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A COMPREHENSIVE REVIEW ON PAGLAJHORA SINKING ZONE LANDSLIDE IN THE SHIVKHOLA WATERSHED OF DARJILING HIMALAYA

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ABSTRACT
The present paper is dealt with the landslide events in Paglajhora Sinking Zone of Darjiling Himalaya. Paglajhora sinking zone, a major landslide prone area, situated in the Southern escarpment slope of Darjiling Himalaya. In the present study, past landslip events, causes of landslip and their destructive impact have been examined in detail. The study revealed that the presence of greater thickness of less cohesive slope soil and increase in topographic wetness due to drainage concentration have made the study area more vulnerable to slope failure. Laboratory test on geotechnical parameters of soil such as wet soil density, dry density, porosity, water holding capacity, cohesion, and friction angle were made to understand the causes behind massive slope failure at Paglajhora. The destruction of road ways (Hill Cart Riad, NH-55) and railway lines (Heritage Rail Line) are the major consequences from landslip in the Paglajhora sinking zone.

Keywords: *Paglajhora Sinking Zone, Landslide Dynamics, Geotechnical Parameters*

INTRODUCTION
The rapid rate of urbanization and tourism in Darjiling Himalaya exhibits an unprecedented pressure on land and soil with the gradual elimination of vergin forest land after independence.

The unscientific and unplanned usage of land coupled with vulnerable geological structure and heavy frequent rainfall have led to the formation of vicious cycle of soil erosion and during and after monsoon landslide causing devastating damage to human lives and properties.

Researchers (Ghosh, 1950; Nautiyal, 1951, 1966; Dutta *et al.*, 1966; Roy and Sensharma, 1967; Acharya, 1972; Lahiri, 1973; Lahiri and Gangopadhyay, 1974; Basu and Maiti, 2001; Paul, 1973; Ghosh *et al.*, 2009b) of Geological Survey of India carried out a demand oriented studies in Darjiling Himalaya and put forward the major landslide occurrences phenomena.

The sudden landslide occurrences along the NH 55/Hill Cart Road passing through southern escarpment slope of Drjiling Himalaya due to only one concentrated 50 mm showers/hour during monsoon may initiate endanger innumerable people and their properties.

The instability of landslide increases due to progressive absorption of moisture from excessive rainfall and cutting of hill slope both artificially and naturally together with defective drainage.

In the present study landslide along the Hill Cart Road has got tremendous impetuous due to large scale impact on the economy and the ecology of the region.

The break of slope which is caused due to formation of road and rail cut benches provide the seat for the deposition of overflowing streams and during every monsoon such benches is covered with slope wash materials consist of large boulders to fine silts.

Sometime large rolled boulders from upslope may disrupt the railway line at several places alone the Hill Cart Road.

Severe erosion at the base of the steep slope below the rail and the road cut benches by fast flowing mountain torrents reduce the basal support of the slope at Paglajhora (Figure 1).

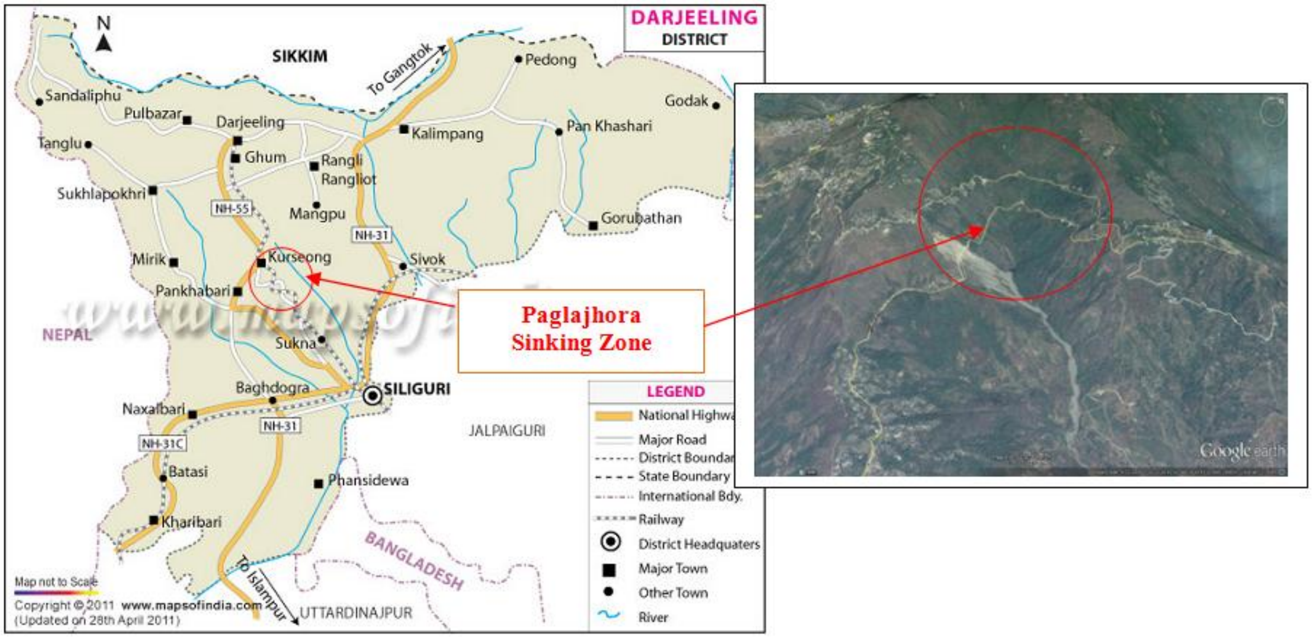

Figure 1: Location of Paglajhora Sinking zone in Darjiling District and in Google Earth Image (2015)

Mallet (1875) opined that in the Darjeeling territory the "Gondwana" rocks are overlain by the metamorphic rocks, which are termed as "Darjeeling Geniss" (mainly mica-gneisses and Schists) and "Daling" (mainly slates and phyllites). Darjiling gneiss and Chungtang formation (upper part of Daling) aer associated basically covered the Paglajhora Sinking area. These two lithological units composed of highly foliated gneiss, mica-schists and occasional bands of flaggy quartzites and granulitic rocks, slates phyllites with occasional quartzite, quartz-schists and greywake schists. Chungtung Formation is composed of Calc-granulitie, marble, Quartz-granulite and mica-schist. The Paglajhora sinking zone covers gneiss, mica-schist & granulitic rocks, mylonitised granite with sub-parallel thrust**,** phyllite, silvery-mica-chlorite-schist, grey sericite, and Slate phyllite with quartzite, quartz-schist & greywake schist (Figure 2). The zone is characterized by the following structurally controlled phenomena.

- Seepage through heavily disintegrated and decomposed materials and formation of clay minerals, which induces slope instability.
- Rocks are traversed by quartz and quartzo-felspathic veins and the rocks are often highly metamorphosed and jointed.
- Recrystallisation and cataclastic deformation have destroyed the clastic texture with intense granulation along narrow zones of fracture.
- The apexes of the sliding zones are predominated with good amount of organic matter which encourages high water holding capacity and volume expansion.
- The apexes of the sliding zones are deforested and are susceptible to both sheet and gully erosion.

In the Paglajhor Sinking zone, the heavily disintegrated fragile lithology makes the slope more vulnerable to landslip. Starkel (1972) for the first time, observed the geomorphic effects of an extreme rainfall event in the eastern Himalaya (Darjiling), India. Froehlich *et al.*, (1990) investigated the same area and found that shallow slides and slumps on steep slope segments occur when 24 hours rainfall reaches 130-150 mm or continuous three days rainfall totals 180-200 mm.

Caine (1980) first established worldwide rainfall threshold values for landslides. Montgomery and Dietrich (1994) introduced a physically based model for the topographic control on shallow landsliding in terms of geomorphic threshold. Recently Guzzetti *et al.*, (2007) reviewed rainfall thresholds for the initiation of landslides worldwide and proposed new empirical thresholds based on the statistical analysis

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of the relationship between rainfall and landslide occurrences. They defined intensity-duration threshold as:

$I=73.90^{-0.79}$ …………………….(1).

Where, I is the hourly rainfall intensity in millimeters (mm hr-1) and D is duration in hours.

The major Landslide events occurred in the Shivkhola Watershed and in Paglajhora Sinking Area:
Paglajhora sinking zone is located in the Shivkhola watershed of Kurseong sub-division of Darjiling district (Figure 3). The watershed is dominated by few devastating landslides such as Tindharia, Mahanadi, Gayabari and Shiviter. The major landslide events in the watershed are documented here in a temporal scale.

- The landslip in Tindharia on 15th January, 1934 due to Bihar-Nepal earthquake.
- Between the 11th and 13th June, 1950 a series of devastating landslide after a spell of 834.10 mm rainfall around Kurseong.
- Landslide at Giddapahar near Kurseong damaged over 175 m of road and railway track and demolished many bustee hamlets between 3rd and 5th October, 1968 due to heavy rainfall of 1121.40 mm.
- During 3rd and 4th September, 1980 again Tindharia was affected by severe landslide due to heavy and concentrated rain of 299.1 mm.
- During 15th and 16th September, 1991 numerous landslide phenomena at Paglajhora and Chunabhati.
- During 11th and 13th July, 1993 innumerable landslide devastated Mahanadi, Gayabari and Tindharia.
- The year of 1995, 1998, 2001, 2002, 2003, 2006 and 2007 are major cases of landslips along the Hill Cart Road mainly at Paglajhora, Giddapahar, Tindharia and Gayabari.
- A devastating landslide at Shiviter Tea Estate in 2005, which destroyed a tea garden area of 1.5 acres.
- On 10th September, 2006 a devastating landslide took place along the Hill Cart Road at 14 Miles Bustee and blocked the railway line for few days. The major cause of this landslip was sudden and catastrophic rainfall.
- A road crack was formed along NH-55, the road to Darjiling from Siliguri, at Tindharia following heavy rain in the past few days on 4th August, 2007. Another landslide incident happened in the same year on 16th July along the Hill Cart Road and completely broken down the guard wall nearby Kurseong town.
- A major landslides at 14 Mile near Paglajhora disrupted traffic along the National Hoghway-55 and toy train services between New Jalpaiguri and Kurseong on 16th June, 2010 morning.
- A devastating landslide took place in the Paglajhora area in May, 2011 and there was complete elimination of roads for about 100 meter as a result of road subsidence.
- Landslide along Hill Cart Road at Paglajhora and disruption of traffic movement in July, 2012.
- Complete elimination of Hill Cart Road for about 250 meter at Lower Paglajhora Sinking area in May, 2015.

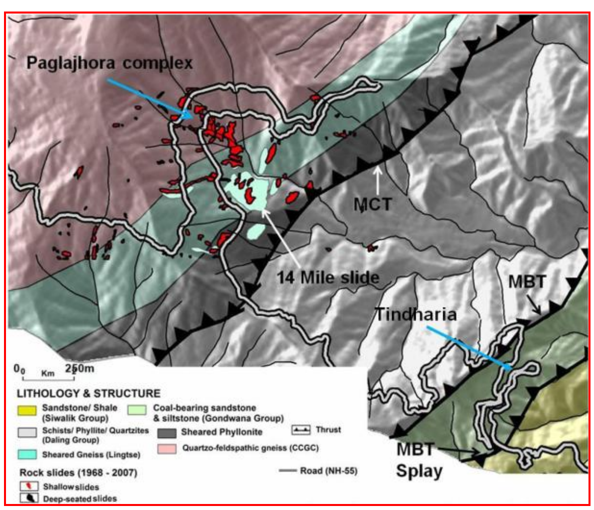

Figure 2: Paglajhora sinking zone with lthology and structure (Ghosh *et al.*, GSI)

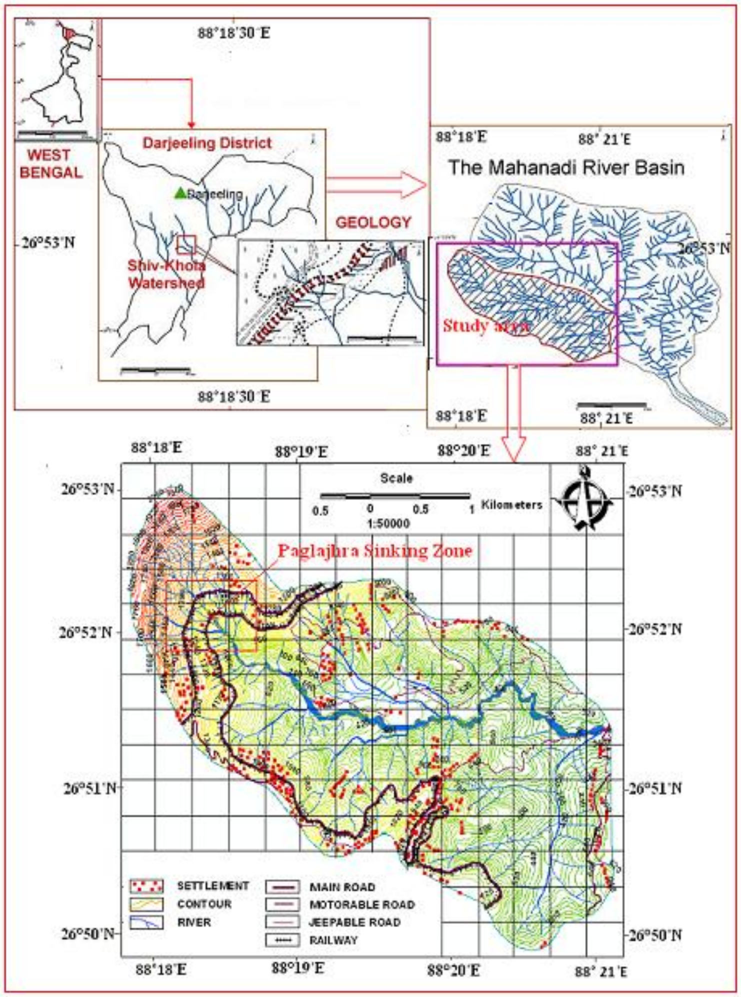

Figure 3: Location of Paglajhora Sinking Zone in the Shivkhola Watershed

A Brief account on Paglajhora Sinking Zone (along National Highway 55)

The National Disaster Management Authority (NDMA) constituted a Post-Earthquake Reconnaissance Team (PERT) (vide Office Memorandum No. 5-83/2011-MIT, dated 04 November 2011) to study the damages sustained in the areas affected by the 18 September 2011 Sikkim Earthquake in the state of West Bengal. The PERT will conduct field investigations during 10-13 November 2011 and came into conclusion with the following terms of reference.

- The National Highway 55 (Siliguri-Darjeeling Highway) has suffered repeated failures for decades in the Pagalajhora sector and remained a major eyesore as far as traffic movement is concerned. The area exposes the highly tectonised sheared gneissic rocks close to Main Central Thrust (MCT) (Figure 2) belonging to the Darjeeling and Daling Groups, which are separated with each other by the Main Central Thrust (MCT). In the 14 Mile slide, a 500 m reach of the Highway has remained breached, thereby totally disrupting the movement along the road and Heritage Rail Route since 16 June 2010 and impacting the socio-economic activity in the hill region in very significant way (Figure 4).
- On the southeastern fringe of the slide zone, highly sheared and mylonitized gneiss and micaceous schistose rocks are exposed that indicate their involvement in the thrusting process. A detailed map of this slide zone has been prepared by the Geological Survey of India. The slide scar presently extends for almost 100 m above the road level. The field investigation revealed that a major portion of the slide zone has been restored by clearing the debris and redressing the road surface besides treating the disturbed

slopes by shotcrete. However, consequent to the 18 September 2011 earthquake, a huge rock block having rough dimensions of 15m×10m×8m slipped along steeply dipping joints, thereby blocking the restored reach once again (Figure 5).

Figure 4: Gradual subsidence of the outer edge of the Hill Cart Road at Lower Paglajhora, 2010

Figure 5: Dislodgement of the debris and rocks block after September, 2011 Earthquake at Paglajhora

- The Pagala Jhora sector, comprising a compound slide zone, is a perennial trouble spot along the Highway as the rock mass here is inherently of very low shear strength amenable to severe erosion and even straining due to possible tectonic creep. Even a slight provocation like consistent rain fall in the area or excitation by earthquake motions mobilizes the slide mass off and on. It is, therefore, imperative to carry out a detailed geotechnical assessment of the Pagla Jhora zone by a competent agency. For seeking a permanent solution to the problem it may be worthwhile to study an alternate road alignment or even consider bypassing the slide zone by a traffic tunnel, if the former is not possible.

- The huge rock slide at Paglajhora is at 14th mile on the Darjeeling Himalayan Heritage Railway (DHR) route on the eastern slope of the Kurseong mountain range. The rock slide extends from relief of 1280m at the crown to 900m at the valley bottom with a length of 500 m and width of 450 m at the road level and depth > 30m. It is the largest landslide observed during field investigation. As per local information, the present landslide started on 16 June 2010 during road widening and thereafter its dimensions increased. On 18 September 2011, it got reactivated as one of the major disjointed block slided down the slope on the northern part of the slide completely destroying the partially restored road (Figure 5). As a result, the NH 55/Hill cart road and the heritage railway running parallel to each other remain disrupted since June 2010 and it is a matter of great concern as it affects tourism as well general communication. The present landslide was initiated as a rock slide. The area is underlain by highly folded, crumpled sheared gneissic and schistose rock (Lingtse) and the area is on the hanging wall side of the MCT that passes towards southeastern part trending in NE-SW direction (Figure 2). The Paglajhora is prone to rockslide for last many years as reported in 1980, 1998 and now a major landslide has occurred in 2010 which was reactivated again in 2011 due to Sikkim earthquake (Figure 6). A small lake was also reported at Paglajhora due to debris of rock slides blocking the drainage in August 2011.

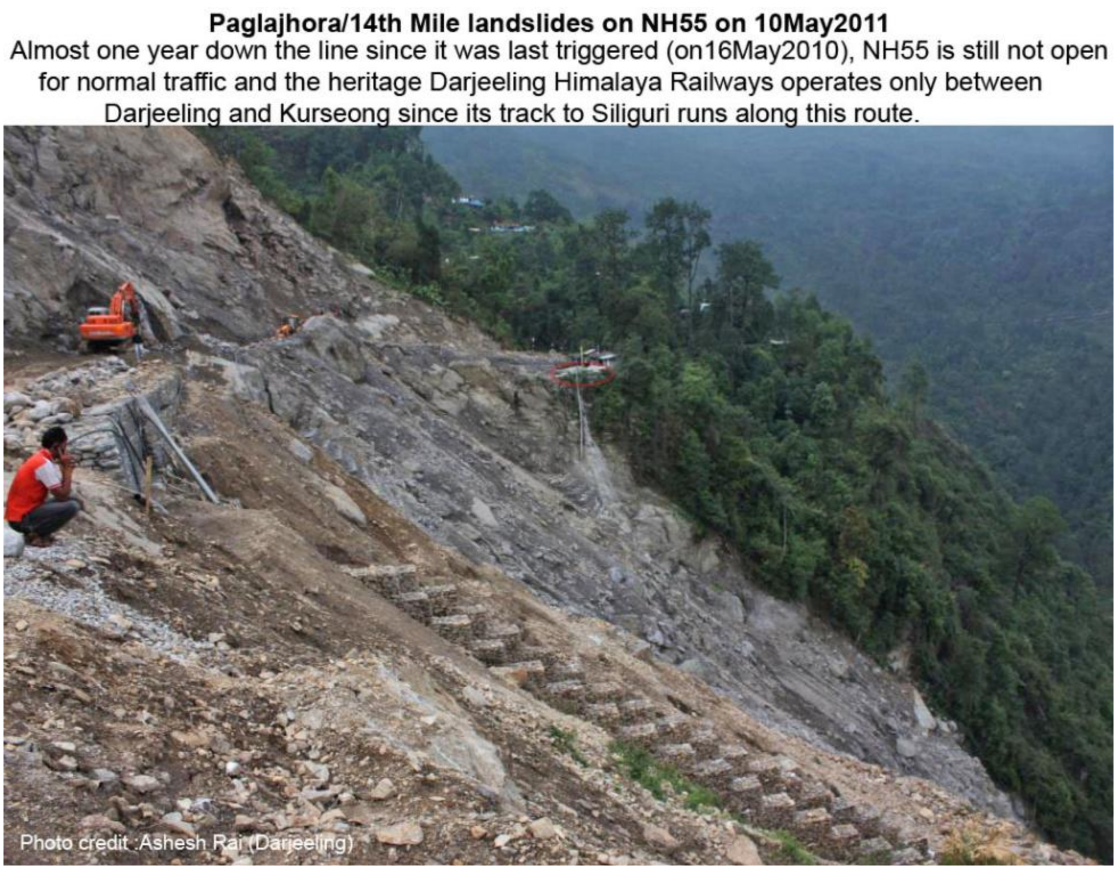

Figure 6: Lower Paglajhora (14 Mile landslide) on NH 55, May 2011

The landslide has severely affected NH 55/Hill cart road and Darjeeling Himalayan Heritage Railway which started in 1881 and the slope stability was maintained although there were occurrences of landslides in the past. Most importantly, the landslide crown has reached an elevation of 1280 m and human settlements are observed at 1310m and the same NH 55 with settlements is observed at 1360m which can be affected unless remedial measures are taken up at the present site which is at the lower elevation. The remedial measures require detailed geotechnical and geological analysis and large scale engineering intervention as it has potential to affect two stretches of NH 55 and human settlements. The alternate route alignment is the first cost effective possible solution through a tunnel of 800m can be suggested to completely avoid the landslide affected 14 mile site, if the alternative route is not possible. However, as the area lies very close to MCT and dominated by sheared gneiss and phyllonites, it is recommended that a thorough geological, geotechnical investigations must to be carried out before taking up any remedial measures. As informed, GSI has carried considerable work in the region, based on their study and additional investigation as required, further recommendations can be suggested. The Paglajhora landslide in the Shivkhola watershed is more dynamic in character. There is gradual and continuous changing of areal extent of the slides (Figures 7, 8, 9 & 10) and subsidence of the trunk road between Siliguri and Kurseong, at Paglajhora. Recently, Paglajhora sinking zone faced massive slope failure in 1998, 2002, 2005 and 2011 which has proved the region as more dynamic in nature due to gradual and continuous spatial expansion of the slide area. The dynamic nature of the landslides in the Paglajhora sinking zone is experienced with drainage concentration and development of first order and second order drainage through headword erosion. The expansion of the slided area at Paglajhora causing the changes in the normal land use character both upslope and down slope of the Hill Cart Road.

Figure 7: Landslide at Paglajhora, 2002

Figure 8: Landslide at Paglajhora, 2006

Figure 9: Landslide at Paglajhora, 2009

Figure 10: Landslide at Paglajhora, 2011

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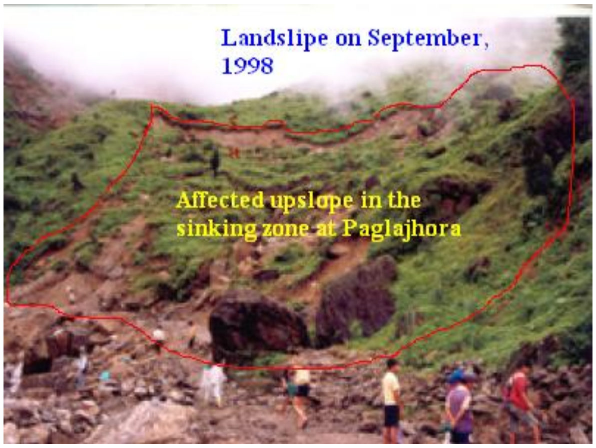

Figure 11: Landslip on September, 1998

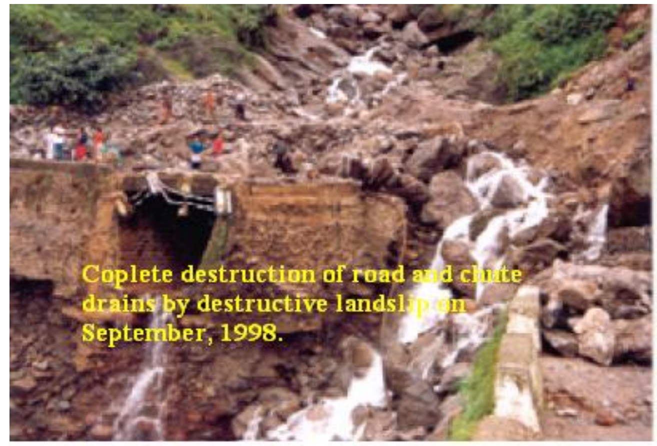

Figure 12: Landslip on September, 1998 at Sinking zone

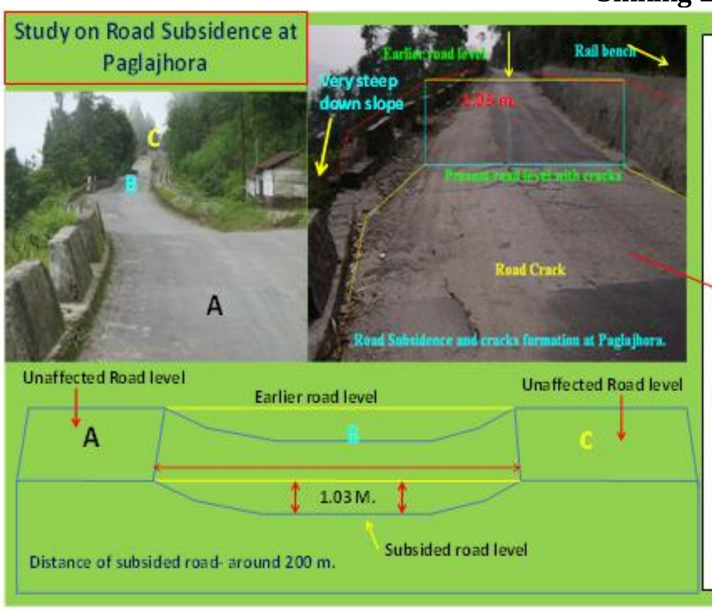

Figure 13: Road subsidence at Lower Paglajhora (2009)

Figure 14: Situation of NH-55 at Paglajhora (2010)

Figure 15: The destruction of the Hill Cart Road at Lower Paglajhora in June, 2015

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Figure 16: Damaged NH-55 at Paglajhora

Figure 17: Deplorable situation at the base of Hill Cart Road

Figure 18: Removal of debris from steep upslope at Paglajhora

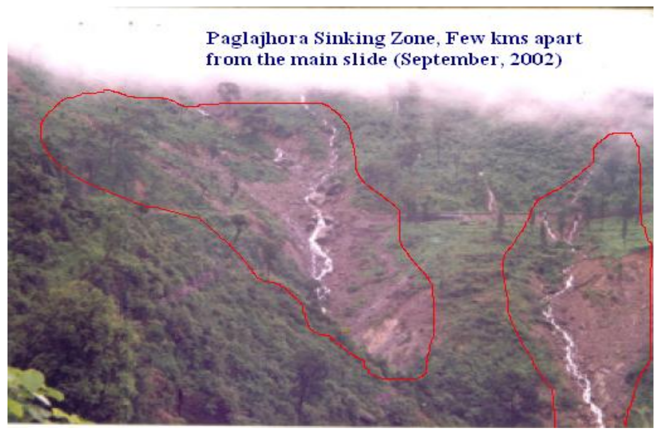

Figure 19: Initiation of drainage and slope failure

Shearing stress of the deformed and less cohesive steep slope surface material is higher than the shearing resistance because these types of materials are affected by over saturation and more hydrostatic pressure and thus the materials subside gradually (Figure 11 & 12). The N.H.55 road cum rail bench trails at two different levels within the Paglajhora Sinking Zone for a total length of almost 2.5 km. (Figure 13). The N.H.55 within this stretch has suffered heavy sinking (6-8 meters even) and continuous distress with ages**.** At Paglajhora to preserve the deep sliding masses high retaining walls have been erected to resist downward movement of slope materials. But such constructions are putting an immense pressure on slope day by day (Figure 17).

Near Pagla Jhora a distance for about 2 km. road tract acutely suffers from severe subsidence (Figure 16). Randomly oriented surface run-off triggers active headward and toe erosion within this loose unconsolidated landmass (Figure 19). Maximum erosion is being done by underground seepage water that causes tremendous piping action by removing fine particles giving rise to continuous creep and subsidence of slopes (Figure 18).

The river Paglajhora and its tributary from 37.5 km to 45.5 km have had devastating effects on road and rail cut benches. The very high surface discharge on the eastern slope is concentrated through Paglajhora and its tributaries. By the processes of valley widening toe erosion and headward erosion of the river a large number of slides are being originated at Paglajhora. The records of subsidence (Table 1) of Hill Cart Road at Lower Paglajhora are a significant landmark of slope instability in the Shivkhola Watershed. Near about 2 km. length of the Hill Cart Road which is stretching along the steep north, east and south facing slope with fragile lithological composition is heavily affected by the down slope movement of slope materials and the subsidence of road and rail-cut benches (Figure 23).

Table 1: Records of the rate of road subsidence from Lower Paglajhora Sinking Zone

Years	Rate of subsidence of Hill Cart Road from Rail Bench	Result of the subsidence
May' 2006	No Prominent subsidence took place	Unaffected the Hill Cart Road.
July' 2007	0.75 m.	Affected the Hill Cart Road
September' 2008	1.03 m.	Affected the Hill Cart Road during continuous rainfall.
August' 2009	1.50 m.	Road blockage due to lowering of road bench by heavy monsoon rainfall
June' 2010	5.00 m and above	Failure washed away the marginal subsided part and damaged the transport network completely.
May' 2011		Reactivation of Paglajhora landslide and again destruction of road and railway line and

Sources: Author Himself

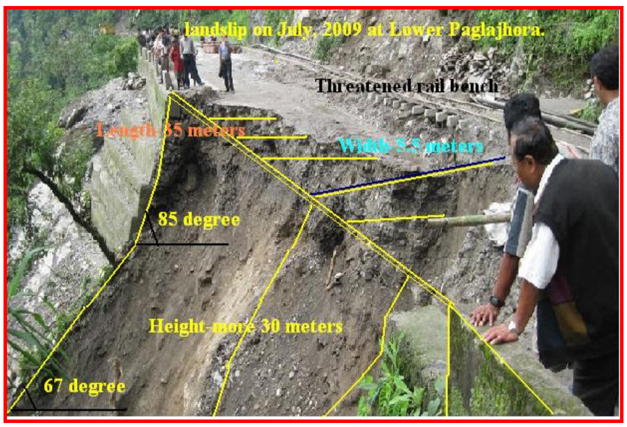

Figure 20: Destruction of NH-55, Paglajhora

Figure 21: Elimination of road and railway line

The road-rail bench subsidence and related problems like frequent road blockage and disruption to traffic movement as well as the flows of tourists have brought an attention to Government and Non-government organization and research workers to study the area and to make a proper management proposal for the concerned road section of the watershed. Road crack (Figure 13) was a recent observation at lower Paglajhora. This crack has been formed as a result of the down slope movement of the non-cohesive slope materials and the vibration caused by the plying of heavy loaded vehicles. The formation of road cracks aggravates the problem of road subsidence and ultimately invited a massive slope failure in the region.

Causes and Consequences of Slope Instability at the Sinking Zone of Lower Paglajhora

Slopes characterized by in situ competent rock mass are found to be stable in nature. Rocky slopes become unstable where they are weathered and heavily jointed. Apart from the rocky slopes, there are slopes exhibited by thick overburden and old slided debris. These types of slopes are most vulnerable as per as instability and mass wasting are concerned. In Paglajhora Sinking Zone huge protection walls have been constructed, which at places appears to be rebundant. These heavy CRM put unnecessary dead load on the unconsolidated debris mass (Figure 20) which invites slope failure. In Paglajhora region, no arrangement has been made to extricate the seepage water and it acts more heavily in destabilizing the slopes. The subsidence and sinking zone at Lower Paglajhora has affected extensive area on both the sides of the River Shivkola and the extent along the road will be approximately 500 m. Just above the road the slope is around 65^0. The downhill slope is around 70^0. Others physical properties of soil also exhibit the slope surface is more vulnerable to failure (Figure 21). The area is influenced by number of nalas along which the seepage is a quite common phenomenon. The slide is reported to occur mainly during the monsoon when the area receives heavy precipitation. A road Subsidence took place in July, 2009 during continuous heavy rainfall and destroyed around 35 m. road on the right bank of the Shivkhola. The cumulative effects of the joints have made the rock fissile which in conjunction with its soft nature has become incompetent and prone to easy erosion and slope failure. The area contains very fragile and thick accumulation of decomposed materials with micaceous soil components having no less cohesion and plasticity. There is very easy seeping and percolation of water through non-cohesive materials in the sinking zone at Lower Paglajhora (up slope & down slope) which has caused a massive destruction (Figure 21).

A study was conducted on 14 mile bustee landslide in 2007 after the occurrences of fresh landslide along the Hill CART Road (Figure 22). Study showed that 14 mile bustee landslide is located at the distance of 37.25 km from Siliguri where the elevation is 1118 meter. The average length of the slide is 90 meter and average width is 25 meter covering the total area of about 2250 sq.m. The average slope angle of the slide is 59^0 with less cohesion (0.18) and friction angle (17^0 30′). The calculated safety factor on the basis of geo-technical parameters of soil is 0.96266 (Mandal and Maiti, 2012). The collected soil sample from different location of the sinking zone revealed that the low cohesion, low friction angle and high wet soil density of the soil leads to gradual and continuous subsidence of slope materials at Paglajhora (Table 2).

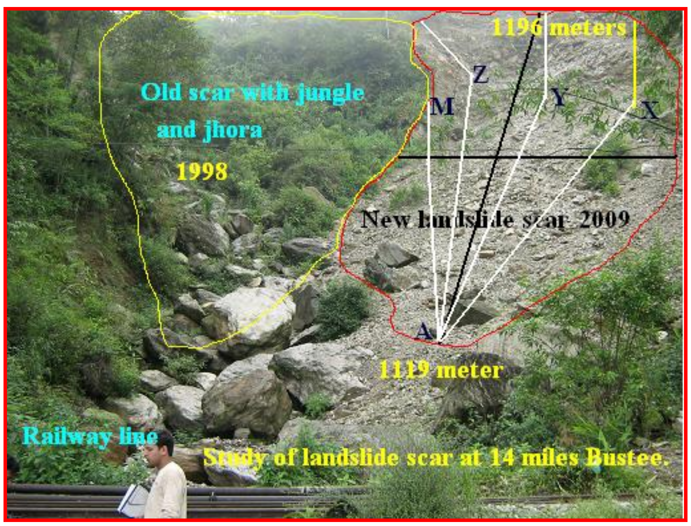

Figure 22: Study of landslide at 14 Mile Bustee (2007)

Table 2: Result of the laboratory test of soil samples from Lower Paglajhora and 14 Miles Buste

Sample No.	Lithology	Cohesion (kg/cm^2)	Friction angle	Wet density(gm/cm^3)	Dry density(gm/cm^3)	Water holding capacity (%)
I	Foliated gneiss & mica-schist	0.12	$22^0$30′	2.14	1.86	32%
II	”	0.25	19^0	2.08	1.79	28%
III	”	0.18	$17^0$30′	2.02	1.74	23%

Observation on Road Abandonment at Lower Paglajhora

- Location : 38 km from Siliguri (Elevation-1135m)
- Date of the survey: September’2008

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- Length of subsided road: 125 meter.
- Amount of subsidence: 1.42 meter.
- Gradient of the slope: > 70^0; wet density:-2.14 and dry density: -1.86.
- Lithology: Highly foliated gneiss & mica-schist; Cohesion-0.12; friction angle-$22^0 30'$.
- Causes of subsidence: loss of basal support of the slope by active down cutting of the Shivkhola, easy saturation of unconsolidated slope material through seepage, steepening of slope by road cutting and plying of loaded vehicles and related vibration.

Observation on Road Abandonment at Lower Paglajhora (14 Miles Bustee)

- Location: 37.5 km from Siliguri (Elevation-1130m).
- Date of the survey: September' 2008.
- Length of subsided road: 68 meter.
- Amount of subsidence: 0.95 meter/year.
- Gradient of the slope: > 65^0(down slope of the subsided road); friction angle-19^0.
- Lithology: Highly foliated gneiss & mica-schist; cohesion- 0.25; wet soil density:-2.08 and dry soil density: - 1.79.

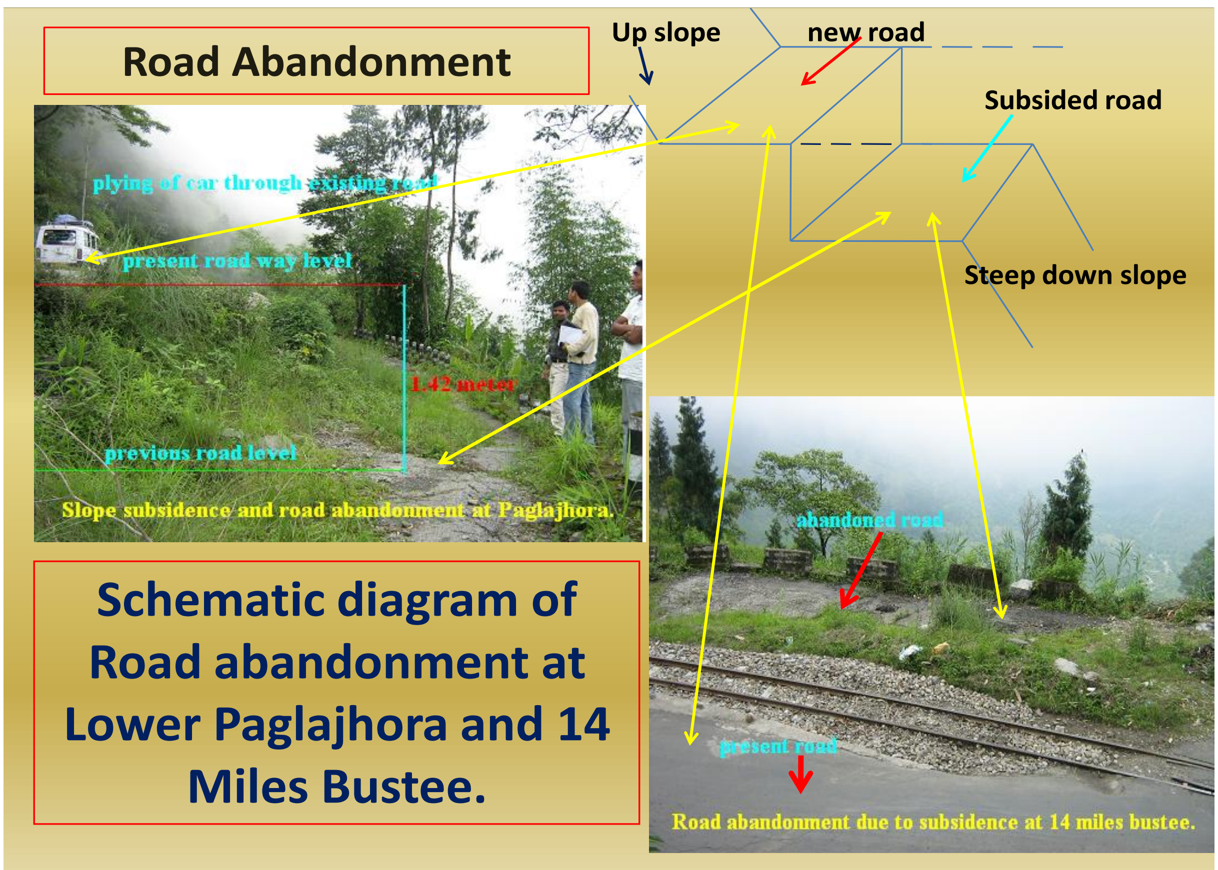

Figure 23: Road abandonment in Paglajhora and 14 Mile Bustee

Since 2010, the abandoned roads as well as unaffected road are being affected by consecutive destructive landslip events of 2011, 2012, 2014 and 2015 (Figure 23). The reactivation of the landslide events at Paglajhora sinking zone has brought a tremendous threat to the local people. Such reactivation of landslide phenomena at the sinking zone is the result of drainage concentration over the fragile lithology and soil.

Table 3: Study on the soil geo-technical parameters at Paglajhora Sinking Zone

Sample no.	Soil Density (gm/cc)			Grain Size analysis (%)			Direct shear test result	
	Wet	Dry	Saturated	Sand (%)	Silt (%)	Clay (%)	Cohesion (c)	Friction (φ)
1	1.94	1.62	2.12	85	11	4	0.11	30
2	2.18	1.96	2.39	83	12	5	0.22	19
3	2.01	1.52	2.54	90	3	3	0.41	24
4	2.08	1.84	2.27	87	11	2	0.02	35
5	1.98	1.65	2.46	80	14	6	0.04	41
6	1.82	1.45	2.18	79	17	4	0.01	37
7	1.76	1.42	2.38	75	20	5	0.7	13
8	1.99	1.30	2.09	81	16	3	0.23	32
9	1.70	1.36	2.25	73	22	5	0.16	33
10	1.83	1.47	2.06	80	19	1	0.21	30
11	1.66	1.20	2.02	78	15	7	0.06	29
12	1.97	1.36	2.58	82	13	5	0.21	22

Source: Mandal and Maiti (2012)

The study on the geo-technical parameters of the soil from different locations of Lower Paglajhora shows that the soil is composed mainly of average 75% of sand particles, 15% of clay and very minimum % of clay particles. Such grain size distribution in the soil has reduced the cohesion as well internal friction which promotes easy percolation of water through the soil and decrease the shearing strength. Study also shows that Paglajhora sinking area possesses most fragile rock-soil composition such as scree, mixed with coarse colluviums, sheared gneiss, granite gneiss, and phyllites and old as well as recent slide debris. The main sinking area at Paglajhora is covered with recent and old slide debris where cohesion in the soil ranging between 0.196 and 0.010 (Table 3). The passing of first order channels through this fragile zone is responsible for destructive slope failure. The angle of internal friction (φ) of the soil is extending between 20^0 and 32^0.

At the sub-surface layer of the soil percentage of pore space is high but at greater depth pore space decreases because of the existence of large percentage of finer particles. The reduction of pore space at greater depth results in the increase of water holding capacity and volumetric expansion at the sub-surface soil which also increases the pore-water pressure and reduces cohesion and finally invites slope soil failure at most of the places of the Paglahora sinking zone.

Table 4: Depth wise distribution of water holding capacity, pore space and volumetric expansion (%)

Location	Parameters	Depth of the soil in cm						
		0-10	10-20	20-30	30-40	40-60	60-80	80-100
AT LOWER PAGLAJHORA 33.5 KM FROM SILIGURI	Water holding capacity %	29.22	25.54	22.45	18.50	12.34	9.08	5.45
	Pore spaces %	86.75	85.62	81.35	73.93	60.12	46.53	39.82
	Volume expansion %	21.11	19.21	15.42	12.22	9.75	6.45	5.40

Source: Basu & Sarkar (1985)

The following facts and findings were being recognized in the sinking zone of Paglajhora which have made the places more vulnerable to slope failure.

1. Physiographic configuration (arcuate) of the Paglajhora sinking area provides favourable condition to produce hydrostatic pressure.
2. Proximity to Main Central Thrust (MCT).

3. Intensely fractured and sheared nature of the bed rock existing in the region.
4. Toe cutting and headward erosion of debris covered slope by first flowing tributaries.
5. Immense pressure over the fragile slope materials by man-made concrete structure.
6. Moderate to steep slope gradient.
7. Improper drainage network orientation throughout the region.
8. Accumulation of highly anisotrophic materials with a great thickness and low shearing resistance.

CONCLUSION

In Paglajhora sinking zone special care should be taken to combat frequent landslip events. The alignment of the Hill Cart Road over the steep slope has created a platform where upslope water can rest and percolate downward. This situation increases the topographic wetness and reduces cohesion and increases shearing stress of the slope materials. Increase in shearing stress crosses the threshold limit of the slope and promote landslides in the concerned study area. The fragile lithological composition, passing of MCT and MBT and existence of bedding planes have aggravated the problems of slope failure in the region. Analyzing all the geomorphic and geohydrologic parameters and its role in landsliding, in can be inferred that the development of the new road alignment to communicate between Siliguri and Darjiling is the best solution from the devastating destruction in Paglajhora Sinking Zone. Not only has that to ensure slope stability extensive plantation and aforestation programme been to be introduced in the sinking zone.

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