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SLOPE STABILITY ANALYSIS WITH GEO5 SOFTWARE FOR MALIN LANDSLIDE IN PUNE (MAHARASHTRA)

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ABSTRACT

In recent times the natural hazards in India & all around the world are increasing day by day. Many of the hazards are happening due do man made activities. One such example of man -made hazard is landslide. One such landslide which came under news was in Pune district in Ambegaon Taluka in small village like Malin. In Malin Landslide more than 200 people were died within a minute & the entire village banished from the map of India. Analysis of the stability of natural and manmade slopes and embankments is a difficult geotechnical task. The slope stability analysis is carried out to minimize the circumstance of failing slopes and landslides. Through proper measurement of slope stability the Slope failing can be determined. The consideration of interslice force and the complete equilibrium of the sliding mass is the main difference between limit equilibrium analysis methods. The appropriate analysis method results the effectiveness of all slope failure remediation method. The software GEO5 allows geotechnical engineers to carry out limit equilibrium slope stability analysis of existing natural slopes, unreinforced man-made slopes, or slopes with soil reinforcement. The program uses many methods such as: Bishop's Modified method, Janbu's Simplified method, Spencer method, Morgenstern-Price method and others. GEO5 allows these methods to be applied to circular, composite, and non-circular surfaces.

The objectives are what exactly is landslide. What happened in Malin & what are the causes behind such tragedy & what can be the remedial measures to avoid landslide. This paper shows application of a GEO 5 slope stability software to evaluate stability of the Malin Landslide in Pune.

Keywords- *landslide, GEO 5, geo-environmental hazards.*

I. INTRODUCTION

Slopes may be natural or manmade or earth dam. Every slope has forces acting on it that tend to disturb its stability. The main force is the self-weight of soil mass forming the slope, but seepage, seismic activity and external loads are also disturbing forces. In a stable slope, resisting force due to shear strength are larger than disturbing force. Slope failure is related to the following reasons: soil properties or soil type of slope, geometry of slope, weight, water content (one of the most aggressive factor reducing shearing strength of slope), tension cracks and vibrations due to earthquakes. Key factors in slope stability investigation include determining the boundaries of the slope instability, establishing a history of previous slope movement, assessing landslide causation, modelling landslide initiation as well as the travel paths taken by moving landslide debris, assessing the damage to affected buildings and structures, and preparing the recommendations for stabilizing slopes. Conventional limit-equilibrium techniques i.e. they evaluate the slope as if it were about to fail and determine the resulting shear stresses along the failure surface, are the most commonly used analysis methods. Excellent commercial soft wares like Geo5, PLAXIS, Z-soil, have made a powerful viable alternative to the assistance of the geotechnical engineer. The aim is to obtain a comparison of solution to a man-made slope by conventional method and using Geo5 software.

A slope is an unsupported, inclined surface of a like soil mass. Slopes can be natural or man-made. These may be above ground level as embankments or below ground level as cuttings. Earth slopes are formed for railway embankments, earth dams, canal banks, levees, and at many other locations. Instability related issues in engineered as well as natural slopes are common challenges to both researchers and professionals. Instability may result due to rainfall, increase in groundwater table and change in stress conditions. Similarly, natural slopes that have been stable for many years may suddenly fail due to changes in geometry, external forces and loss of shear strength. In addition, the long-term stability is also associated with the weathering and chemical influences that may decrease the shear

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strength. In such circumstances, the evaluation of slope stability conditions becomes a primary concern everywhere. When a mass of soil has an inclined surface the potential of slope to slide from higher level to lower level always exist. The sliding will occur if shear stress developed in the soil exceeds corresponding shear strength of soil. However certain practical considerations make precise stability analyses of slope difficult in practices. The engineering solutions to slope instability problems require good understanding of analytical methods, investigative tools and stabilization measures. One says, "The primary aim of slope stability analyses is to contribute to the safe and economic design of excavation, embankment and earth dams". Slope is an exposed ground surface that stands at an angle with the horizontal. Slopes are required in the construction of highway and railway embankments, earth dams, levees, canals etc., and are generally less expensive. Failure of natural slopes and man-made slopes has resulted in much death and destruction. Slope stability analysis consists of determining and comparing the shear stress developed along the potential rupture surface with the shear strength of the soil. In the present study the software GEO 5 has been used to analyze the homogeneous slope for various cohesive strengths. Natural or landscaped slopes may lose their stability by a detachment and sliding of a soil volume along a failure surface, as a result of exceeding its shear strength. This collapse may be developed due to excavation activities and rainfall infiltrating. The slope stability analysis consists determining the soil mechanical properties, the shape and the position of the possible failure surface. Since Fellenius and Bishop, several authors have proposed calculation methods for slope stability based on the limit equilibrium. This procedure coupled with the advanced optimization techniques is adequate for regular slope stability problems. The development of finite elements methods led to an effective approach for assessing the safety factor of soil slopes within its strength reduction. In order to prevent the sliding, different techniques have been evolved to ensure the slope stability. Stabilizing piles have been used to secure or recover slopes that have already collapsed. The soil shear strength could be improved using steel nails. The groundwater level could be lowered within drainage trenches that increase the slope stability especially during rainfall.

In this study, we present a slope stability analysis using a numerical modelling. The confrontations methods mentioned above will be considered and modelled. The soil mechanical parameters of the slope layers are determined from laboratory tests. Once these characteristics have been extracted, we proceed to examine the stability of an existing slope in Malin, which has collapsed due to excavation during the rainfall season. The calculation of slope stability is established taking into account the factors affecting slope instability and the disposition of resistance elements in order to stabilize the slope.

site investigation and slope stability analysis and risk assessment.

Ammar Rouaiguia et al. carried out work on, limit equilibrium types of analyses for assessing the stability of earth slopes have been in use in geotechnical engineering for many decades. This paper describes numerical simulation study of slope stability problems by using the computer based geotechnical software code Slope/w (Geo-slope 2007). The factor of safety (FOS) has been determined using the limit equilibrium within the Morgenstern–Price method along with Mohr-Coulomb expression. The influence of pore water pressure, cohesion, internal friction angle, and unit weight of upper soil layer on the factor of safety for slope stability problems were investigated through a series of examples. The results show that the factor of safety of the slope stability increases with an increase in cohesion and internal friction angle. However, more pore water pressure present in the soil layer causes a significant reduction in the factor of safety. In addition,

II. LITERATURE SURVEY

A. Ghosh, et al. carried out work on, slope instability problems at Agrakhal on Rishikesh-Uttarkashi-Gangotri National Highway of Uttarakhand State has induced distress in many houses situated on the slope. Geological and geotechnical investigations were carried out to assess the slope instability and risk assessment. Topographic survey of the slope was carried out and a contour map was prepared for topographic analysis. Geologically the rocks present in the area are highly weathered phyllites. The outward dipping discontinuity in the rocks favor slope instability. From the field investigation it is inferred that continuous water flow in a drain and water seepage at various locations are the main contributing factors for the instability. Soil samples were collected and tested in the laboratory for their geotechnical engineering properties. The paper presents the details of

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the increase in unit weight of soil layer produces lower factor of safety

Ali Fawaz et al. this paper aims to analyses slope stability based on the numerical simulation using Plaxis software. The mechanical parameters of soil layers constituting the slope are evaluated from laboratory results and numerical simulations of in-situ pressure meter tests. The study of the slope consists to determine the failure surface and the corresponding safety factor. This coefficient is calculated taking into consideration the influence of factors that contribute slope instability and following the use of several methods of reinforcement to strengthen the slope

Nima Farshidfar et al. this research uses the shear strength reduction method to study soil slopes stability. In this method shear strength is considered to be reduced as less as failure occurs. It uses Plaxis, which is capable of calculating deformations rates and safety factors by gaining geometry data of a problem and soil specifications and using the finite element method (FEM). The analysis is performed at both static and pseudo-static modes. The effects of different parameters on slopes stability are shown by performing several analyses. Finally, the analyses performed by this method are compared with the ones obtained by finite difference method (FDM).

Upto the present, the various research is done and going on various design methods of slope stability and its analysis. The design by considering various parameters such as cohesion, angle of internal friction, unit weight in the design approach. Still there is need of research to improve the stability of slope which helps to prevent landslide happen Malin.

III. LANDSLIDES IN INDIA:

India due to its varying geological characteristics, diverse climatic pattern & due the rapid increasing development on mountainous & coastal region due to increasing population has caused more damage to the hills. Western ghats, Himalayas are the one such examples where increased man made activities are causing landslides in these region more often. Landslides & avalanches are causing economic losses nearly in all the states in India. The most affected parts due to landslide in India are Himalayas, Westerns Ghats, Nilgris, & Vindhyas. About 15% of the terrain in India is susceptible to landslide or 0.49 million sq. km. are prone to landslide. This includes 0.098 million km^2 of north eastern region, comprising Arkan Yoma ranges & 0.392 million sq km of Himalayas, Nilgiri, Ranchi Plateau & Eastern, and Western Ghats. States like Sikkim & Mizoram have been assessed to be falling under very high to severe hazard classes. In the peninsular region, the hilly tracts of states like Karnataka, Andhra Pradesh & Kerala constitute low to moderate hazard prone areas.

Some Major Landslides:

Following are the some major landslide that have taken place in India in last 25 years:

- July 30, 2014 – Malin (Dist. Pune, Tal Ambegaon) in Maharashtra - More than 200 people were died due to landslide.
- June 16, 2013- Kedarnath, Uttarakhand – In June 2013, a multi-day cloudburst centred on the North Indian state of Uttarakhand caused devastating floods & landslides in the country's worst natural disasters, which saw more than 5700 causalities.
- September 24, 2012- Northern Sikkim – 27 people died, including members of Indo- Tibetan Border Police (ITBP).
- July 26, 2005- Raigad- 54 people were killed in landslide, floods in Maharashtra Raigad.
- July 26, 2005- Sakinaka, Mumbai – More than 74 people were died in Landslide.
- November 2001- Amboori in Kerala – 40 people were died.
- August 1998- Malapa – Entire village was wiped out. The landslide saw approximately 400 casualties August 14, 1998- Okhimath – 69 people were killed in the incident.
- June 1994- Konkan coast – 20 people were killed, breaching of ghat damped road to an extent of 1 km.
- August 1993- Nagaland – 200 houses were destroyed, 500 people died, about 5km stretch of road was damaged.
- August 1993- Kalimpong, West Bengal – About 40 people were killed, leading to heavy loss of property.

July 1993- Itanagar – 25 people were buried alive.

IV. PRIMARY SURVEY OF THE MALIN VILLAGE

A rumbling sound echoed through Malin village. Before anyone could understand what was happening, the tiny village was destroyed in a torrent of mud as a portion of the hill overlooking the village came tumbling down burying around 50 houses.

Day 1: Wednesday, July 30

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A state transport bus driver was the first to reach the village from outside he alerted the authorities about the missing village. He recounted that the 20 feet temple tower, houses, community hall, shops all had disappeared and only huge amounts of mud remained. Further NDRF (National Disaster Response Force) was roped in by the district collector. 17 bodies were recovered and the miraculous rescue of a woman and son found alive gave a ray of sunshine in the rescue efforts.

Day 2: Thursday, July 31

On day two of the tragedy, chances of survival of the rest of the trapped were termed as slim. More than 50 bodies were recovered and the first mass funeral of the bodies recovered from the site was carried out. While Union Home Minister Rajnath Singh talked about immediate relief and rescue of the area and announced an ex-gratia payment of Rs 2 lakhs per victim were announced.

Day 3: Friday, August 1

Rescue operations were hampered by rains but continued at a slower pace. Mass cremation of bodies recovered from the debris was carried out. Talks of Rehabilitation gained momentum. District Collector Saurabh Rao announced that the Geological Survey of India (GSI) would conduct a stability study of the mountains.

The landslide struck and effectively wiped out the village of Malin, located close to Bhimashankar in the Western Ghats.

Figure No 1 : The Malin Mishap

Figure No 2 : The debris pile at the foot of the slope appears to be exceptionally wet

Figure No 3 : Deep rill formed due to heavy rain

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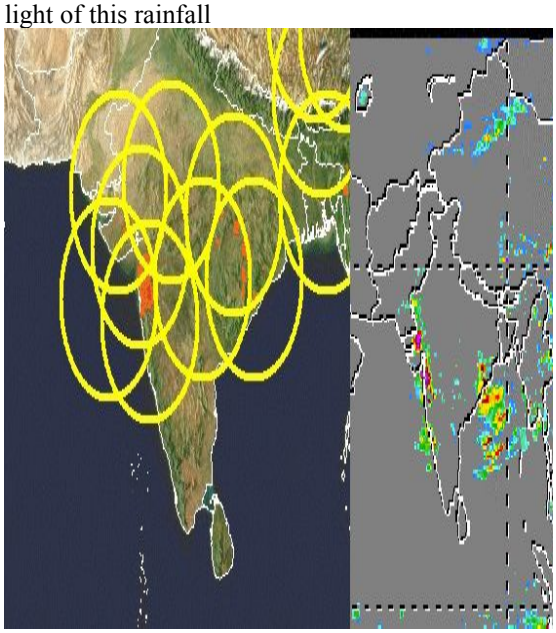
Figure No 4: Deep hole formed due to soil erosion

Figure No 5 : The site of the landslide on Google Earth

V. CAUSES OF MALIN LANDSLIDE

Inevitably there is huge speculation about the causes and triggers of the Malin landslide. The trigger is clear this area was affected by very strong monsoon rainfall in the two days prior to the landslide. The NASA TRMM landslide warning tool highlighted this as a zone that was very susceptible to landslides in light of this rainfall



VI. SCOPE OF PROJECT

Six months after the tragedy that killed over 150 people, the district administration of Pune has zeroed in on Amde village to rehabilitate survivors of the Malin landslide. About 72 houses will be built once the state government makes provision for funds. The administration had identified two spots for rehabilitation, but received consent of both survivors and residents for the eight acre land in Amde village, about 2 km from Malin. A team from the Geological Survey of India will check the location and conduct experiments to check the soil and rocks. The ideas for the houses include-it will have around 451 sq.ft of built-up area and the construction cost fora single unit will be around Rs. 5.93 lakh. Besides construction of homes, the administration also plans to provide 18 types of civic amenities at the site, including drainage, drinking water, internal roads, school, and open space among others. The rehabilitation work will be taken up under the state tribal government. Currently, the affected families are residing in temporary shelters put up by the administration in a near village. We as engineers are expected to provide a platform for rehabilitation of all those affected in Malin Landslide disaster. So this is our small effort for doing what is expected from us. This is project serving demand of a basic plan and platform for rehabilitation work. Village rehabilitation process means to regain the essence of the village that was once present in a good mannerism and hold the importance and uniqueness of the proper livelihood. This is not as easy as it seems to be. There are several things attached to this entity. From agriculture to education, every sector gets affected in a huge way. Bridging the gap in between stable life and unstable habitat is what rehabilitation process is all about. This is why Village Rehabilitation Projects are launched by various organizations to help the needy at the right moment to gain an upper hand in the management system.

The various organizations that are working with the district administration in relief and rehabilitation work in Malin include- IIT Mumbai, Karve Institute (Pune), the Centre for Disaster Management, Maharashtra Arogya Mandal and the Tata Institute of Social Sciences (TISS). Apart from these members from Shashwat and Chaitanya, two community NGOs enjoy a good rapport with villagers and the administration in the region.

VII. SLOPE STABILITY ANALYSIS METHODS

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Introduction Slope stability analysis using computers is an easy task for engineers when the slope configuration and the soil parameters are known. However, the selection of the slope stability analysis method is not an easy task and effort should be made to collect the field conditions and the failure observations in order to understand the failure mechanism, which determines the slope stability method that should be used in the analysis. Therefore, the theoretical background of each slope stability method should be investigated in order to properly analyse the slope failure and assess the reliability of the analysis results. 2 D slope stability methods are the most common used methods among engineers due to their simplicity. However, these methods are based on simplifying assumptions to reduce the three-dimensional problem to a two dimensional problem and therefore the accuracy of the analysis results vary between the different analysis methods. 2 D slope stability methods using limit equilibrium technique can be divided into the method of slices, circular methods, and noncircular methods. The method of slices is based on dividing the slope into different slices and analysis the stability of the failing mass taking into consideration the static equilibrium of the slices individually and the overall equilibrium of the failing mass as whole. The static equilibrium of the slices can be achieved by different assumptions including neglecting or considering the interslice forces and the moment equilibrium of the slices. On the other hand, circular and noncircular limit equilibrium methods consider the equilibrium of the whole failing mass only, and therefore the internal equilibrium of the sliding mass is not considered. Such methods may not be appropriate if the slope remediation method involves installing structural elements in the sliding mass such as slope stabilizing piles.

Limit Equilibrium Methods

Limit equilibrium methods are still currently most used for slopes stability studies. These methods consist in cutting the slope into fine slices so that their base can be comparable with a straight line then to write the equilibrium equations (equilibrium of the forces and/or moments) [8]. According to the assumptions made on the efforts between the slices and the equilibrium equations considered, many alternatives were proposed. They give in most cases rather close results. The differences between the values of the safety factor obtained with the various methods are generally lower than 6%

1. Swedish Circle / ø = 0 Method.
2. Log-Spiral procedure
3. The friction Circle Procedure
4. Methods of Slices
    - Ordinary method of slices
    - Simplified Bishop Method
    - Janbu's Simplified Method
    - Janbu's Generalized Procedure of Slices (GPS)
    - Spencer's Method
    - Morgenstern and Price's Method
    - Sarma's Method

Software GEO5

GEO5 software suite is designed to solve various geotechnical problems. The easy to use suite consists of individual programs with a unified and user-friendly interface. Each program is used to analyze a different geotechnical task but all modules communicate with each other to form an integrated suite. Geotechnical software with analytical and finite element analysis solutions consist of programs designed to solve large number of problems commonly encountered. It includes integrated modules such as stability of slopes, reinforced slopes, nailed slopes, rock stability, spread footing, plates, beams, piles, cantilever wall, abutment, gravity wall, gabions, earth pressure, sheeting design, sheeting check, settlement, etc. A wide range of geotechnical problems such as beams on elastic foundations, excavation, etc. can be modelled which can be used to study the real behavior of the material in the structure. There are many software packages available in the market. Some that uses the Swedish method of slices and others that use more sophisticated methods.

The program analyses the stability of generally layered soil slopes. It is used mainly for stability checks of embankments, earth cuts and anchored sheeting structures. The slip surface is considered as circular (the Bishop, Fellenius/Petterson, Janbu, Morgenstern-Price or the Spencer method) or polygonal (the Sarma, Janbu, Morgenstern-Price or Spencer method).

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