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Innovative Solution for Widening of Existing Highway in a Drawdown L and slide area at Hunthar Veng, Aizawal, India

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ABSTRACT – Anthropogenic activities and natural factors have created catastrophic condition in the seismically active young Himalayan foothills. Continuous build-up of pore pressure in the slope creates decrease in intermolecular shear strength due to lubrication between these particles and rock joints. In addition, toe erosion in the valley side due to Perennial River is common in India, most of these in monsoons create destruction to the adjoining watershed areas. Similar case of the road collapse due to toe erosion in valley side generated from devastating stream and rotational failure above the road has been envisaged. Hunthar Veng area where the landslide event has been took place and the land instability problem adding on continuously due to various factors such as rainfall, earthquake, and toe erosion. Stability measures has been considered and analysed based on the severity of the problem. Structural adequacy of load bearing components has been analysed and consequently its effect and interaction with natural slope profile has been modelled using finite element technique. Innovative solution for highly unstable slope has been derived using 8 m deck slab using two rows of pile consideringthe continuous toe erosion.

Keywords: Perennial river, toe erosion, rotational failure, eroded slope, deck slab, pile

I. INTRODUCTION

Mizoram faces many disastrous catastrophic landslide and eroded slope event every year. Many of these are rain water triggered event and recurred every monsoon. The slope area lies between north and south flowing streams. Main road of about 50m is completely destroyed which caused major problems including transportation of goods, daily lives of the peoplesincluding school going children. Annual rainfall of this area is about 235 cm out of which 70 percent occurs in the month ofMay to August.

The landslide event occurred past since 1990, in which the area is traversed by NH 54. The highway itself has its importance for majority of state population. The erosion of slope continue to active during increase of destabilizing pore pressure between soil particles. This catastrophic event had resulted in to dismantle of around 50 houses in the locality.

Hunthar veng area is seismically active, where earthquake with intensity of IX on Mercalli intensity scale can occur and lies in Zone- V as per seismic zonation map of India. Accordingly, Seismic acceleration coefficients (horizontal and vertical earthquake acceleration coefficients) has been considered for the FEM analysis as per described Seismic Coefficient(Zone-V) with Importance-1.

II. GEOTECHNICAL DESCRIPTION OF PROJECT AREA

The problematic land subsidance area is located on the North Western part of the Aizwal city, In Hunthar Locality. Area falls under 84A/NE and at the intersection of lat. 23° 46’ and long. 92° 44’ and 1188m above MSL. The geology of area comprise of flysch facies rocks having monotonous sequences of shale and sandstone dipping towards NS folds belong to Bhuban formation (of Miocene age) of Surma group. Lithology of rock and soil matrix comprise of loose, friable unconsolidated pebbles of sand stone and fragment of shale in sandy matrix. A few bands of argillaceous sandstones are also present within the siltstone near the upper slope levels. The siltstones are generally grey in colour, massive, hard and well bedded. The shale bands/beds are thinly laminated and splintery in nature. The strike of the rocks is N10°W with dips varyingin the range from 15° to 40° towards east and 25° to 65° towards west.

Field investigations revealed that rocks are overlaid by about 1m to 5m slope wash material. Deep gullies are located at the site dissecting the hill slope at various locations and meeting at a common stream at the lower level in the valley side of slope. Rotational movement is observed above the road site, which is causing trouble to the stability of road in terms of roadstability and movement.

Fig. 1: (a) Distant view of Hunthar Venj landslide (b) Closure view of Hunthar Venj landslide (c) Main scarp of slide (d) Distant viewof landslide with toe erosion due to two flowing streams at the bottom meeting a common stream.

2.1. Geotechnical Parameters

Geotechnical investigation shows that the study area comprise of overburden of loose and unconsolidated silty clayey soil mixed with rock fragments of siltstone and shale below this layer the underlying rock is highly weathered shale and interbedded siltstone-shale. Bed rock has three joints dipping N 210°/ 45° creating vulnerable ad unfavourablecondition to overlying mass.

Fig. 2: Road collapsed due to continuous erosion at valley sideTable 1: Summary of geotechnical material.

Layers	Unit Weight (kN/m^3)	GSI	Cohesion (kPa)	Friction angle (ϕ)	Young's Modulus (Mpa)
Unconsolidated silty clay soil mixed with rock fragments of siltstone and shale	20	-	20	11	25
Highly weathered shale and interbedded siltstone-shale bed rock	22	25	100	38	500

2.2. Problems Description

Rotational movement is creating the mass movement above the road and it continue to happen in every monsoon season.It shows that pore pressure is destabilizing force. In addition two narrow stream in the form of gullies across the slope is making slope more unstable at the upper portion of slope above the road. These streams meet at a common main stream area below the slope at valley side. During monsoon season, the main stream run to its full level and creates flood condition which ultimately scour the toe of slope end. This leads to
gradual erosion of toe and at every high intensity rain fall, flood period. This gradual erosion may lead to concentration of stresses at road level and may collapse.

2.3. Innovative Protection System

Considering the severity of problem a system of hybrid pile and deck slab has been taken. Trial design analysis for structural integrity and safety of road carrying the Class AA vehicular load has been taken. This load is supposed to carry by system of pile and slab. Trail analysis and their design and serviceability condition have been analysed using SAP 2000 v21.20. The generated output is tabulated below.

Table 2: Design Parameters and Checks.

Case	Slab Depth (m)	Pile Diameter (m)	Design Check	Deflection (m)
I	0.5	0.5 Single pile row	Fail	-
II	0.5	0.8 Single pile row	Pass	1.42
III	0.5	0.8m two pile rows	Pass	0.032
IV	0.5	0.5m two pile rows	Pass	0.034

Design analysis is done considering Fe 415 steel bars as main reinforcement for slab and piles with M30 concrete gradeas per IS code 456:2000. Model outputs are shown below.

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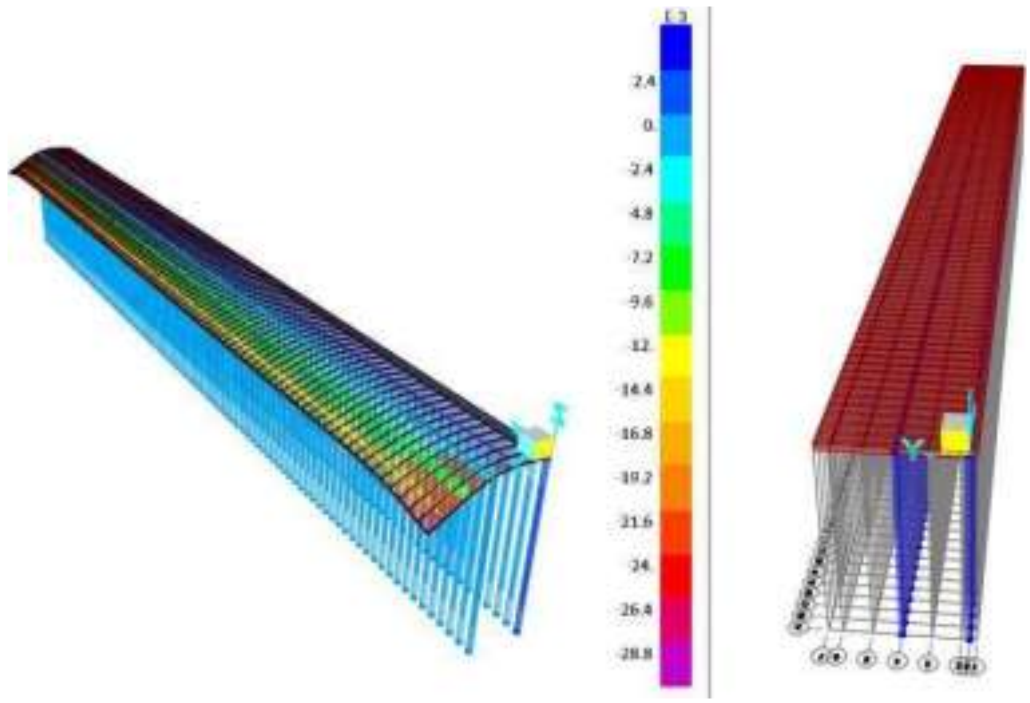

Fig. 3: Figure showing deflection of slab (left side) and model of pile and deck slab under combination of vehicular load (right side).

2.4. FEM Analysis for Soil Structure Interaction

FEM analysis using Phase2 v.8 has been analysed to get critical strength reduction factor. Modelling has been done using multistage to analyse the slope in actual condition. Stages are followed by installation of SDA (self-drilling anchors) of 32mm diameter with 220 Mpa yield strength, which are fully grouted hollow member; used on the upper slope above the road to protect the movement. Installation of two rows of 500 mm diameter piles with 0.5m thick slab has been done in next stage. Geological Strength Index (GSI) of rock mass structure is taken based on its surface discontinuities and conditions of joints from GSI chart by Hoek and Brown (1997). Based on the extent of weathering, joint condition, roughness and presence of infilling material between the discontinuities, joint apertures; ratings have been assigned to derive GSI value for rock layer (Pandit et al., 2019).

Boundaries conditions have been modelled using roller for vertical side to allow vertical displacement, base is restrained for movement. Six-noded uniform mesh is generated for model as recommended in Rocscience manual (2012).

Rolling vehicular load has been applied to modelled deck slab supported by two rows of piles. Analysis has been done considering pore water pressure (Ru= 0.25), horizontal acceleration Coefficient (α_h) = 0.225 and vertical acceleration coefficient (α_v) =0.15 for this critical earthquake zone of V. Factor of safety in terms of critical shear strength reduction has been concluded which is defined as $SRF_{critical} = C/Cm = \tan \phi / \tan \phi_m$ where, C and φ are input shear strength parameters, and C_m and φ_m are mobilized shear strength values (Griffiths et al., 1999)

III. GENERATED OUTPUT FROM FEM ANALYSIS

Following model output results shows the stage wise toe cutting of the slope considering the erosion problem. Figure 4 to 6 shows the trajectories of deformation vectors due to slope under gravity effect, its layer wise toe erosion.

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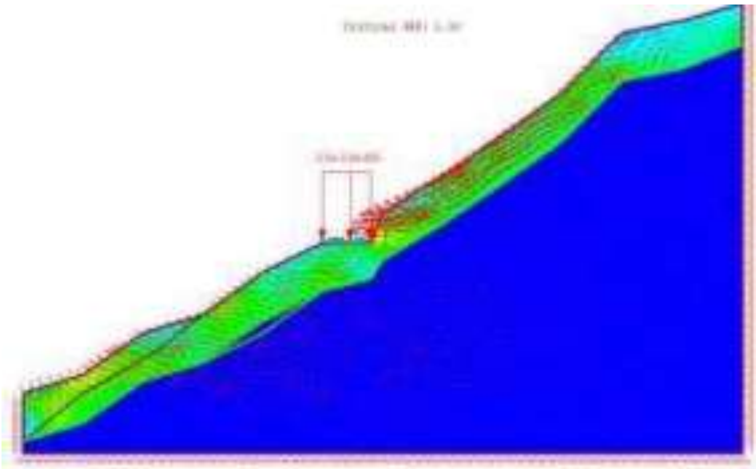

Fig. 4: Figure showing deformation vectors path concentrated greater above the road at its original position.

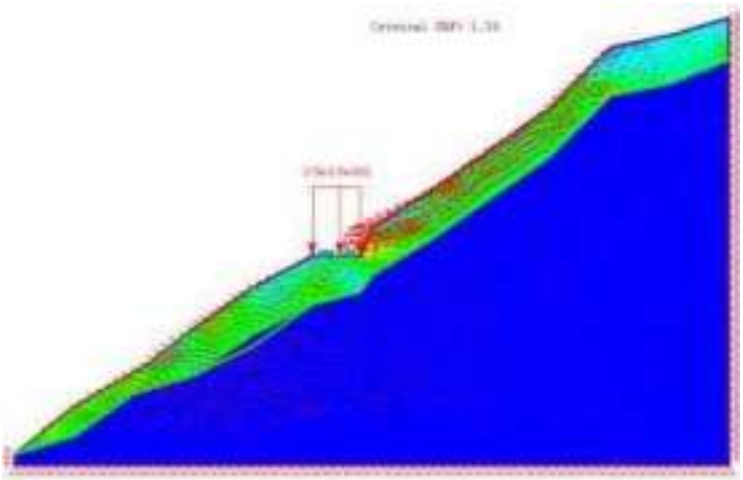

Fig. 5: Figure showing deformation vectors path concentration above and below road due to erosion at level below road.

Continuous removal of slope wash material below the road level led to decrease in strength reduction factor, which ultimately left the road in unsafe position. To encounter this problem, there need to protect the zone above the road level. Active reinforcement member used to restrict the upslope movement. SDA (self drilling anchor) of 12m length at 3m x 3mspacing used for this purpose.

Deck slab modelled integrated with two rows of pile of 15 m length spaced at 1m out of plane in both rows and secondseries spaced at 4m form first series of piles as concluded from SAP analysis.

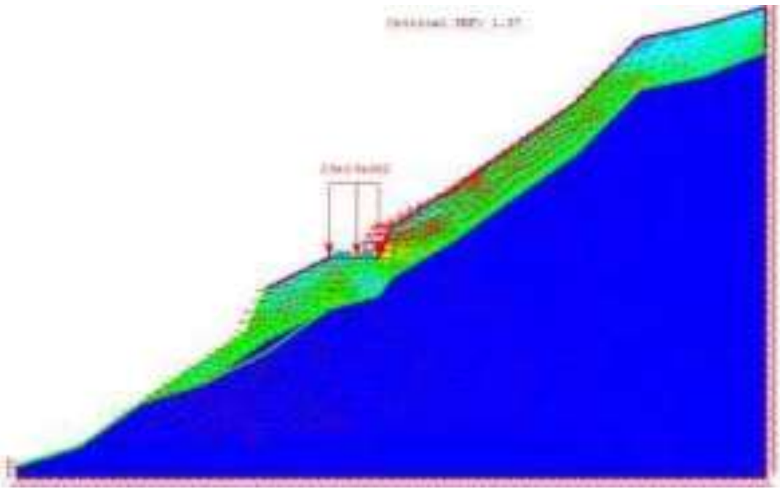

Fig. 6: Figure showing deformation vectors path concentration after slope wash material partially left.

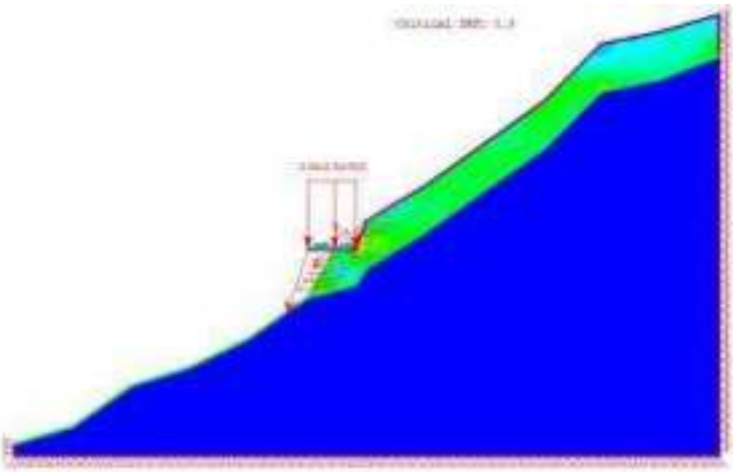

Fig. 7: Figure showing deformation vectors path concentration after complete removal of slope wash material.

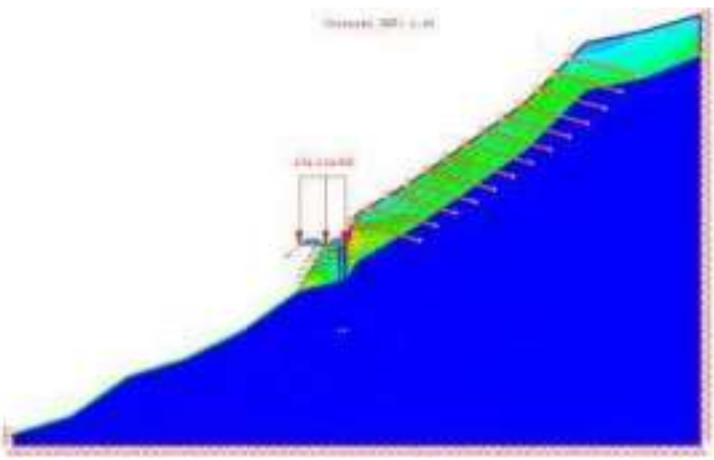

Fig. 8: Figure showing control of deformation vectors path concentration after using hybrid protection system below and above road.

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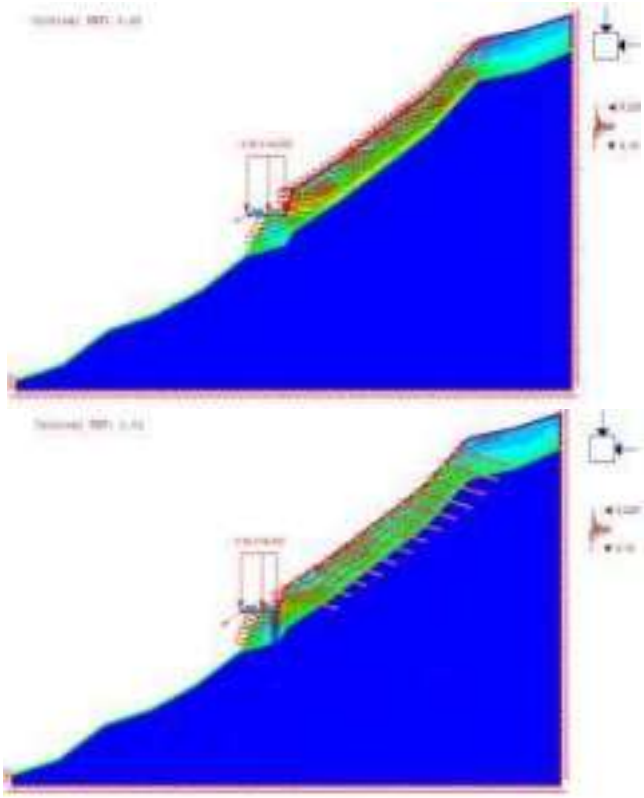

Fig. 9: Figure showing safety factor results before and after protection system at seismic condition

IV. CONCLUSION

Presented case study represented the approach of modelling using structure analysis interface to check the adequacy of the integrated deck slab pile system and finite element modelling to analyse the stability of the slope. Significant improvement has been observed after removal of slope wash material below the roadway after using system of deck slab piling system. Around 88% improvement has been observed at static condition and 67% at seismic condition after using discussed protection systems.

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