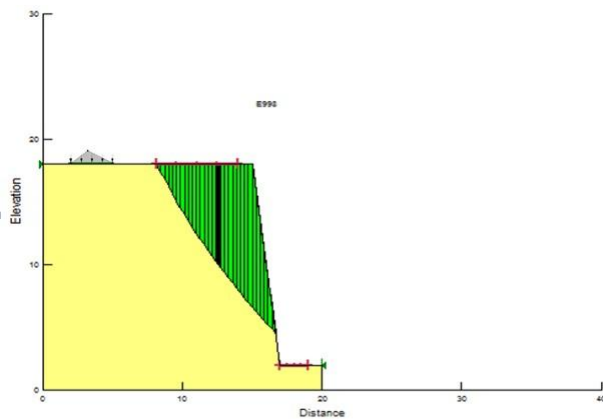
Soil samples were collected from the rear side of the water tank (Sample 1) and from the top of the collapsed wall (Sample 2). A Survey was conducted among the local people for collecting more details about the condition of the slope before and after collapse and the possible reasons for the collapse. Details regarding the water tank and the landslide were collected from the Water Authority and Mini Civil Station. The height of the hill and the position of the water tank from the edge of the hill were obtained by conducting a field survey. Geotechnical tests were conducted on soil samples as per Indian Standard specification and are given in fig 3. The stability of the existing slope was obtained by calculating the factor of safety of the slope by using Geostudio software.

### 5. OBSERVATIONS AND RESULTS

After conducting the sieve analysis, the soil is being classified as well graded silt soil. The following were the test results for the soil samples:

Experiments	Sample 1	Sample 2
Sieve Analysis	D10= 560 μ Cu =6 Cc = 0.67	D10= 560 μ Cu = 6.4 Cc = 1.2
Field density	Bulk unit weight=16.9 KN/m <sup>3</sup> Dry density = 15 KN/m <sup>3</sup>	Bulk unit weight = 16.9 KN/m <sup>3</sup> Dry density = 13.6 KN/m <sup>3</sup>
Specific gravity	2.43	2.62
Liquid Limit	34 %	34 %
Plastic limit	25 %	21.42 %
Proctor test	OMC =15 % Max dry density =18.9 KN/m <sup>3</sup>	OMC = 14 % Max dry density =18 KN/m <sup>3</sup>
Direct shear	φ = 17.74 C = 46 KN/m <sup>2</sup>	φ = 13.62 C = 49 KN/m <sup>2</sup>

Fig- 3 : Geotechnical properties of the soil samples



Free body diagram and force polygon

Slice 12	
Factor of Safety	0.998
Phi Angle	17.74 °
C (Strength)	45.1 kPa
Surcharge Load	100 KN/m <sup>2</sup>
Slice Width	0.29835 m
Mid-Height	12.764 m
Base Length	0.4964 m
Base Angle	-53.056 °
Weight (vertical)	62.072 kN
Top Left Coordinate	14.104948, 18 m
Top Right Coordinate	14.403298, 18 m
Bottom Left Coordinate	14.104948, 5.4345813 m
Bottom Right Coordinate	14.403298, 5.0378503 m

Fig-4: Determination of FS using Geostudio

The factor of safety obtained for the sample 1 and 2 were 0.998 and 0.994 and are given in table 1.

Table- 1: Values of FOS for sample 1 and 2

	Sample 1	Sample 2
Factor of safety	0.998	0.994

## 6. CONCLUSION

As per the case study, it can be concluded that the root cause of the landslide was due to the unscientific cutting of the hill and thus this incident can be regarded as a manmade disaster. Every hill is having its own natural slope, if any alterations are made which is worthy enough to disturb its natural condition without providing any assistance to

support the remaining slope. The obtained value of factor safety implies that the slope is not at all stable and need sufficient protective measures to stabilize the slope. On the basis of the survey conducted among the local people it can be concluded that the heavy rainfall occurred at midnight before incident initiated the landslide. Based on the geotechnical study it is clear that the soil is having very low shear parameters. The increased pore pressure couldn't be balanced causing the collapse of hill. As per the present condition of the slope, the hill cannot withstand the huge surcharge of the water tank located at the top of the hill. Thus immediate preventive measures should be taken to stabilize the slope either by providing a stable slope or by constructing an economical retaining wall.

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