LANDSLIDE INVESTIGATION AT KM 221, NH-39 – A CASE STUDY

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ABSTRACT: The NH-39 in the stretch between km 162.00 in Nagaland and km 236.1 in Manipur experiences frequent landslides at different locations which cause disruption to the traffic and damages to the road infrastructures and agricultural land. One of the severely affected locations on NH – 39 at km 221 in the Manipur state, experienced unprecedented subsidence and landslide phenomenon in 2008. This failure has been classified as a compound landslide. Multi-directional tension cracks are observed all over the landslide area. The soil has high clay content as verified by shrinking and swelling observed in the field. About 7m high gabion wall constructed earlier have sunk and distorted. Another old gabion retaining wall down below, has also been broken and moved. Slope stability Analysis was carried out by GEO 4 software. The paper highlights the outcome of the study along with design of suitable remedial measures for its prevention based on the field and laboratory investigations.

INTRODUCTION

The National Highway 39 is the life line of Nagaland and Manipur state and also important from the point of view of its strategic location. The hills along NH-39 are very fragile and experience landslides and subsidence which have been active since inception of this road. Due to sinking and sliding of road along NH-39, particularly during monsoon period, traffic movement gets disrupted for months together. The hills of the Nagaland, like of other states of Northeastern region are made up of one of the youngest and geologically folded immature formations. These hills are geodynamically active like Himalayan ranges and climatically varied with the combination of low and high hills, deep gorges, steep slopes, vertical escarpments and devastating rivers.

The Landslide located at km 221 on National Highway 39 is shown in fig 1. The slide has damaged a two pipe (with one meter diameter pipes) culvert which had been constructed to carry the seepage water from uphill side to downhill side. About six steps of gabion (gabion) wall constructed at this site have sunk and distorted. Each step of the gabion wall is about 1 to 1.1 m in width and its height is about 0.5 m. Another old gabion wall down below, has also been broken and moved. A deep depression in the form of a bowl of semi spherical shape (diameter about 9.5 m) has formed due to sliding down of the slope material in spite of the gabion wall. Due to formation of this depression, the road width has narrowed and this is a bottleneck for traffic movement.

GEOMORPHOLOGY

Above National Highway

This failure area is an example of compound landslide. On the upper left flank of the landslide there are fields that are still being cultivated. By observing the rest of part, it appears that cultivation was being done in recent past but has been stopped due to sprawling of the land. Surrounding area is immensely cultivated. Just above the National highway is a plain that may be referred to as vestige of the earlier cultivated field. The slope inside the landslide boundary is gentle that causes water to stay for longer duration thereby propping up the infiltration. Tension cracks are observed all over the landslide area and they show multi-directional orientations.

Outcrops of the rock are scanty, yet they have preserved the geometric conformation that is a pre-requisite for the geological and structural analysis. In the uphill side, rock exposure is seen on both RHS as well as LHS flanks adjoining the road alignment (Fig 2).
The central portion of this vertical cut adjoining the road has clayey soil which is saturated. The rice field has extensive cracks and is depressed towards the uphill and raised near the road. Thus the entire slope which has failed comprise of many steps which are depressed towards the uphill and are elevated towards the toe. Two Nallahs are seen flanking the rice field (Fig 3(a) and (b)). These Nallahs carry seepage and run-off water. However, the pipe culvert which had been constructed to carry the water from the Nallahs has been damaged and is presently choked. Hence the seepage water is presently percolating into the ground and surfacing again in the slope below the road.

Beyond the rice field, thickly vegetated area having about 1 m high grass and 3 to 4 m high trees. A semi-circular scraps of about 3 to 6 m radius, flanking the landslide beyond this wooded area. This scrap is not vertical but is at an angle of about 60° to 70°. The scrap material consists of weathered, splintered, powdered shale. Below this scrap, slumps of slided material are lying. It comprises of shale which has turned into clay and is covered by thick vegetation but devoid of large trees. This is an old landslide covering a large area. Hence beyond the scrap, a flat terrace and beyond which another older scrap exists.

Below National Highway

Below National Highway, culvert has been constructed to channelize the water below the National Highway. The part below National Highway is entirely cultivated with patches of shrubs and trees at places. The fields below national highway are cultivated and water stay in this part is for a longer time so as to get infiltrated (Slope Map). As shown in fig. 4 the area is settled at varying degree at different places. The soil has high clay content that is verified by shrinking and swelling observed in the soil. On lateral sides, the area is bound by tree habit vegetation and cultivated fields.

Exactly below the National Highway, gabion walls have been constructed for the support. But due to overlying pressure, weak bearing capacity of the soil and their own weight, gabion walls have been collapsed and deformed. As a matter of fact, Kilometer-221 slope failure is a special case of complex landslide wherein more than one mode of failure is involved. The scarp moves downwards as is deciphered from the orientation of the tension cracks on scarp and slope.

Below National Highway is developing a new landslide scarp whose movement direction is almost normal to the movement direction of the above mentioned scarp. Huge tension cracks oriented in different directions indicate multiplicity and variety of the landslide movement. Downwards movement, however, is predominant despite of the above mentioned fact. This may be attributable to the increased load from above. Cultivation and water logging in the area has a significant and relentless contribution to the infiltration process. This case represents an example where mass movement processes (of different kind) combine and primary failure mode changes into other type as it moves.
Wet clayey type of soil is presenting in a major portion of this slide. This land area is fertile, saturated and rice cultivation is practiced. The toe of the slide comprises of wet clayey type of soil and thick vegetation 2 to 3 m high trees are seen but tall, fully grown trees are absent. This may perhaps be attributed to water logging in the area and pruning of vegetation by man.

The hill slope above the toe comprising of the body of the landslide is a cultivated land (rice fields). The rice fields show multi directional extensive cracks. There is a small stream of seepage water flowing down stream at the centre of the rice field. Ponding of the seepage water is also noticed at many locations. There is a ridge (scrap) on the RHS flank of the slide. There is another wooded area having shrubs/ plants of 2 to 3 m height in between the rice fields. This area which has been left uncultivated, has wet and soggy soil and there are many small ponds in this area. Moving further up towards the road, rice fields are seen again.

While the vegetated areas in the downhill slope have a slope of about 20° to 30° (Fig 4), the rice fields have been created by terracing the slope. The terraces of rice fields nearer to the road are not exactly horizontal but have a dipping of the corner nearer to the road and the edge towards the toe of the slide is slightly elevated. The soil in this entire area is clayey. Joom cultivation is practiced in the surrounding areas and burning of grass and shrubs in the adjoining areas was seen at the time of site investigations.

GEOTECHNICAL PROPERTIES OF SOIL

From the road the soil samples are collected from the landslide area on uphill slope (agricultural field with huge cracks) and downhill slope (agricultural field) toe of the slide. The grain size distribution curves of soil samples are shown in fig. 5. The liquid limit of the soil is varies from 41% to 47% and PI is 18%. As per IS classification the soil is classified as CI (inorganic clays of medium Plasticity). The shear strength parameters c’ and \( \tan \phi’ \) Values are 10 KPa and 18° respectively.

STABILITY ANALYSIS

The cross sections were chosen for the stability analysis as shown in fig.6. The stability analysis of the slope was carried out by GEO 5 software. The FOS of slope varies from 0.72(Saturated condition) to 1.25(Dry condition) at different locations under different drainage conditions. The stability analysis clearly shows that the slope is stable in dry condition, but it is failing even when the slope is partially saturated. Both uphill slope and downhill slope, huge cracks were observed in agricultural fields. The seepage points were also observed on the downhill slope.

REMEDIAL MEASURES

The gabion walls are constructed to stabilise the slope. But the existing gabion walls are slides due low bearing capacity of soil as shown in fig 7. Design of existing gabion wall and stability analysis (fig 8) and the proposed gabion wall (fig 9) was analysed by GEO 5 software and the results are as below.

Verification of the entire wall:
Check for overturning stability:
Resisting moment \( M_{res} = 0.9 \times 536.93 = 483.24 \) kNm/m
Overturning moment \( M_{ovr} = 380.10 \) kNm/m
Wall for overturning is ACCEPTABLE

Check for slip:
Resisting lateral force \( H_{res} = 0.9 \times 107.79 = 97.01 \) kN/m
Active lateral force \( H_{act} = 189.62 \) kN/m
Wall for slip is NOT ACCEPTABLE

Bearing capacity of foundation soil check:
Eccentricity of normal force \( e = 88.73 \) cm
Maximum allowable eccentricity \( e,allow = 92.40 \) cm
Eccentricity of the normal force is ACCEPTABLE
Stress at the footing bottom, \( \Sigma = 298.33 \) kPa

Bearing capacity of foundation soil, \( \text{Rd} = 100.00 \) kPa

Bearing capacity of foundation soil is NOT ACCEPTABLE

Overall check - ABUTMENT is NOT ACCEPTABLE

Verification of the proposed gabion wall:

Check for overturning stability:

- Resisting moment, \( \text{Mres} = 0.9 \times 776.82 = 699.14 \) kNm/m
- Overturning moment, \( \text{Movr} = 140.10 \) kNm/m
- Wall for overturning is ACCEPTABLE

Check for slip:

- Resisting lateral force, \( \text{Hres} = 0.9 \times 137.55 = 123.80 \) kN/m
- Active lateral force, \( \text{Hact} = 69.62 \) kN/m

Wall for slip is ACCEPTABLE

Bearing capacity of foundation soil check:

- Eccentricity of normal force, \( e = 0.00 \) cm
- Maximum allowable eccentricity, \( e,\text{allow} = 115.50 \) cm
- Eccentricity of the normal force is ACCEPTABLE

Stress at the footing bottom, \( \Sigma = 97.91 \) kPa

Bearing capacity of foundation soil, \( \text{Rd} = 100.00 \) kPa

Bearing capacity of foundation soil is ACCEPTABLE

Overall check - ABUTMENT is ACCEPTABLE

CONCLUSIONS

Seepage points were observed at the toe of the tilted gabion wall. The downhill slope is composed of multiple slides with seepage points and water ponding for agricultural purposes. Due to low bearing capacity in this area the gabion wall height should not be more than 4m. The gabions should be constructed with proper berms or by inclusion of reinforcement in the soil. The stability of the gabion wall was improved by inclusion of 3 layers of Geogrids or same gabion mesh extended into the soil for a length of 4m to 5m. Catch water drains suggested for improving the existing drainage system.

REFERENCES

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