Engineering Geological Investigation for Sudden Subsidence and Outward Migration of Excavated Slope Accompanied by Muck Flow and Subsurface Seepage at North-east Frontier Railway's Broad Gauge Excavation near Rekho Village, Dima Hasao District, Assam

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Abstract

Subsidence and outward migration of slope from crown to toe, covering up the already excavated portion of the Railway track bench which was short of achieving its target hardly by 12 m near Rekho village of Harangajao Railway Station in the midnight of May, 23, 2011 during heavy rain for three consecutive days. The affected slope length: 500 m; the base width: 280 m and the height of crown: 323 m. Slope condition was observed to be moderately gentle except the areas of slump cracks and movement of slumped debris. The total affected area is around 80,000 sq m with vertical subsidence to the tune of 2-3 m in crown region at an elevation difference of >100m at a distance of >500 m from the toe of the affected zone, ending up well ahead of the left bank of a narrow bouldery stream the "Chota Rekho Nalah" flowing into the mighty Jatinga river at a very acute angle confluence after flowing parallel for a distance beyond >300 m. There are significant evidences of toe erosion at the left bank of the Nalah though it is at a distance from the toe of the slide/subsidence affected slope.

There are three numbers of longitudinal cracks, two on either flank and one along the middle of the affected area and several relief cracks with vertical slump towards the top portion of the affected zone. There are also minor cracks with indication of seepages in different heights with respect to the bench under excavation. While excavating the bench at about 12 m above the target depth, the Railway authorities faced with the problem of sudden slope failure from the crown level of excavation at El.84 m and RD 268.35 m down to the toe at a distance of 138 m from the excavation at a level difference of 30 m above the left bank of the rivulet.

The nature of material was soil mixed with gravel, pebble, sand, silt and clay. The underlying rock was found to be sedimentary rocks of Tipam Sandstone, Surma shales/siltstone and Barail sandstone interlayered with shale; no geodynamic process was readily visible. The loose non cohesive residual overburden soil in this stretch is generally studded with boulders, which allows considerable amount of rain water to percolate inside the subsoil. The subsoil water adversely affects the stability of the hill and cuttings. The problem classified into three main categories: (1) Choking of side drains and header drains by slipped earth (2) Toe erosion by river at the bottom of the slope during flood water rise, (3)Poor rock condition on the hill slope subjected to deep weathering by percolating water. The drainage is one of the major factors contributing to the instability of the section. Within and around the subsidence scars showing cracks and seepage points or seepage paths which have now been concealed under the cover of shotcreting and construction of catch water drains. These are however conspicuously visible where the soil nailed and shotcreted surface has been very strongly disrupted (Photo-1). Conspicuous sag pond (Photo-2) is visible towards north-north-western corner down the slope below catch water drain and above the centre line of the Railway bench, as shown in the map below. The pond water was advised to be pumped out through lined chute drain and constantly monitored for the rate of accumulation.

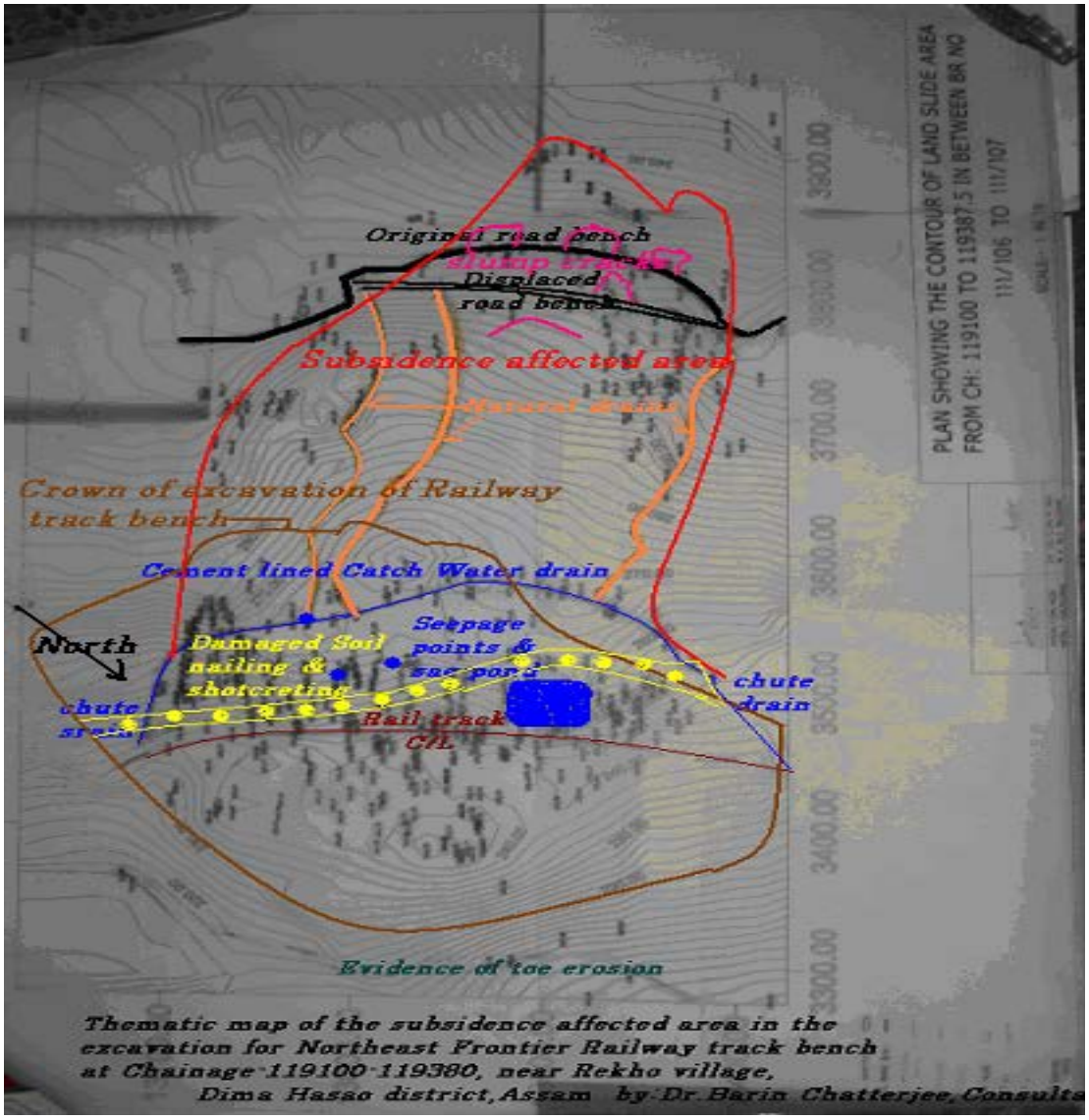


Figure 1

The present observation has been projected as it is in the thematic map (Figure-1) which indicates that this is a two-tier slide/subsidence affected zone. The North-eastward elongated creep-affected zone has been superimposed by the sudden north-ward subsidence affected zone. While the former is the result of seepage water along the contact between the bouldery sandstone underlain by carbonaceous shale, the latter or the most recent abrupt subsidence has been caused by steepening of angle of slope excavation and obstruction to seepage by providing soil nailing and shotcreting. In Figure-2, it has been observed that the steepening of back slope from 30° to 45° between RD 268.35 m and 262.436 m for reaching the depth below 12 m at the center-line of the finished grade of the bench has resulted the sudden failure of the slope which was collectively

effected by continuous heavy rainfall and development of tremendous pore pressure behind the just shotcreted and soil nailed surface cover.

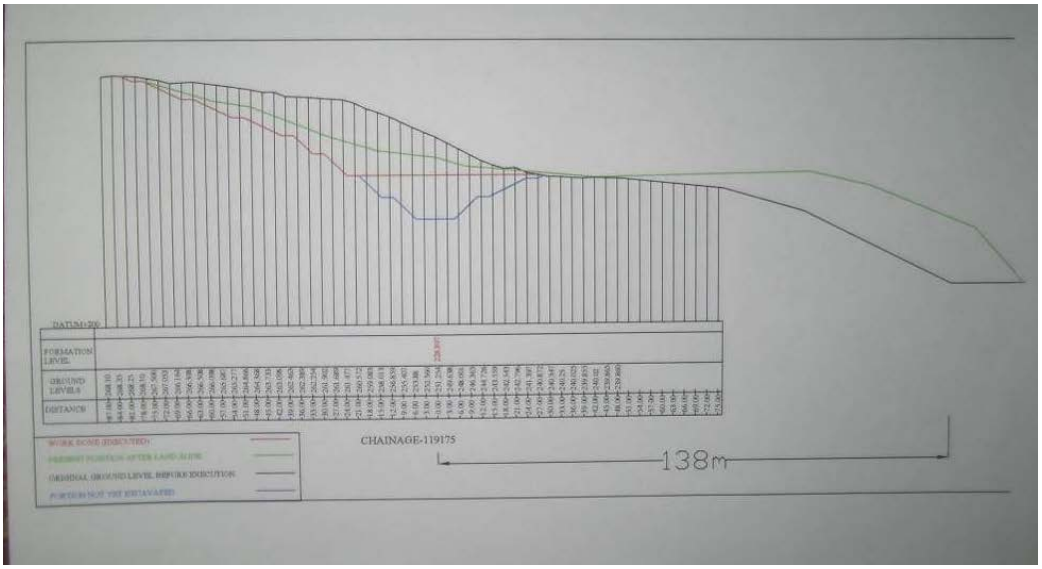
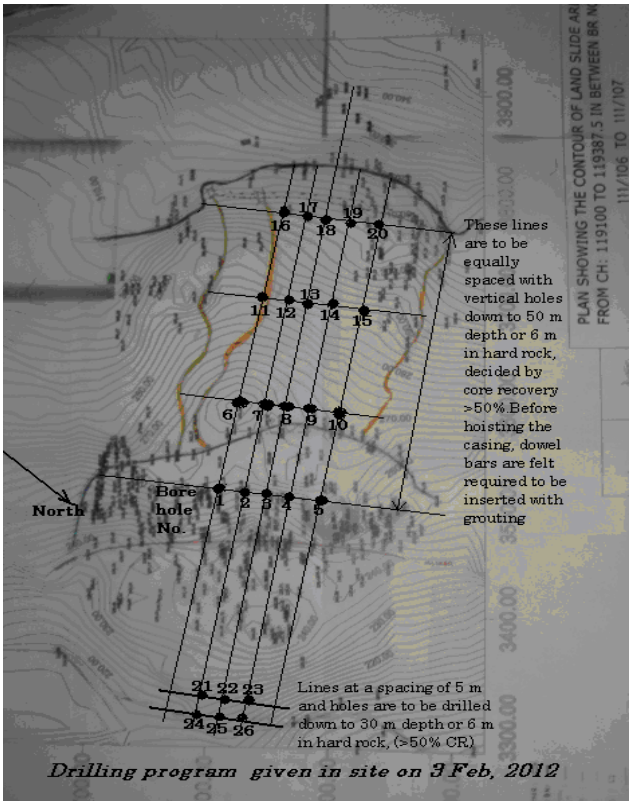


Fig-2

At present, though it is a simple case of seepage and slump affected slope, unless urgent protective measures are taken, it is likely to develop into a deep seated failure of a Rotational or wedge type. Toe-erosion, followed by excavation of bench, changing to steeper slope of cut (Figure-2) in a rainy season, having very high precipitation for three consecutive days causing super saturation in the slope as a whole and concentrated in the middle between the two gullies, particularly under the shotcreted-covered surface. This in turn caused tremendous pore pressure to develop behind the shotcreted surface between the two gullies flowing along the either side. Geological discontinuities like Joints / fractures / bedding/ foliation/ Fault have all contributed to the cause.

It has been suggested that the subsurface water has to be tapped and released through completely lined chute drain cascading down with super-elevation at every step and garland (contour) drain with adequate carrying capacity, designed on the basis of intensity of rainfall in the area. The subsurface water pressure needs be released by providing trenches with gradient leading towards the side vertical cement lined chute drains along existing depressions on either side of the disturbed slope. At least two numbers of trenches have to be made each 2-3m wide and 4-6m deep as indicated on ground, lined with geotextile to the hillside and geomembrane to the valley side as well as the base of the trench in order to prevent escape of the collected water from the bottom. "Geocell/ Geoweb" buckets (Geosynthetic material made of geopolymer to be filled by assorted spherical cobbles and pebbles and lowered into the trench in rows and columns, reaching down to less than 1 m from top level. The water within the trench has to be discharged to the chute drain by providing sufficient gradient in the invert of the trench. The purpose of the geotextile will be to allow subsurface water to enter into the trench while retaining the soil material behind. The purpose of the geomembrane will be to retain the accumulated subsurface water within the interstices of the hand-packed cobbles and pebbles and leading it to the side chute drains on either side. The trench should be covered at top 0.5 m by soil and subjected to vegetation turfing. In between the rows of trenches, properly designed cement lined storm water contour/ garland drains also have to be provided leading to the side chute drains, for taking care of the storm rainwater. Installation of cement lined hillside drains is also essential at the junction of every berm and back of the excavated slope on the uphill side.



In addition to the removal of the subsurface water, a massive buttress wall has to be erected as a restraining structure at the bottom of the already activated slope near the lines of bore holes 20-26 (Figure-3). For total uplift of the face of the present problem it is suggested to accurately detect subsurface water in rock formations, which is of course now difficult, because the problematic area is covered by dumped material. The subsurface drilling is expected to provide sufficient data, which may necessitate additional measures.

The entire slope area should be provided with vegetation turfing towards up-slope region of the restored shotcreted surface. It may also be explored whether perforatory filter pipes in the form of herringbone drains can be provided within the restored shotcreted surface. Bitumen top roads with hillside cement-lined drains leading to the Chute drains have to be provided. The domestic sewerage water (if any) as well as the water pipe lines should not be allowed to enter the subsurface by leakage.

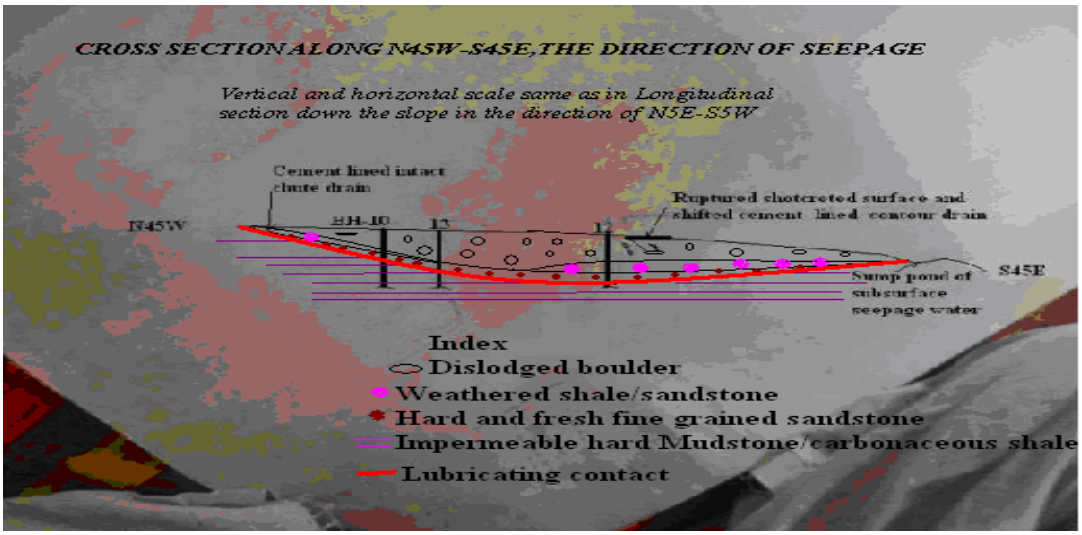


Figure 3: Geological profile of the subsurface in the direction of N45W-S45E

The ultimate objective is to keep the slope-surface as well its subsurface, as dry as possible. While the bottom of the railway track bench, the slope can be loaded to the maximum by sausage walls supported on the proposed buttress wall at the toe region (Figure-3), the upper part of the slope should be left without any additional loading by any construction like sausage wall etc.