Role of discontinuities in the determination of slope stability at Pattikad along NH-47, Kerala.

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Abstract - slope failure is one of the major concerns along highways all around the world. Mannuthi- Kuthiran road segment is one such region which is highly vulnerable and suffers from recurrent rock slide and fall mostly in the rainy season. The steep and highly jointed rock cut cliffs along the road makes the zone prone to slope failure due to the infiltration of water during rainy season. Attempts have been made in this study to understand the stability of the cut cliff. The influence of joints on the stability of slopes is determined using Markland test. The study shows that some sections of the cliff face is highly unstable taking into consideration the environmental condition and heavy traffic. Proper case is to be taken to avoid potential hazard in the area.

Keywordss- **Slope stability, Pattikad, stability analysis, Charnockite, Factor of safety.**

I. INTRODUCTION

The slope stability is a very common phenomenon along the highway sections in Kerala state. The problem is severe during monsoon in road cut cliff along Mannuthi to Kuthiran segment of NH-47 extending from Kanyakumari to Salem. Many highway cuttings are hazardous and failure is frequent especially during heavy rainfall periods. A typical hard rock profile which is identified as slide prone is the Pattikkad profile and is considered for detailed study. Landslides have been reported along cut slops of Munnar area and it was observed that the slide occurred because no consideration to slope characteristics [1]. Most of the rock falls; slides take place on the cliff face due to continuous process of weathering which reduces the rock strength and further open the joints and fractures [2].

The prominent slope failure elements identified are the gradient of the hill slope, material properties of the rock, orientation and spacing of discontinuities and hydrological conditions. The rocks are traversed by innumerable joints. The orientation and spacing of these discontinuities limit the extent of the free body with the rock slope that has a tendency to slip along open discontinuity planes. Role of joint in stability of slopes have been identified by [3].The stability analysis of rock slopes have been carried out by [4], [5]. The hydrostatic thrust along joint planes caused by seepage and infiltration after heavy rain storms is a contributing factor accelerating landslide. The study carried out by [6] stress the need of detailed geotechnical appraisal of the road cut slopes to mitigate the effect of landslides.

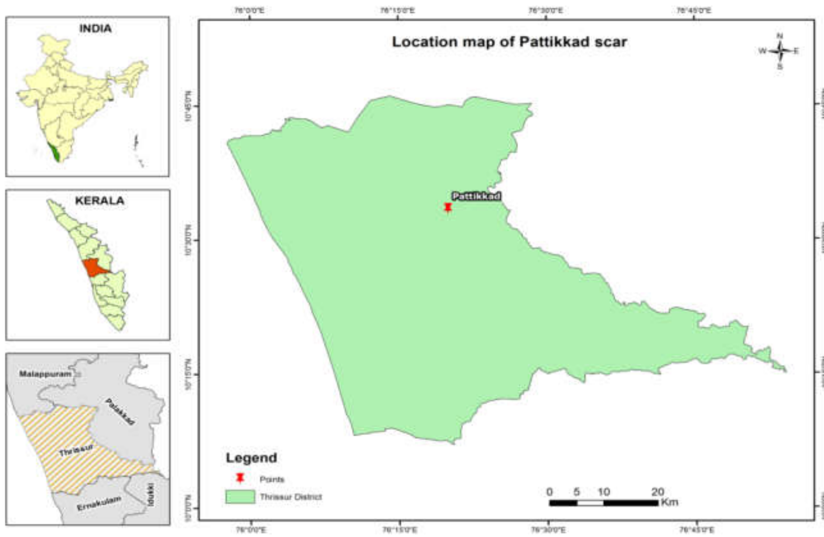

Fig.1: Location map of Pattikkad profile

II. METHODOLOGY

Methodology and technique applied in this study are after [7] – [13]. Beta (β) diagram for each sector and Pie (π) pole diagram for the entire profile are constructed from the orientation data. The circle representing the cone for the angle of internal friction and the trace of the great circle passing through the slope angle are also incorporated. The area prone to wedge failure is determined using Markland's test [14]. The convex periphery of the crescent moves towards the outer greater circle when water is present in the fractures [15]. Potential slide surface along which overhanging plane failure and toppling failure can occur are also determined [10], [12], [13]. Geometric techniques [12] are used to identify the potential slide surfaces which are pre-existing discontinuities such as joints and fracture planes. The volumes of the rock mass that may be wasted as consequence of probable slides also could be computed using geometric techniques. The factor of safety of each sector is calculated using the formula, $F= \cot\theta\ ^{\chi} \tan\varphi$ (where θ is plunge of joint intersection and φ is the angle of internal friction). Factor of safety of the slope during wet condition is calculated using the equation $\tan\theta + (1-rw/rt)\tan\varphi$ (where rw is the density of water and is equal to 1gm/cc, rt is the bulk density of rock and water, φ is the angle of internal friction). The Unconfined Compressive Strength of the rock is determined in the field using Schmid rebound hammer. The bulk density and friction angle is determined in a geotechnical laboratory.

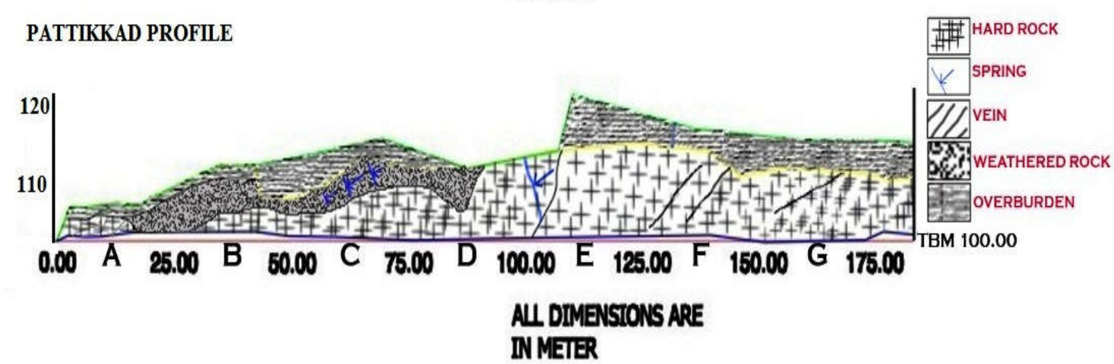

Fig.2: Longitudinal Profile of the Road cut cliff A, B, C, D, E, F and G are sectors

Pattikkad profile is located 15 Km away from Thrissur along the Palakkad road at longitude 76˚20' 1.39" and latitude 10˚ 33' 25.41". The road cut in this locality is very steep. The natural slope of the hillock is 30˚towards north. The height of the cut cliff ranges from 3 to 8m. The total length of the profile is 225m (Fig. 2).

Seasonal water seepage is also observed in this area. The road is at an elevation of 120m above MSL. The maximum height of the hillock is 125m. The entire profile is divided into seven sectors: A, B, C, D, E, F and G. Though hill slopes is characterized by mixed vegetations. Road cut cliff is sparsely vegetated. The slope angle of each section, Lithology, unconfined compressive strength, joint types, friction angle, Bulk density, Dip of joint intersection, Types of probable failure, Factor of Safety at dry and wet condition is found out and presented in Table.1

III. THE ROCK TYPES

The important rock types forming the slopes are charnockite and granite gneiss. Pegmatite veins of width 2 to 50 cm transverse the rock profile. The rocks are weathered to different degrees. The thickness of overburden ranges from 3m to 5m. Charnockite rock is medium to coarse grained with blue quartz, feldspar and hypersthene. At sector B and F weathered rocks are seen bounded on both sides by unweathered rocks. The rocks are well jointed and may be classified into well-developed gaping joints with width greater than 5 cm (A type), joints with minimal separation 5 cm- 1 cm (B type) and inferred joints less than 1cm (C type). Spring spout at the interface of hard crystalline rock and highly weathered rock resting on it at sectors B and C. Water seepage is observed only along joints traversing in the weathered rocks in sectors D and F. Joint sets are dipping approximately in three directions NE, NW and SW and towards North. The profile is divided into sectors A, B, C.D, E, F and G for detailed stability analysis. An assessment of stability of the slope along all sectors has been done. The Unconfined compressive strength of rock varies from sector to sector. In sector D and E, the value is relatively high throughout (25 to 56). However the other sectors the value show wide variation (7 to 52). The low UCS values are an indication of weathering to a great extent in different parts. The factor of safety in hard rock profiles has been calculated assuming that the cohesive strength across the potential slide surface is minimal and that the joints are planar surfaces.

IV. STABILITY ANALYSIS AT SECTOR A

The length of the sector (Fig.3) is 25 m and the height of the cult cliff is ranges from 3.5m-4m. The slope of cut cliff is 60° towards N. There are four major joints (A type) in the sector. Probability for the occurrences of the wedge and plane failure is identified from the β diagram (Fig. 3). Factor safety of the slope is 0.89, when the rocks are wet. Intersection of J1 and J5 falls within the crescent shaped area. The plunge of the intersection is 60 N 30. Chances of plane failure also exist in the sector along the potential slide surface J5. Factor of safety of the cut slope is 1.453 at dry condition and it becomes unstable during wet condition (FOS 0.89)

V. STABILITY ANALYSIS AT SECTOR B

Length of the sector is 25 m and the height of the cut cliff is 5m. The cliff is slopping 52° towards north. The major rock type is charnockite and is highly weathered. There are 10 joints including 4 parallel joints in this sector. During rain storms water seeps through the discontinuities and in the presence of water along these joints, factor of safety may be further reduced to 0.45. Occurrences of the wedge failure are probable in this sector. Slumping of debris is seen in the sector B, which consists of boulders weathered rock fragments and lateritic soil (Fig.4). Factor of safety is less than one even when the rock is dry. The intersection of J2 and J6 falls within the crescent shaped area. The plunge of the intersection is 10°N 27 and is the potential slide surface along which a wedge failure can occur. The rock is sitting safely because of the presence of joints with irregular surface.

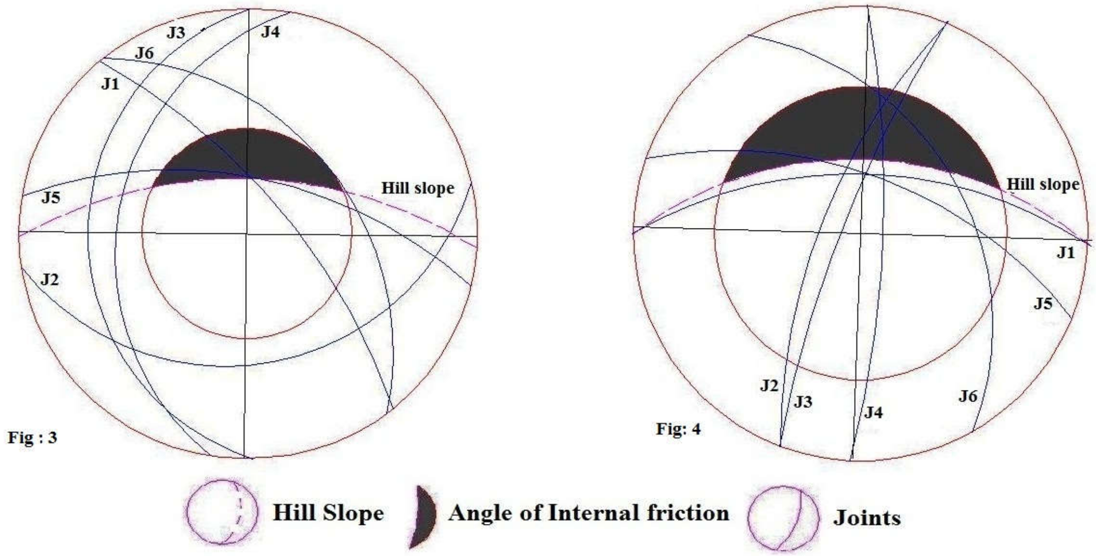

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Fig.3 and 4: β Diagram for Sectors A and B respectively. Broken arcs are the traces of Slopes, the Inner Circle are the Angle of Internal Friction for the materials; Crescent shaped shaded areas represent the Limit for Wedge failure caused by intersection of joint planed.

VI. STABILITY ANALYSIS AT SECTOR C

The sector has length of 25 m and the height of the cliff is 8m, and sloping is 30˚ towards N. Charnockite rock is unaltered. Including 6 parallel joints of C type, nine joints occur in this sector. This sector is found to be stable from geometrical analysis (Fig.5).

VII. STABILITY ANALYSIS AT SECTOR D

The total length of the sector is 25 m and the cliff height is 7 m. The natural slope is 30˚ towards N. and the road cut slope is 70˚ N 200. Charnockite with fresh blue quartz feldspar and hypersthenes is the rock type. There are four joints present in this sector. (Fig.6).This sector is found to be stable.

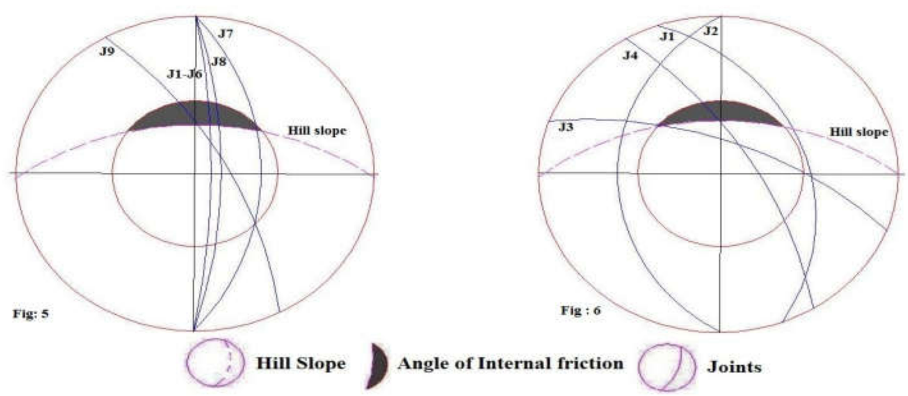

Fig.5 and 6: β Diagram for Sectors C and D respectively. Broken arcs are the traces of Slopes, the Inner Circle are the Angle of Internal Friction for the Materials, Crescent shaped shaded areas Represent the Limit for Wedge failure caused by intersection of joint planed.

TABLE .1: STABILITY STATUS OF THE ROCK SLOPES ALONG THRISSUR –PALAKKAD, KERALA STATE

sector	A	B	C	D	E	F	G
Slope angle	60/360	52/360	53/360	52/360	55/360	60/360	60/360
Rock Type	Charnockite	Wethered Charnockite	Charnockite	Charnockite	Charnockite	Wethered Charnockite	Charnockite
UCS (range)	7-50	10-52	17-46	25-56	26-52	14-51	10-48
Number of joints A-type	4	6	3	2	3	12	5
B-type	2	-	-	-	-	3	-
C-type	-	4	6	2	-	-	1
Angle of internal Friction	40	24	40	40	40	24	40
Bulk Density	2.6	2.1	2.6	2.6	2.6	2.4	2.6
Dip of joint intersection	30	27	-	-	-	50	-
Type of probable failure	Wedge/ Plane	Wedge	Stable	Stable	Stable	Wedge	Stable
Factor of safety(dry)	1.45	0.87	>1	>1	>1	1.28	>1
Factor of safety(wet)	0.89	0.45	>1	>1	>1	0.68	>1

VIII. STABILITY ANALYSIS AT SECTOR E

The total length of the sector is 25 m and the cliff height is 8m. Three joints including one vertical joint are observed in the sector. Natural hill slope is 30° towards N, and the cut cliff slope is 85° towards North (Fig. 7). This sector is presently stable.

IX. STABILITY ANALYSIS AT SECTOR F

Length of the sector is 25 m and the height of the cliff is 7m. The hill natural slope is 30° towards N and the cliff slope is 70 ° towards N. The main rock type charnockite and is highly weathered. Fifteen joints including 7 parallel joints are observed in this sector. (Fig.8).The intersection of J12 and J13 falls within a crescent shaped area, and the intersection plunge 50°towards N350. J12 and J13 are also the potential surface identified as wedge failure. The factor of safety of the sector is estimated as 1.28 at dry condition and is reduced to 0.68 when wet. There are 12 joints are A category and 3 joints are B category. Whereas J3 to J9 are parallel joints.

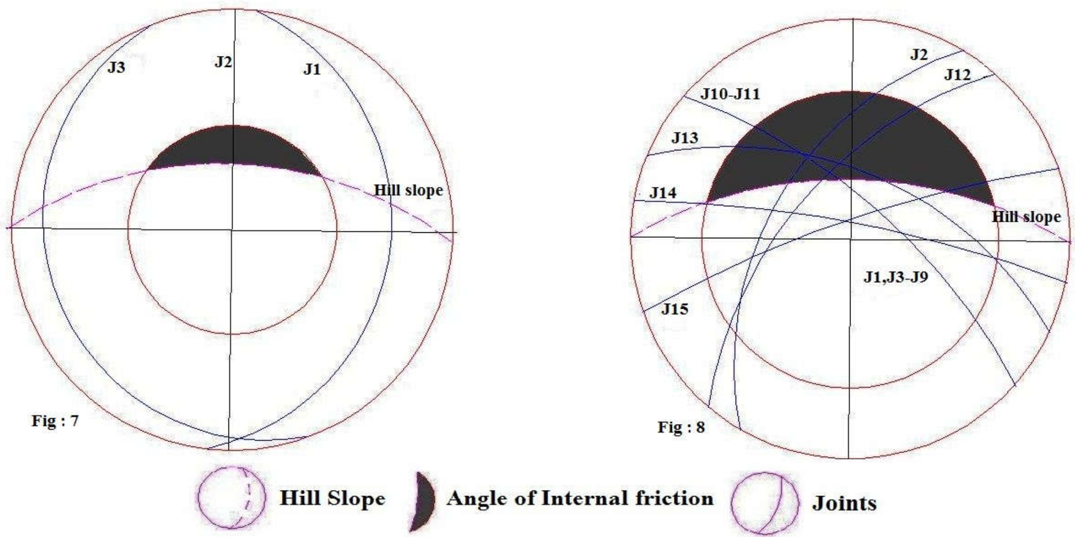

Fig.7 and 8: β Diagram for Sectors E and F. Broken arcs are the traces of Slopes, the Inner Circle are the Angle of Internal Friction for the Materials, Crescent shaped shaded areas represent the Limit for Wedge failure caused by intersection of joint planed

X. STABILITY ANALYSIS AT SECTOR G

Length of the sector is 25 m. and the height of the cliff is 7 m. the cliff slope **is** 30˚ towards N. and the cliff slope is 70˚ towards N. The charnockite is highly weathered. A pegmatite vein is seen in this sector. Width of the pegmatite vein is around 30 cm. six joints were observed in the area. All the joints are dipping away from the cliff slope (Fig.9). This sector is highly stable.

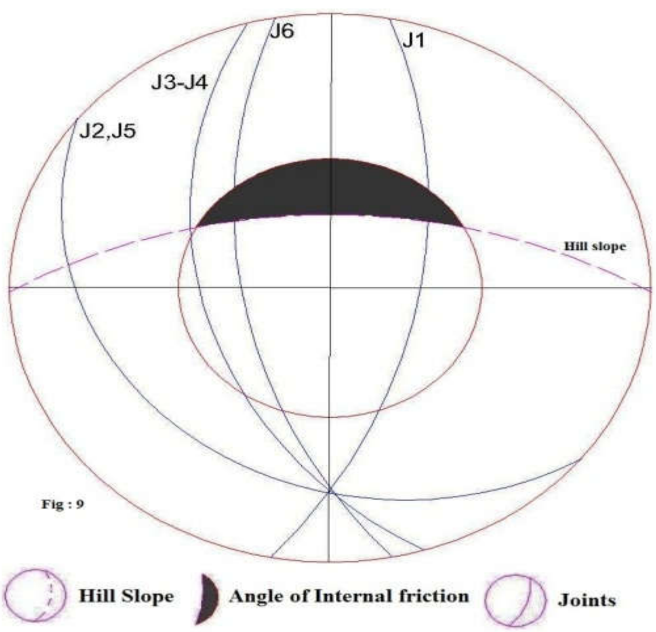

Fig.9: β Diagram for Sector G. Broken arcs are the traces of Slopes, the Inner Circle are the Angle of Internal Friction for the Materials, Crescent shaped shaded areas represent the Limit for Wedge failure caused by intersection of joint planed.

XI. CONCLUSION

On the basis of the geometric analyses it is concluded that the profiles, in general area prone to wedge failure. The problem is severe in sectors A, B and F. Probability of the occurrence of overhanging plane failure is identified at sector A. Factor of safety for each sector is calculated during dry and wet condition. Sectors A, B and F are at the geotechnical threshold whereas all the other sectors have factor of safety greater than one. However, the material forming the slope remains in place even during dry season. It is obvious that determining the factor of safety is not valid in some situations. Many gaping joints have mineral infillings. Occasionally plant roots bolt the potential free body blocks. Deforestation can weaken the root bolts and cause sudden slides in some sectors. The study point towards pressing requirements of stability management practices in these sectors. It is understood that rock discontinuities play crucial and critical role on the slope failure in road cut cliffs.

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