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Kinematic Analysis of Slopes along National Highway-5

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Abstract

The slope failure in the Himalayan terrain are common specifically along the roads where modified slopes are found to be more vulnerable. Those slope can be better studied using kinematic analysis to identify the problematic slopes. Seven slopes along NH-5 have been selected for the present study. Stability and mode of failure was determined using stereo-plots and factor of safety which resulted in planar, wedge and planar-wedge failure conditions.

Introduction

Mountainous terrain in the Himalaya faces a number of slope failures in the Satluj river valley along national highway-5 (NH-5). Nature of reoccurrence of such events makes slopes more vulnerable to landslide hazard and the frequency of which increased in almost every monsoon. NH-5 is the lifeline of the people living in the region and the highway is of strategic importance as it connects border areas of India bordered with Tibet, which gets blocked and damaged due to such failures. The poorly investigated slopes while constructing roads/highways and also other engineering structures like dams, tunnels etc., leads to failure of slopes. Rocks in the part of NW Himalaya are fractured, faulted and jointed.

As discontinuity, a controlling factor in the kinematics of slopes and by applying Markland's test (Markland, 1972) by using stereographic projection of discontinuities, slopes and friction circle, mode of rock failure can be defined, thus it was thought to apply the same in case of seven selected rock slopes out of 154 landslides investigated.

Geological setup of the Study Area

The area under present investigation forms a part of NW Himalaya along the NH-22 in the Satluj river valley from Rampur (130 Km from Shimla towards Kaurik) to Powari (92 Km from Rampur towards Kaurik) area in Himachal Pradesh. Study area is traversed by major thrusts and fault like Munsiari Thrust (MT)/MCT-I, Karcham Thrust (KT), Vaikrita Thrust (VT)/MCT-II, Raura Gad Fault (RGF) (Kumar et. al. 2017). The geology of the area is comprising of metamorphic rocks of Rampur Group, Jeori-Wangtu Gneissic Complex, Karcham Group and Vaikrita Group. Rock mass investigated is highly jointed and thus more vulnerable for slope failures.

Methodology

Study is focused on defining the mode of failure of selected slope and is carried by the following steps:

1. Joints and slope data collection during field survey.
2. Projection of joints data (includes dip amount and dip direction) and slope (inclination of slope face and direction of inclination).
3. Plotting friction circle by taking the maximum possible value for the rocks present on site (Hoek and Bray 1981).
4. By Markland's test the modes of failures were identified.

Markland's test

According to Markland (Hoek and bray 1981), if dip of plane of discontinuity is less than the inclination of slope and greater than angle of internal friction and dip direction of discontinuity is in the direction or in +20^{o} or -20^{o} with the slope then the mode of failure will be recognised as Planar failure (eq. 1). While failure will be called as wedge failure if plunge of intersection of joints will be less than slope angle and steeper than friction angle followed by the condition that plunging direction should be in the direction of slope or ranges between +20^{o} or -20^{o} (eq. 2). The slopes in which qualify both the conditions (eq. 1 and 2) may categorised with both failure as planar-wedge failure (eq. 3).

$S > D_J > \varphi$ .... (1)

$S > P_J > \varphi$ .... (2)

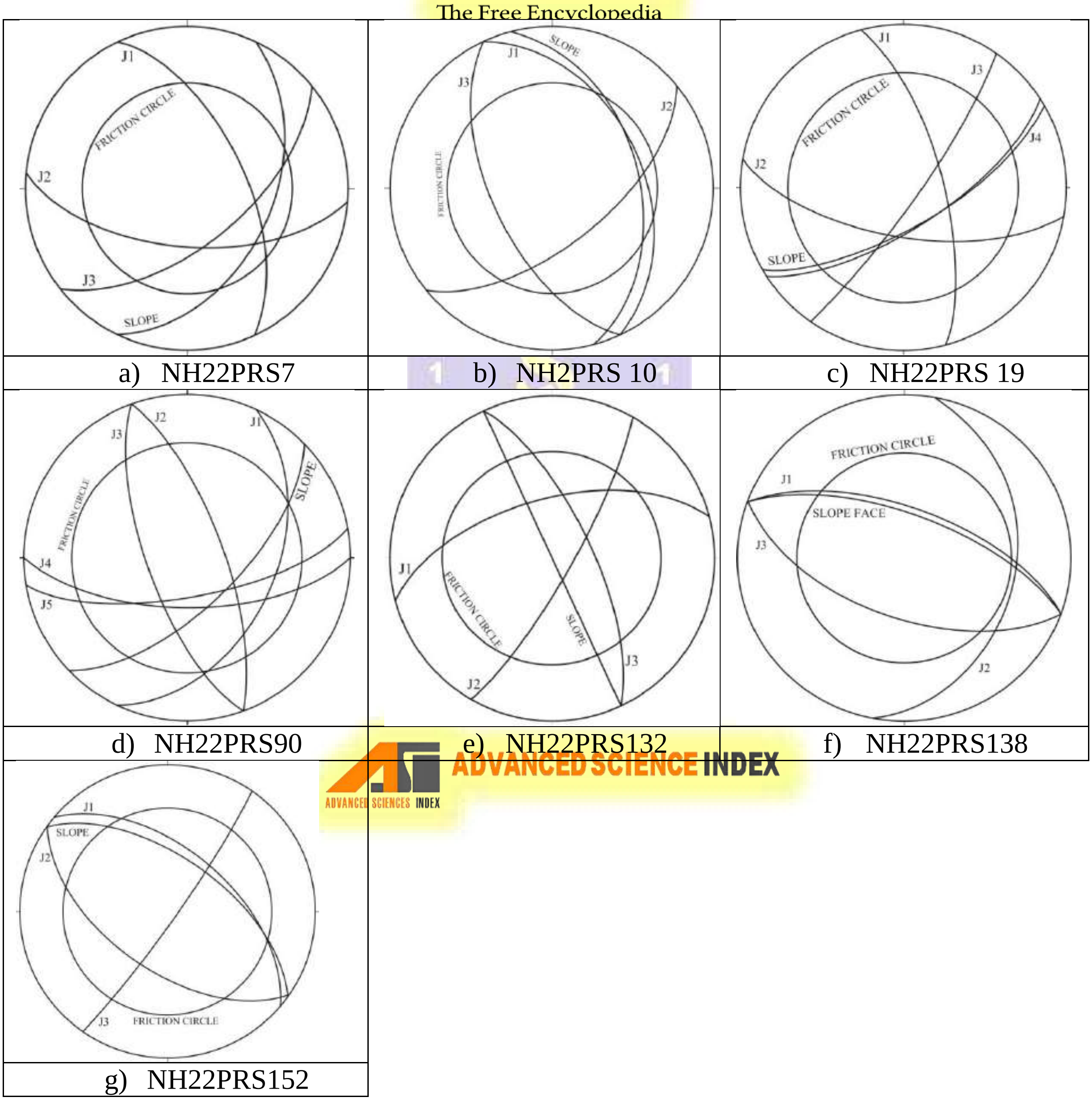
$S > D_J$ and $P_J > \varphi$ .... (3)

Where, S is slope angle, D_J is dip of joint plane, P_J is plunge of intersection of joints and φ is angle of internal friction or friction angle.

Since toppling failure was not noticed in the investigated slopes hence case is not explained for it.

Results and Discussion

Primary collected data during field surveys from seven locations was analysed to define mode of rock slope failure using stereographic projections. Slope angle vary from 45 to 90 (very steep slope) which itself makes slope critical in view of failure conditions. By plotting discontinuities, slope and friction circle data for individual slopes, mode of failures were suggested/determined. Slopes qualifying eq. 1 are SLOPE-138 and 152, showing planar failure while the slopes daylight as per eq. 2 are SLOPE-7, 10 and 90, representing wedge failure. SLOPE-19 and 132 showing results as per eq. 3 therefore, planar-wedge will be the mode of failure. Representation of all the data sets for seven slopes is shown as figure 1 while modes of failure of studied slopes are represented as table 1.



a) NH22PRS7 b) NH2PRS 10 c) NH22PRS 19

d) NH22PRS90 e) NH22PRS132 f) NH22PRS138

g) NH22PRS152

Fig 2. (a-f) Stereographic projections, representing the mode/s of failure for seven different slopes along NH-5 in the study area i.e., SLOPE-7, 10, 19, 90, 132, 138 and 152 respectively.

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Table 1: Slopes are represented with the type failure in terms of wedge and planar rock failures (Since no toppling is noticed in the selected slopes hence not mentioned here).

LOCATIONS			SLOPE INFO		FAILURE TYPE	
SLOPE ID	LATTITUDE	LONGITUDE	SLOPE ANGLE	SLOPE FACE	WEDGE (W)	PLANAR (P)
SLOPE-7	31.55228	78.27853	45	S65°E	W	
SLOPE-10	31.54433	78.27852	45	N75°E	W	
SLOPE-19	31.51933	78.27186	70	S35°E	W	P
SLOPE-90	31.51796	78.12956	65	DUE E	W	
SLOPE-132	31.55136	78.00102	90	N65°E	W	P
SLOPE-138	31.56383	77.96967	68	N20°E		P
SLOPE-152	31.45479	77.69043	60	N35°E		P

Conclusion

Analysis using stereographic projection is a great, easy and quick technique to classify the modes of failures in the rock slopes. The investigated seven slopes discussed above are representing three modes of failures as planar (two slopes), wedge (three slopes) and planar-wedge (two slopes). This classification as mode of failure is significant while slope stability analyses are to be done. In roads/highways constructions or excavation for such projects to be done prior to such activities the analysis must be done so that we are able to identify the mode of failure of the current slope and can suggest the proper remedial measures or supporting system. Further, such studies make us aware that cut slopes made after or during excavation, may also qualify such equations which leads to failures.

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