# Slope Stability Analysis and Design Their Control Measures

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***Abstract:-* The incidences of slope failures are recurrent in Kathupparai hills in Bondinayakkanur, particularly along the Ghost road cutting and hill slopes carrying disruption in traffic, loss of life and damage to the property. This demand needs critical assessments of stability of slope along the hill roads. This research deals with stability analysis of soil slope at study area. A number of soil samples and slopes parameters have been collected, examined and studied; the orientation of discontinuities of slopes has been identified as one of the major inherent factors influencing slope instability along soil profile. As the laterite soil slope is mostly homogenous, limit equilibrium and circular failure charts methods were adopted for stability analysis of soil slopes based on height of slopes. That these methods are highly useful in determining the factor of safety in soil profiles and suggested recommendation for remedial measures. The outcome of this research exposed in the form of maps in GIS environment and suggested preventive measures in CAD design. This research would help planners and engineers in their assortments of the sites of their engineering projects and in the treatment of slopes that exists in critical state of stability.**

***Keywords: Limit equilibrium, circular failure chart methods, factor of safety.***

## I. INTRODUCTION

Landslide is one of the important natural disasters, which commonly availed on cut slopes along Ghat section roads in mountainous region, while events are also reported in residential areas causing affects to human life, loss of properties, damage to established road network, and urban development in each year. Landslides also occur in natural slopes, influenced by various geo-environmental parameters and triggered by cloud precipitation, heavy rainfall, earthquake, etc. The natural slopes are converted into cut slopes by anthropogenic intervention for the purpose of transportation network, construction of dams, bridges, and tunnels are more prone to landslides occurrences in hilly terrain, landslides are natural denudation process and its occurrence is subjected to various causative factors and triggered by several inherent factors like lithology, structure, and exherent factors such as seismicity, rainfall, water level change, strom waves, and rapid stream erosion. Hill slopes in mountainous areas are affected by human activities such as building road network, urban development, deforestation, and rapid land use modification, may also influence occurrence of landslides.

The stability of road cut highway slopes is always considered to be crucial as the slightest failure can be destructive in terms of monetary losses and harm to human lives. The cut slopes need to be carefully analyzed for this failure mechanism, prior to excavation, during excavation and post excavation.

Slope stability analysis should be used to determine whether a proposed slope meets the required safety and performance criteria during design. This type of analysis is also utilized to determine stability conditions of existing natural or constructed slopes and evaluate the influence of proposed remedial methods if required.

The project finding are expected to benefit civil and geotechnical engineers of government transportation agencies, conultants, and contractors dealing with slope stability, slope remediation, and geotechnical testing.

### *A.PROBLEM DEFINITION*

Generally, the works of PWD and highway department are not in pre-planned way in the case of slope surfaces. When the process of vertical slope cutting or overturning of slope are done by means of using explosives such as dynamites, the slope failure occurs with time along the loading direction. So, we had taken the particular study as our project.

Since 2007, the extension of the roads are being takes place. In this study area, we are planned to adopt the suitable control measures, based on soil and geotechnical parameters of the study area.

### *B.METHODOLOGY*

The methodology is exposed in the form of flowchart.

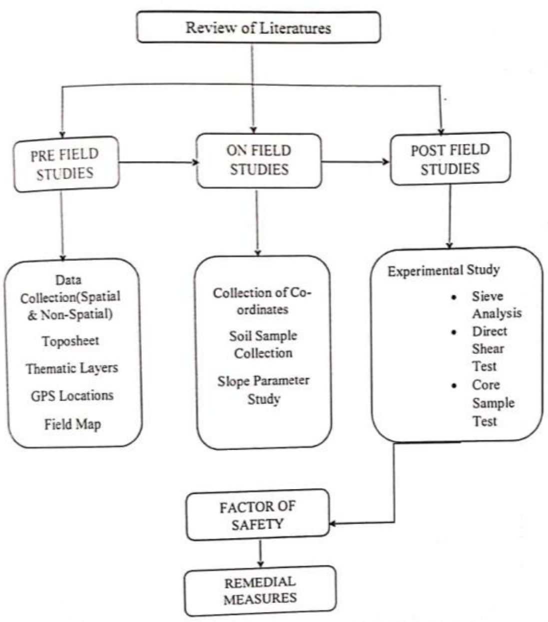


Fig 3.1 METHODOLOGY- FLOWCHART

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## II. FIELD AND EXPERIMENTAL ANALYSIS

### *A.PREPARATION OF SPATIAL AND NON-SPATIAL DATA COLLECTIONS:*

During the research phase all existing data and maps of the field in question are collected. All suitable maps available whether physical, political, relief, road, physical, and topographic should be carried to the field as it is possible that details in one may is expected of the field and the detail required, the, scale of the map is an important aspect to consider.

GPS (Geographical Positioning System) is a satellite based navigation system comprising three basic parts; the satellite in space, monitoring stations on earth and the GPS receiver. This equipment is used in geological field mapping for finding ones position, mapping lithologies, tracking structure, measuring elevation, storing sampling points and descriptions of formations when samples are collected. The GPS function and capabilities are improving rapidly with advancement in technology and such it is important to purchase one that is relatively modern.

### *B.SPATIAL AND NON-SPATIAL DATA*

Spatial data, also known as geospatial data, is information about a physical object that can be represented by numerical values in a geographic coordinate system. Spatial data represents the location, size and shape of object on planet earth such as a building, lake, mountain or township. Spatial data may also include attributes that provide more information about the entity that is being represented. Geographic information system (GIS) or other specialized software applications can be used to access, visualize, manipulate and analyze geospatial data.

A non-spatial data is a kind of data which does not depends upon the geometric co-ordinate. They are one dimensional and independent.

| SECTION | NORTHING | EASTING | ELEVATION (m) |
|---|---|---|---|
| S1 | 10° 2' 7.301" | 77° 16' 35.686" | 985 |
| S2 | 10° 2' 7.226" | 77° 16' 30.416" | 983 |
| S3 | 10° 2' 7.301" | 77° 16' 24.392" | 928 |
| S4 | 10° 2' 4.59" | 77° 16' 18.143" | 926 |
| S5 | 10° 2' 4.967" | 77° 16' 26.625" | 914 |
| S6 | 10° 2' 4.666" | 77° 16' 33.954" | 907 |

### *C. BASEMAP*

A map depicting background reference information such as landforms, roads, landmarks, and political boundaries, onto which other thematic information is place. A basemap is used for locational reference and often includes a geodetic control network as part of its structure . a map to which GIS data layers are registered and rescaled.

### *D.CORE CUTTER METOD THEORY*

A cylindrical core cutter is a seamless steel tube. For determination of the dry density of the soil, the cutter is pressed into the soil mass so that it is filled with the soil. The cutter filled with the soil is lifted up. The mass of the soil in the cutter is determined. The dry density is obtained as

Where M= mass of the wet soil in the cutter
V= internal volume of the cutter

w= water content

THE DIRECT SHEAR TEST PARAMETERS

| | | | | | |
|---|---|---|---|---|---|
| | MIDDLE | 0.5 | 49.05 | 0.196 | 54.44 |
| | | 1.0 | 98.10 | 0.350 | 97.22 |
| | | 1.5 | 147.15 | 0.479 | 133.06 |
| | | 2.0 | 196.20 | 0.508 | 141.11 |
| | | 2.5 | 245.25 | 0.543 | 150.83 |
| | BOTTOM | 0.5 | 49.05 | 0.196 | 54.44 |
| | | 1.0 | 98.10 | 0.350 | 97.22 |
| | | 1.5 | 147.15 | 0.479 | 133.06 |
| | | 2.0 | 196.20 | 0.508 | 141.11 |
| | | 2.5 | 245.25 | 0.543 | 150.83 |
| STATION 2 | TOP | 0.5 | 49.05 | 0.196 | 54.44 |
| | | 1.0 | 98.10 | 0.350 | 97.22 |
| | | 1.5 | 147.15 | 0.479 | 133.06 |
| | | 2.0 | 196.20 | 0.508 | 141.11 |
| | | 2.5 | 245.25 | 0.543 | 150.83 |
| | MIDDLE | 0.5 | 49.05 | 0.196 | 54.44 |
| | | 1.0 | 98.10 | 0.350 | 97.22 |
| | | 1.5 | 147.15 | 0.479 | 133.06 |
| | | 2.0 | 196.20 | 0.508 | 141.11 |
| | | 2.5 | 245.25 | 0.543 | 150.83 |
| | BOTTOM | 0.5 | 49.05 | 0.196 | 54.44 |
| | | 1.0 | 98.10 | 0.350 | 97.22 |
| | | 1.5 | 147.15 | 0.479 | 133.06 |
| | | 2.0 | 196.20 | 0.508 | 141.11 |
| | | 2.5 | 245.25 | 0.543 | 150.83 |
| | TOP | 0.5 | 49.05 | 0.245 | 68.06 |

| STATION ID | SAMPLE ID | NORMAL STRESS in kN | NORMAL STRESS in kN/mm² | SHEAR LOAD in kN | SHEAR LOAD in kN/mm² |
|---|---|---|---|---|---|
| STATION 1 | TOP | 0.5 | 49.05 | 0.196 | 54.44 |
| | | 1.0 | 98.10 | 0.350 | 97.22 |
| | | 1.5 | 147.15 | 0.479 | 133.06 |
| | | 2.0 | 196.20 | 0.508 | 141.11 |
| | | 2.5 | 245.25 | 0.543 | 150.83 |

| | | | | | |
|---|---|---|---|---|---|
| STATION 3 | | 1.0 | 98.10 | 0.438 | 121.67 |
| | | 1.5 | 147.15 | 0.543 | 150.83 |
| | | 2.0 | 196.20 | 0.658 | 182.78 |
| | | 2.5 | 245.25 | 0.867 | 240.83 |
| | MIDDLE | 0.5 | 49.05 | 0.245 | 68.06 |
| | | 1.0 | 98.10 | 0.438 | 121.67 |
| | | 1.5 | 147.15 | 0.543 | 150.83 |
| | | 2.0 | 196.20 | 0.658 | 182.78 |
| | | 2.5 | 245.25 | 0.867 | 240.83 |
| | BOTTOM | 0.5 | 49.05 | 0.245 | 68.06 |
| | | 1.0 | 98.10 | 0.438 | 121.67 |
| | | 1.5 | 147.15 | 0.543 | 150.83 |
| | | 2.0 | 196.20 | 0.658 | 182.78 |
| | | 2.5 | 245.25 | 0.867 | 240.83 |
| STATION 4 | TOP | 0.5 | 49.05 | 0.211 | 58.61 |
| | | 1.0 | 98.10 | 0.362 | 100.56 |
| | | 1.5 | 147.15 | 0.508 | 141.11 |
| | | 2.0 | 196.20 | 0.638 | 177.22 |
| | | 2.5 | 245.25 | 0.783 | 217.50 |
| | MIDDLE | 0.5 | 49.05 | 0.211 | 58.61 |
| | | 1.0 | 98.10 | 0.362 | 100.56 |
| | | 1.5 | 147.15 | 0.508 | 141.11 |
| | | 2.0 | 196.20 | 0.638 | 177.22 |
| | | 2.5 | 245.25 | 0.783 | 217.50 |
| | BOTTOM | 0.5 | 49.05 | 0.211 | 58.61 |
| | | 1.0 | 98.10 | 0.362 | 100.56 |
| | | 1.5 | 147.15 | 0.508 | 141.11 |
| | | 2.0 | 196.20 | 0.638 | 177.22 |
| | | 2.5 | 245.25 | 0.783 | 217.50 |
| STATION 5 | TOP | 0.5 | 49.05 | 0.188 | 52.22 |
| | | 1.0 | 98.10 | 0.381 | 105.83 |
| | | 1.5 | 147.15 | 0.506 | 140.56 |
| | | 2.0 | 196.20 | 0.675 | 187.50 |
| | | 2.5 | 245.25 | 0.709 | 196.94 |
| | MIDDLE | 0.5 | 49.05 | 0.188 | 52.22 |
| | | 1.0 | 98.10 | 0.381 | 105.83 |
| | | 1.5 | 147.15 | 0.506 | 140.56 |
| | | 2.0 | 196.20 | 0.675 | 187.50 |
| | | 2.5 | 245.25 | 0.709 | 196.94 |
| | BOTTOM | 0.5 | 49.05 | 0.188 | 52.22 |
| | | 1.0 | 98.10 | 0.381 | 105.83 |
| | | 1.5 | 147.15 | 0.506 | 140.56 |
| | | 2.0 | 196.20 | 0.675 | 187.50 |
| | | 2.5 | 245.25 | 0.709 | 196.94 |
| STATION 6 | TOP | 0.5 | 49.05 | 0.235 | 65.28 |
| | | 1.0 | 98.10 | 0.361 | 100.28 |
| | | 1.5 | 147.15 | 0.548 | 152.22 |
| | | 2.0 | 196.20 | 0.683 | 189.72 |
| | | 2.5 | 245.25 | 0.857 | 238.06 |
| | MIDDLE | 0.5 | 49.05 | 0.235 | 65.28 |
| | | 1.0 | 98.10 | 0.361 | 100.28 |
| | | 1.5 | 147.15 | 0.548 | 152.22 |
| | | 2.0 | 196.20 | 0.683 | 189.72 |
| | | 2.5 | 245.25 | 0.857 | 238.06 |
| | BOTTOM | 0.5 | 49.05 | 0.235 | 65.28 |
| | | 1.0 | 98.10 | 0.361 | 100.28 |
| | | 1.5 | 147.15 | 0.548 | 152.22 |
| | | 2.0 | 196.20 | 0.683 | 189.72 |
| | | 2.5 | 245.25 | 0.857 | 238.06 |

## RESULT AND DISCUSSION

Evaluation of factor of safety and suggesting suitable remedial measures. Based on the equilibrium method and circular failure chart method, the values of factor of safety was evaluated for the selected station points in our study area, kathupparari. Facet wise distribution of the total estimated hazards values in the area facilities classification of the terrain into five zones like very high hazards, high hazard, moderate hazard, low hazard, and very low hazard the factor of safety values are shown in table. The landslide hazard of the ghats section, thus prepared, indicates that, some stations fall under the moderate hazard zone and some stations are comes under high hazard zone. The locations of landslides were collected using GPS. The landslide inventory points are incorporated to suitable remedial measures. The field study supplemented with further analysis for hazard concluded that about 82% of the vulnerable slide points are found in high hazard zone. Some of the field photographs and factors of safety values are shown below.

## FACTOR OF SAFETY

The factor of safety is being determined by the following equation with the help of the slope parameters collected from the study area.

$$FOS = \frac{c + (\gamma - \gamma')\, H \cos^2 i \tan\varphi}{\gamma\ H \cos i \sin i}$$

Where,
C – Cohesion factor
γ – Unit weight of samples in KN/mm
H – Height of slope in meter
i – slope angle in degrees

THE PARAMETER WHICH ARE EVALUATED TO DETERMINE FACTORS OF SAFETY BY LIMIT EQULIBRIUM METHOD:

| STATION ID | SAMPLE ID | FACTOR OF SAFETY | AVERAGE FACTOR OF SAFETY |
|---|---|---|---|
| STATION 1 | TOP | 0.86 | 0.860 |
| | MIDDLE | 0.8579 | |
| | BOTTOM | 0.858 | |
| STATION 2 | TOP | 0.71 | 0.710 |
| | MIDDLE | 0.707 | |
| | BOTTOM | 0.712 | |
| STATION 3 | TOP | 0.645 | 0.645 |
| | MIDDLE | 0.6446 | |
| | BOTTOM | 0.64 | |
| STATION 4 | TOP | 0.877 | 0.868 |
| | MIDDLE | 0.8689 | |
| | BOTTOM | 0.8678 | |
| STATION 5 | TOP | 0.712 | 0.712 |
| | MIDDLE | 0.7116 | |
| | BOTTOM | 0.7115 | |
| STATION 6 | TOP | 0.9437 | 0.940 |
| | MIDDLE | 0.9339 | |
| | BOTTOM | 0.941 | |

THE PARAMETER WHICH ARE EVALUATED TO DETERMINE FACTORS OF SAFETY BY CIRCULAR FAILURE METHOD:

REMEDIAL MEASURES FOR UNSTABLE SLOPES
GENERAL REMEDIAL MEASURES:

The most commonly adopted remedial measures for steep cut slope is to alter the slope geometry to stable angle. For that purpose the soil slopes will be cut into a small cut slope benches with overall cut slope angle to 1:1.5 (vertical: horizontal). On the hill side just adjoining the slope may be supported with the help of a retaining wall.

| STATION ID | SAMPLE ID | FACTOR OF SAFETY | AVERAGE FACTOR OF SAFETY |
|---|---|---|---|
| STATION 1 | TOP | 1.2 | 1.196 |
| | MIDDLE | 1.195 | |
| | BOTTOM | 1.192 | |
| STATION 2 | TOP | 1.121 | 1.120 |
| | MIDDLE | 1.119 | |
| | BOTTOM | 1.120 | |
| STATION 3 | TOP | 1.116 | 1.116 |
| | MIDDLE | 1.113 | |
| | BOTTOM | 1.119 | |
| STATION 4 | TOP | 1.040 | 1.040 |
| | MIDDLE | 1.044 | |
| | BOTTOM | 1.036 | |
| STATION 5 | TOP | 1.160 | 1.160 |
| | MIDDLE | 1.157 | |
| | BOTTOM | 1.163 | |
| STATION 6 | TOP | 1.211 | 1.211 |
| | MIDDLE | 1.210 | |
| | BOTTOM | 1.212 | |

A retaining wall is a structure that holds or retains soil behind it. There are many types of materials that can be used to create retaining walls like concrete blocks, poured concrete, treated timbers, rocks or boulders. Some are easy to use, others have a shorter life span, but all can retain soil.

Cantilever walls are walls that do not have any supports and thus free unsupported excavation. Cantilever walls restrain retained earth by the passive resistance provided by the soil below the excavation.

Reinforced concrete cantilever walls these walls can be different shapes usually some sort of “L” shape. Stability of the wall comes from the weight of soil on the ‘heel’ of the wall. The vertical ‘stem’ of the wall acts like a cantilever structure to support the lateral earth pressure on the back of the wall. They are suitable for walls up to 6m high.

Reinforced concrete cantilever wall advantage : i) take up small with much of structure below ground ii) no specialist equipment required – standard reinforced concrete skills required for construction.

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