NOTE ON POST-DISASTER PRELIMINARY GEOLOGICAL STUDIES OF THE KOTLEN LANDSLIDE ALONG NH-37 (IMPHAL-JIRIBAM ROAD), 5 Km SSW OF KOTLEN, NONEY DISTRICT, MANIPUR

By:
Visahono Zaphu, Sr. Geologist
Project Landslide, GSI-NER, Dimapur
&
Lorhienu Tase, Assistant Geologist
Project Landslide, GSI-NER, Dimapur
Under the Supervision of:
S. P. Dhanvijay
Director,
Project Landslide, GSI-NER, Dimapur

Abstract

Preliminary geological appraisal of a landslide was carried out along NH-37 (Imphal-Jiribam road) situated 5 km SSW of Kotlen, Noney district, Manipur. The incident occurred on 12.06.2018 and damaged the road bringing vehicular movement to a halt. A post disaster investigation of the reported site was undertaken with an objective to understand its causative factors, failure mechanism in order to recommend short term remedial measures. The landslide is approximately 95 meters in length and 130 meters in width with run out distance of about 200 metres flowing NW to Kharam Lok stream below the road. Slide area encompasses variably weathered, rocky mass of Disang Formation. Delineated slide mass consists of grey splintery shale, siltstone and sandstone. The landslide has been caused by failure of overburden material due to increased pore water pressure resulting from incessant rainfall and toe erosion by the stream. Hence the landslide has been categorized as "deep planar failure" in terms of the failure mechanism. Based on the stability assessment of the slope forming materials as well as consideration of the elements at risk, short term remedial measure like construction of a lined drainage along the road, quick removal of overburden materials, channelling and diversion of rain water in the crown portion etc., has been suggested to the agency (HVS) managing the highway.

Background Information

Preliminary investigation of the landslide was taken up on priority basis by the team from Geological Survey of India, State Unit: Manipur and Nagaland, Dimapur on 23.06.2018. The massive landslide occurred along NH-37 about 5 kms SSW of Kotlen. The landslide located at Lat: 24° 47′28.7″N and Long: 93^{0} 44′ 8.4″ E is about 39 kms from Imphal. The slide is on the WSW facing slope along NH-37 (Imphal-Jiribam) towards the

SSW of Kotlen, Noney district, Manipur (Photo 1). The affected area falls in SOI Toposheet no. 83 H/09 and the detail of the slide is provided in Annexure-I. At other places along the NH-37, 12 nos. of landslides of medium to small sizes has also been observed and respective latitudes and longitudes are mentioned Annexure-II.

A second order perennial stream flows towards the right flank of the slide. Prior to the slide the area received heavy rainfall for many days. The slide was initiated on 12.06.2018 at around 18:00 hrs causing blockage to the highway. The authority maintaining the highway (HVS) cleared the debris to facilitate vehicular movement. Again the slide got reactivated in the early hours of 22.06.2018 and brought the vehicular movement to a halt on either side of the road. The highway authority (HVS) worked with heavy machinery to clear the debris off the road to ease the vehicular movement. There was no report of casualties except damage to the cable wires. The dimension of landslide is 95 meters in length and 130 meters in width with run out distance of about 200 metres (Photo 2).

Physiography and Drainage

The terrain comprises of highly rugged hill ranges partially capped by sandstone cliffs and intervening deep valleys, which are invariably drained by perennial streams. It is represented by long linear ridges/hill ranges and valleys with its highest and lowest elevation of 1925m and 340m above mean sea level at points ENE of Wapang Jhongjong hill and NNE of Noney (along the Ijai river), respectively. The hills show north-easterly as well as north-westerly trends. The area is drained by the Ijai, the Iring and the Tupul rivers which follow the structurally weak zones. Drainage pattern in the area is dendritic while some of the small tributaries/ rivulets exhibit rectangular drainage pattern which is indicative of joint or fault controlled drainage system.

Site Geology

The geology around the landslide site exposes Disang Formation consisting of bedded grey shales with thin partings of fine grained sandstones. The shale is splintery in nature. Ripple marks were observed in the competent sandstone beds which are also well jointed.

Slide Morphometry and Material

The slide measures 95m length, 130m width, 4m depth, 90m height and a total runoff of 200m. Failure mechanism is deep planar failure. The slide material is mainly transported soil derived from weathered shale of Disang Formation from upslope and the thickness is more than 6m.

Structural data

The trend of the bed in the study area is NNW-SSE ($350^o/47^0 \rightarrow 260^o$). Joints have been recorded in all the rock types of Disang Group. Sandstone beds show four sets of joints. The predominant sets of joints recorded in the area are: i) J_1: $290^o/76^0 \rightarrow 20^o$, ii) J_2: $215/62^0 \rightarrow 125^o$ iii) J_3: $60/78^0 \rightarrow 150^o$ and iv) J_4: $105^o/66^o \rightarrow 15^o$ along which sliding of the unconsolidated weathered materials occurred (Fig:1)

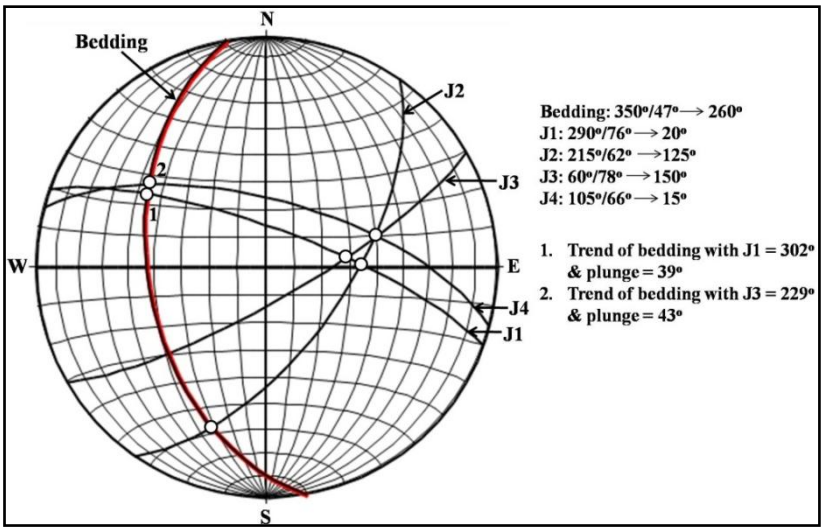

Fig:1. Stereographic representation of the structural data.

Characterization of the slide material

The rock debris material is mainly constituted by the lithic arenite material of Upper Disang Formation. This overall material is grey in colour, soil with minor clay content and rock fragments derived from shale portion of the rock mass. The fresh overburden material was occupying the gap area and resting over the Disang rock.

The material excavated from the uphill side of the road and consisting of alternate sandstone and shale of Disang Formation was dumped on the downslope side of the road.

Failure Mechanism of the Landslide

The failure mechanism of this landslide is categorised as deep planar failure. It is directly related to the type and nature of material, disposition of the beds, road cutting etc. In addition to reduced rock mass strength due to saturation and unfavorable orientation of joints and fractures, the intensity and effect of landslide in the area increased with various geomorphic factors such as steepness and height of slopes, water ingress in rock joints and fractures, saturation of rock material due to heavy rains. Again, anthropogenic factors as a result of developmental activities such as poorly designed roads and encroachment on steep

slopes, further aggravated the process. Due to incessant heavy rainfall high infiltration of water caused increase in pore pressure, volume, saturation and weight and decrease in load bearing capacity and cohesion of the material. As a result, material in the slope collapsed and slided down along the planes.

L-Section of landslide

A section along AB line was prepared on 1:1000 scale (Fig. 2), to delineate shape of the slide and disposition of slided material along the length of the slide. Trend of AB line is 295°-125°.

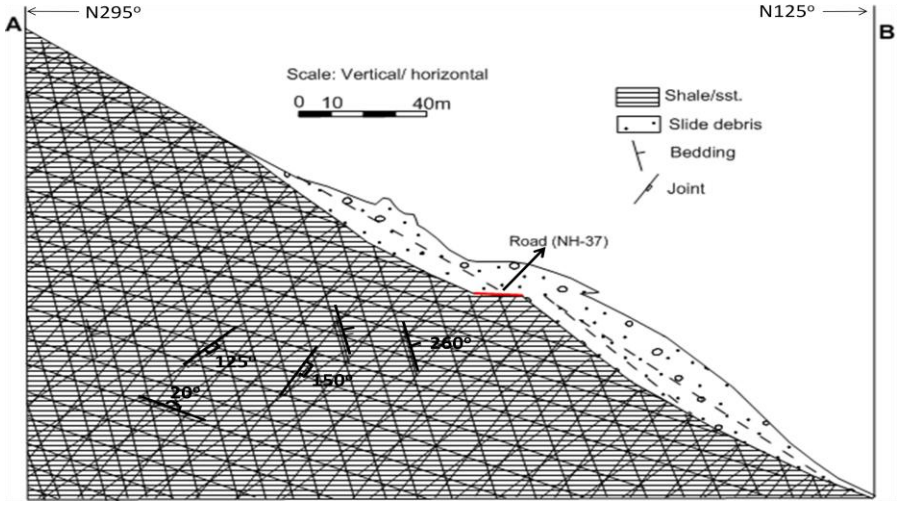

Fig: 2. L-section along AB line.

Causative Factors of the Landslide

Based on the preliminary investigation and analysis of the collected data, it has been interpreted that the landslide had occurred due to a combination of the factors, summarised below:

1. Failure of overburden material due to increased pore water pressure as a result of incessant rainfall.
2. Probable extensive slope cut for communication thereby aggravating the instability of the slope.
3. Inherent poor rock mass i.e. the rocks are profusely jointed and composed of splintery grey shale, thinly bedded sandstone and siltstone.
4. Unguided down slope flow of surface runoff from the road.
5. Toe erosion by the stream at the base of the slope.

Field-based Stability Assessment

1. The landslide has occurred in the mid-slope where the NH-37 is aligned.

2. The slope is moderately dissected and the slope angle is moderate but the slope below the NH is relatively steep >45^{o}.
3. The slope hosts variably thick (2-5m) debris overburden (transported soil) and is sparsely vegetated.
4. The slide is on the WSW facing slope along NH-37 and the attitude of the rock exposure is So-350^{o}/47^{0}→260^{o} which also gives the dip direction of the slope. The overburden slided along the bedding plane and their interface provided a passage for the percolating water which acted as a lubricant along the bedding plane and drastically reduced the shear parameters of the soil material.
5. Lack of a lined drain along the road led to percolation of surface runoff into the weak rockmass.
6. The dimensions of the landslide are 95 m length x 130m width x > 2 m depth with run out distance of about 200 metres flowing to the stream below the road. The height of the landslide is estimated as 90m upto road level and total inclined height (Length of slide) is around 220 m (up to stream).
7. No cracks were observed in the proximity of the crown.
8. Debris were still sliding at the time of investigation and JCB excavators were employed by the authority (HVS) for clearing the debris to let vehicles ply from both sides (Photo 3).
9. Dumping of slided material towards the downslope side of the road have increased the runoff distance.

Recommended remedial measures

1. Removal of the loose overburden debris in the upslope portion (which is already been carried out by the road maintenance agency) Photo 3.
2. Channelling and diversion of rain water in the crown portion away from the slide area by constructing lined contour drains.
3. Lined contour and cross drainage to divert the surface runoff away from the road.

Photographs

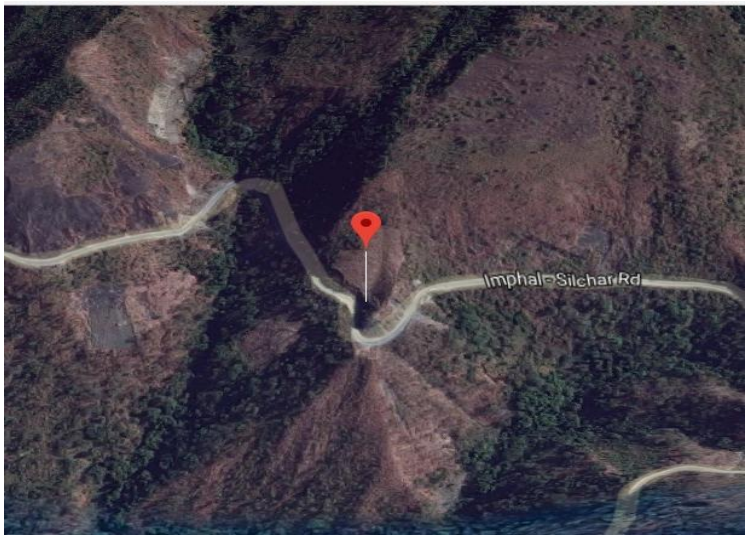

Photo 1: Location of the slide from Google Earth imagery

Photo 2: Perspective view of slide Kotlen landslide.

Photo 3: Slide area showing debris on the failure plane. Heavy machinery engaged in clearing and removal of debris.

Geoparameter data sheet (42-points) Annexure-I

1	Slide	MN/NON/83H/9/2018/0006
2	State	Manipur
3	District	Noney
4	Toposheet	83 H/09
5	Name of the slide	5 Km SSW of Kotlen Landslide (NH-37)
6	NH/SH/Locality	NH-37/ Imphal-Jiribam Highway/ 5Kms from Kotlen towards Noney.
7	Latitude	$24^{o}47'28.7"N$
8	Longitude	$93^{o}44'8.4"E$
9	Length	95m
10	Width	130m
11	Height	90m
12	Area	12,350sq m
13	Depth	≈ 6m
14	Volume	74100 cubic m (approx)
15	Run out distance	200m (approx)
16	Type of material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Active
20	Distribution	Advancing
21	Style	Multiple
22	Failure mechanism	Deep translational failure
23	History	Initiated on 12.06.2018 and reactivated on 22.06.2018
24	Geomorphology	The slide formed on a moderately dissected slope of the hill.
25	Geology	Alternate beds of shale and sandstone.
26	Structure	$S_{0=}$350°/47°→260°, J1=290°/76°→020°,J2=215°/62°→125°, J3=060°/78°→150°
27	Landuse/landcover	Sparse vegetation.
28	Hydrological condition	Dripping
29	Triggering factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Livestock loss	Nil
33	Communication	NH-37 road blocked.
34	Infrastructure	Road damaged for a length of 130m and cables damaged
35	Agriculture/ Forest/ Barren	Barren
36	Geoscientific causes	1. Extensive slope cut for communication aggravated the instability of the slope. 2. Inherent poor rock mass i.e. the rocks are profusely jointed and composed of splintery grey shale. 3. Failure of overburden material due to increased pore water pressure as a result of incessant rainfall. 4. Unguided down slope flow of surface runoff from the road.

37	Remedial measures	1. Removal of overburden materials. 2. Channelling and diversion of rain water in the crown portion. 3. Lined drainage along the road. 4. A retention wall with proper weep holes to be constructed on the slope of the NH-37. A culvert across the NH to
8	Remarks, if any	
39	Photos, sketch of the plain and section of the slide	Refer Fig. 1, Photo 1, Photo 2, Photo 3
40	Landslide Category	Category- II.
41	Summary	
42	Pdf	Enclosed

Annexure-II

1		2	3	4	5	6	7			8			9	10	11	12.0	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Sl No	**Slide No**	**State**	**District**	**Topos heet no**	**Name of the slide**	**NH/SH/ Locality**	**Latitude**			**Longitude**			**Lengt h (in m)**	**Width (in m)**	**Height (in m)**	**Area (m^2)**	**Volume (cu.m)**	**Runout distance**	**Type of material**	**Type of movement**	**Rate of moveme nt**	**Activity**	**Distribution**	**Style**	**Failure mechanism**	**History**	**Geomorphology**	**Geology**	**Structure**	**Landuse/ Landcover**	**Hydrolog ical condition**	**Triggering Factor**	**Death of persons**	**People affected**	**Live stock loss**	**Communi cation**	**Infrastru cture**	**Agricultu re/forest/ Barren**	**Geo-scientific Causes**	**Remedial measures**	**Remarks**	**Photos. Sketch of Plan &**	**Summ ary/Ab stract**	**Pdf**	**Category**
LS 1	MN/NON/83H/ 9/2018/0001	Manipur	Noney	83H/9		NH 37	24	48	4	93	39	11.2	9	4	9				Debris	Slide		Active	Retrogressive	Single	Shallow translational		Moderately dissected slopes	Shale and Siltstone	S : 335 /15 →235°	Moderate vegetation	Wet	Rainfall							Extensive slope cut failure and increased overburden pore pressure due to rainfall.	Hardening of slope and benching of slope.					1
LS 2	MN/NON/83H/ 9/2018/0002	Manipur	Noney	83H/9		NH37	24	47	54	93	39	18.2	9	12	8				Debris	Slide		Active	Retrogressive	Single	Shallow translational	Reactivation in 2018	Moderately dissected slopes	Disang rocks		Moderate vegetation	Wet	Rainfall							Increased overburden pressure due to rainfall.	Slope hardening by plantation.					1
LS 3	MN/NON/83H/ 9/2018/0003	Manipur	Noney	83H/9		NH37	24	47	41	93	39	20.8	10	6	8				Debris	Slide		Reactivated		Single	Shallow translational	1. Initiated in July 2017 and Reactivation in 2018	Moderately dissected slopes	Shale		Moderate vegetation	Damp	Rainfall					Road blockage			Cut-fill failure.	Construction of Gabion wall from toe to the road.					1
LS 4	MN/NON/83H/ 9/2018/0004	Manipur	Noney	83H/9		NH37	24	47	15.6	93	40	0	12	8	10				Debris	Slide		Active	Retrogressive	Single	Shallow translational		Moderately dissected slopes	Sandstone and Shale	S : 030 ø18 →330 JI-NS/89 → E J2-310 /55 →040	Moderate vegetation	Wet	Rainfall							extensive slope cut and overburden pore pressure.	Slope stability by plantation and slope benching.	Planted Hibiscus plant for				1
LS 5	MN/NON/83H/ 9/2018/0005	Manipur	Noney	83H/9		NH37	24	47	53.7	93	43	26.7	15	3	20			80	Debris	Slide		Reactivated	Retrogressive	Single	Shallow translational		Escarpment	Shale, Sandstone and Siltstone	S : NS/51 →W	Thick vegetation	Damp	Anthropogenic					Damaged cables		Improper filling of the steep side of slope.	Slope benching by gabion wall from toe to road.					1
LS 6	MN/NON/83H/ 9/2018/0006	Manipur	Noney	83H/9	Kotlen Landslide	NH37	24	47	29	93	44	7.5	95	130	90			200	Debris	Slide		Active	Advancing	Multiple	Deep translational	Initiated on 12.06.18. Reactivated on 22.06.18.	Moderately dissected slopes	Shale , Siltstone and Sandstone.	S : 350, /47 →260 , J1: 290 /86 →20 , J2: 215ø62 ↔125, J3: 60/78 →150 and J4: 105 /66 →15	Sparse vegetation	Dripping	Rainfall and anthropogenic.					Blockage of road	Damaged cables		Increased overburden pressure due to incessant rainfall.	1.Removing of overburden materials from the slope. 2. channeling water (rain water)					11
LS 7	MN/NON/83H/ 9/2018/0007	Manipur	Noney	83H/9		NH37	24	47	43.8	93	44	9.8		5	8				Rock	Fall		Active	Retrogressive	Single	Shallow translational	Initiation in 2018	Escarpment	Massive shale		Barren	Wet	Anthropogenic							Failure along weak plane.	Removal of debris and construction of gabion wall for 5m along the road.					1
LS 8	MN/NON/83H/ 9/2018/0008	Manipur	Noney	83H/9		NH37	24	47	50.2	93	44	16	9	4	9				Debris	Slide		Active	Retrogressive	Single	Shallow translational	Initiation in 2018	Moderately dissected slopes	Disang shale	S : 200 /57 →290	Sparse vegetation	Wet	Rainfall							Increased pore pressure due to rainfall on overburden.	Removal of debris.					1
LS 9	MN/NON/83H/ 9/2018/0009	Manipur	Noney	83H/9		NH37	24	47	52.8	93	44	9.6	30	28	29				Debris	Slide		Suspended	Diminishing	Single	Shallow translational		Moderately dissected slopes	Shale and sandstone	S : 010 /48 →290	Sparse vegetation	Wet	Rainfall							Increased pore pressure on overburden.	Slope stabalization by plantation					1
LS 10	MN/NON/83H/ 9/2018/0010	Manipur	Noney	83H/9		NH37	24	48	15.3	93	43	58.3		23				22	Debris	Slide		Active	Retrogressive	Single	Deep Translational failure		Moderately dissected slopes	Shale		Moderate vegetation	Damp	Rainfall				Road partially damaged	Damaged cables		Gully erosion by run-off.	1.Construcion of gabion wall from the toe to the road 2. Proper drainage system					1
LS 11	MN/NON/83H/ 9/2018/0011	Manipur	Noney	83H/9		NH37	24	48	31.1	93	44	8.6	19	14	18				Debris	Slide		Active	Retrogressive	Single			Moderately dissected slopes	Sandstone		Moderate vegetation and Quarry	Damp	Rainfall							Increased pore pressure on overburden.	1. Removal of debris 2. Lined drainage along the road.					1
LS 12	MN/NON/83H/ 9/2018/0012	Manipur	Noney	83H/9		NH37	24	48	35.7	93	44	10	13	12	10				Debris	Slide		Active	Retrogressive	Single	Shallow translational		Moderately dissected slopes	Sandstone and shale		Moderate vegetation	Wet	Rainfall							Toe erosion by nala.	1. Slope hardening by plantation 2. concrete wall along the toe.					1
LS 13	MN/NON/83H/ 9/2018/0013	Manipur	Noney	83H/9		NH37	24	48	57	93	44	24.7	36	37	36				Debris	Slide		Active	Retrogressive	Multiple	Shallow translational		Moderately dissected slopes	Shale and sandstone	S : 180 /27 →W	Moderate vegetation	Flowing (Spring)	Rainfall							Toe erosion by nala.	Proper channelling of stream.					1