International Journal of Humanities and Social Science Invention
ISSN (Online): 2319 – 7722, ISSN (Print): 2319 – 7714
www.ijhssi.org Volume 4 Issue 6 ǁ June. 2015ǁ PP.40-48

Landslide along the Highways: A Case Study of Darjeeling Hill, West Bengal.

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ABSTRACT: *Out of the total landslide occurrences, nearly 20% are found in North Eastern region of India. The official figures of United Nations International Strategy for Disaster Reduction (UN/ISDR) and the Centre for Research on the Epidemiology of Disasters (CRED) for the year 2006 also states that landslide ranked third in terms of number of deaths among the top ten natural disasters, as approximately 4 million people were affected by landslides. Unless human death it poses serious damage on roadways, railways, buildings, dams and many natural resources with untold measure of ecosystem and human society. As transportation is a lifeline of a civilization and lack of self sufficiency of a region it hold an important place to meet daily needs of human beings of a region. The study route (NH 31 A, NH 55 and SH 12 A) of landlocked Darjeeling district is very much prone to landslide vulnerability. The black memories of previous massive landslide hazard took large impression on the inhabited society. Sometime the district remains isolated island due to breakdown of transportation for a stretch of days in the time of massive landslide along study route. The main objective of the study is to highlight/describe the present situation of landslide zone along three study route. The study also highlight the nature of landslide took place according to their vulnerability scale, type of movement, type of activity, type of distribution and lastly type of style for further management.*

KEY WORDS: *Landslide, Vulnerability scale, Type of movement, Type of activity, Type of distribution, type of style.*

I. INTRODUCTION

The term Landslide describes a wide variety of processes that result in the downward and outward movement of slope forming materials including rock, soil, artificial fill or combination of these. The material may move by falling, toppling, spreading or flowing – (USGS). Landslide is a major geo-hydrological hazard, which poses serious threat to human society and various other infrastructures like road and rail routes, and civil structures like buildings, dams and other natural resource such as fertile land, forest resource in the hilly terrain. The statistics reflect that natural hazards account for up to 4% of the total annual deaths globally, not to ignore huge untold suffering of human being by means of death, injury, homeless victims, economic loss and migration of people etc. The official figures of United Nations International Strategy for Disaster Reduction (UN/ISDR) and the Centre for Research on the Epidemiology of Disasters (CRED) for the year 2006 also states that landslide ranked third in terms of number of deaths among the top ten natural disasters, as approximately 4 million people were affected by landslides (Kumar et al., 2008). The intensity, magnitude, frequency and type of the landslide may be different in different parts. The Himalayan terrain including Darjeeling Himalayan characterized by its high relative relief, high seismicity, active tectonics activity, frequent high precipitation, unstable ecosystem, highly weathered, jointed, fractured and sheared rocks, youthful stages of river, and varied rock types witnesses extreme slope failures. This trend is expected to increase in near future due to increased roadways, unplanned urbanization and development, and over exploitation of natural resources.

Out of the total landslide occurrences in the country, nearly 20% are found in North East region of India. Two national (NH - 31 A and NH - 55) and state highways (SH - 12 A) running across the Darjeeling district are the only means of surface transport, for this reason this landlocked district are often blocked by landslides. Constructing and maintaining the roadways in the Darjeeling Himalayan regions have been a major challenge for the engineers. Researchers and scholars (Ghosh, 1950; Nautiyal, 1951, 1966; Dutta et al, 1966; Roy and Sensharma, 1967; Basu, 1985, 1987 and 2001; Verma, 1972; Paul, 1973; Sinha, 1975; Chatterjee, 1983; Sengupta, 1995; Basu and De, 2003; Pal, 2006; Bhandari, 2006; Maiti, 2007; Kumar et al, 2008; Ghosh, 2009; and Sarkar, 2011) carried out a demand oriented studies on Himalayan landslide and identified the causes and consequences of this phenomena. Almost every monsoon period, these roadways get blocked due to landslides sometimes for a stretch of days. Due to limited number of roadways in the region and absence of alternative route, people as well as essential commodities get stranded on the road during such natural calamities. The study area encompasses most of the trouble spots along national highway NH-31A, 55 and State Highway SH 12 A. To restrict this type of slope failure in mention study route we all have to know their characteristics, their nature to take right management procedure.

TABLE – 1: ROUTE AXES OF THE STUDY AREA.

SL.NO	ROUTE ID	STUDY AREA	APPROX. DISTANCE (KM)
1.	NH 31 A	SILIGURI TO RANGPO	80
2.	NH 55	SILIGURI TO DARJEELING VIA KURSEONG	65
3.	SH 12 A	SILIGURI TO MIRIK	55

LOCATION MAP

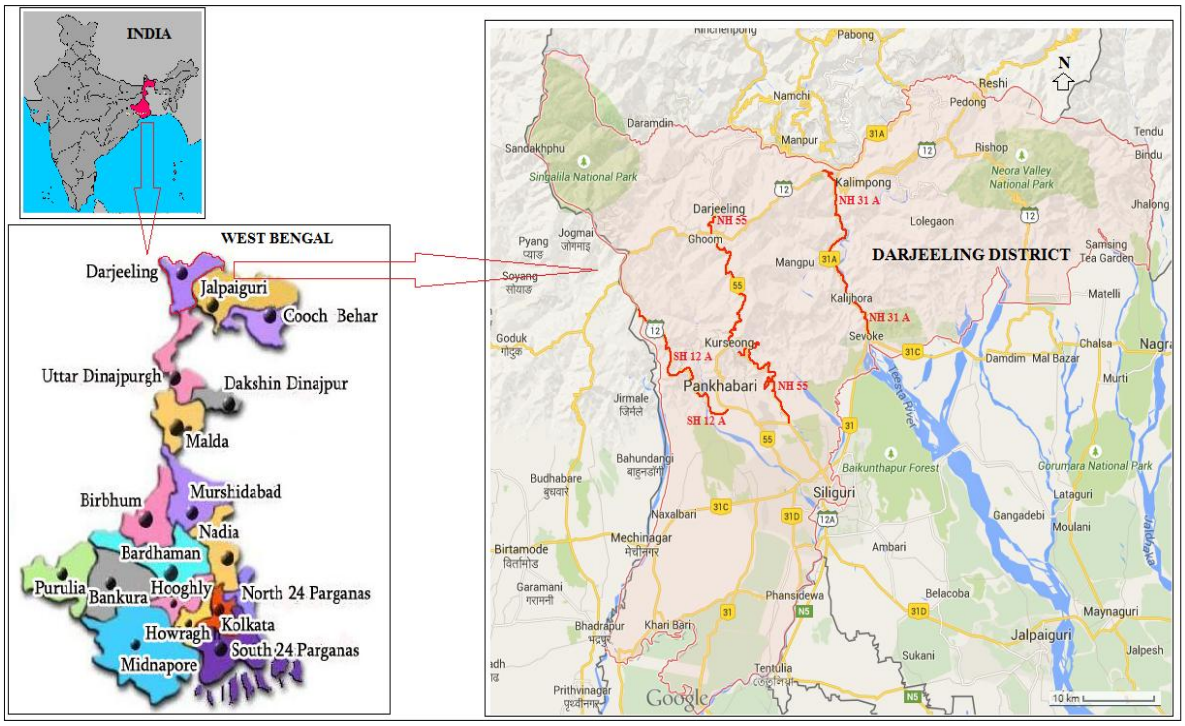

Fig: 1- Location Map of The Study Route i.e. NH 31 A, NH 55 and SH 12 A of Darjeeling District.

I.I. CAUSES OF LANDSLIDE

According to USGS- 2004 the basic causes of landslide are below-

TABLE – 2: THE VARIOUS BASIC CAUSES OF LANDSLIDE.

Geological causes	Morphological causes	Human causes
Weak or sensitive materials	Tectonic or volcanic uplift	Excavation of slope or its toe
Weathered materials	Glacial rebound	Loading of slope or its crest
Sheared, jointed, or fissured materials	Fluvial, wave, or glacial erosion of slope toe or lateral margins	Drawdown (of reservoirs)
Adversely oriented discontinuity (bedding, schistosity, fault, unconformity, contact, and so forth)	Subterranean erosion (solution, piping)	Deforestation
Contrast in permeability and/or stiffness of materials	Deposition loading slope or its crest	Irrigation
	Vegetation removal (by fire, drought)	Mining
	Thawing	Artificial vibration
	Freeze-and-thaw weathering	Water leakage from utilities.
	Shrink-and-swell weathering	

Source- after USGS-2004

I.2 TYPE OF LANDSLIDE

The landslide types can also be understood in terms of the context and situation by knowing the slope history at different times, as given in Bhandari (2006) -

i. Old landslides dormant for decades or centuries, including those which are known to be dormant for decades under a thick cover of vegetation, without showing any signs of instability or activity.
ii. Old landslides which are known to be dormant for decades but are feared to activate due to neglect of slopes, ongoing developmental activities or such other reasons.
iii. Landslides only a few years old, but with no recurrent activity observed since then.
iv. Old landslides, which appear to be dangerously big, but their activity levels remain unstudied and their slope history is unknown.
v. Recent landslides with clear evidence and/unquestionable potential for repetitive activity and enlargement.
vi. Known landslides, periodically treated with partial, inadequate, temporary and non-engineered remediation.
vii. Recent small landslides, with evidence of self-healing.
viii. Landslides, old or recent, under effective (engineered) control.

TABLE – 3: CLASSIFICATION OF LANDSLIDE ACCORDING TO TYPE OF VULNERABILITY SCALE, TYPE OF NATURE i.e. TYPE OF MOVEMENT, TYPE OF ACTIVITY, TYPE OF DISTRIBUTION, AND TYPE OF STYLE.

Type of Vulnerability	Type of Movement Type of Materials Bedrock Engineering soil Mainly coarse Mainly fine	Type of Activity	Type of Distribution
Highly Vulnerable	Fall- Rock Debris Earth fall	Active	Advancing
Vulnerable	Topple- Rock Debris Earth topple	Reactive	Retrogressive
Moderate Vulnerable	Slide- Rotational- Rock Debris Earth Slump Slump Slump	Suspended	Widening
Dormant	Rotational (few)- Rock Debris Earth Block slide Block Slide Block Slide	Inactive	Progressive
Become Vulnerable	Translational- Rock slide Debris slide Earth slide	Dormant	Diminishing
Not So Vulnerable/ Not Vulnerable	Spread- Block- Rock Debris Earth Liquefaction- - - -	Abandoned	Confined
	Flow- Rock Debris Earth	Stabilized	Type of Style
	Complex- (Combination of two or more principle type of movement)	Fossil/ Ancient/ Relict	Complex Composite
	Sinking Zone		Multiple Successive Single

II. MATERIALS AND METHOD

The study was carried out with two parallel methods. In the first process various type of secondary data collected from different sources. Data collected from various government and nongovernmental organisation. Various publication of central and state government, institution, publication prepared by research scholar of different university and organisation are carefully study. In the second process after collecting different type of data all are summarised, analysis to make relationship among them. The road maps of Darjeeling district and landslide occurrence along the study route are carefully study. After that all landslide data are classified and calculated percentage according to vulnerability scale, type of movement, type of activity, type of distribution

and type of style to understand present situation of landslide zone along the study route. Finally the map and cartogram are prepared to represent the paper.

III. RESULT AND DISCUSSION

The study area encompasses most of the trouble spots along national highway NH-31A, NH- 55 and State Highway SH-12 A. In the following study highlight the landslide location, their vulnerability, nature of slide by means of type of activity of slide, type of distribution, and type of style took place in National and State Highway run across the Darjeeling district of West Bengal. As there is no alternative way of this landlocked district after landslide most of the transportation system break down for a certain period. Thus constructer and engineers faced a lot of problem to construct and maintain the highway in the study area. The following tables (Table no. – 4, 5, and 6) are together highlight the major landslide and their general characteristics took place along the study route (NH- 31 A, NH- 55 and SH- 12 A) of Darjeeling district which together approximately 200 km extended.

TABLE – 4: MAJOR LANDSLIDE ALONG **NATIONAL HIGHWAY- 31 A**

SL.NO.	LANDSLIDE	LOCATION	VULNERABILITY	NATURE OF SLIDE
1.	Sevoke Kalimandir Slide	26^0 54.03′ N 88^0 28.46′ E	Highly Vulnerable	Rock slide. State- Active confined and single.
2.	1.8 Km. Sinking zone	26^0 54′ 27″ N 88^0 28′ 14″ E	Not so Vulnerable	Sinking zone. State-Active, confined, single.
3.	6.8 Km. Slide	26^0 56.2′ N 88^0 26.57′ E	Vulnerable	Rock slide. State- Active, confined, single.
4.	8.3 Km. Slide	26^0 56.8′ N 88^0 26.57′ E	Dormant category	Rock slide, State-Dormant, confined and single. It was active till 2003.
5.	Birik Slide	26^0 58.2′ N 88^0 25.7′ E	Not so vulnerable	Rock slide. State- Dormant, confined, single.
6.	27 mile slide	27^0 00′ 12″ N 88^0 26′ 34″ E	Highly vulnerable	Debris slide, state- Active, enlarging, successive.
7.	23.3 Km slide	27^0 01′ 0.02″ N 88^0 26′ 14.4″ E	Moderate vulnerable	Debris slide, state- Active, enlarging, successive.
8.	Lukuvir slide	27^0 02′ 55″ N 88^0 25′ 46″ E	Highly vulnerable	Rock slide, State- Active, retrogressive and composite in nature.
9.	Tista Bridge slide	27^0 03′ 12″ N 88^0 25′ 50″ E	Highly vulnerable	Rock cum debris slide/complex slide. State- Suspended, enlarging, single.
10.	Lepcha Jhora slide	27^0 04′ 04″ N 88^0 25′ 57″ E	Highly vulnerable	Sinking zone. State- Active, advancing and complex in nature.
11.	Melli Bazar slide	27^0 05′ 15″ N 88^0 27′ 32″ E	Not vulnerable	Debris slide. State- Dormant, diminishing and single.
12.	Melli slide-II	26^0 06′ 07″ N 88^0 28′ 14″ E	Become vulnerable	Debris slide. State- Reactivated, confined, complex.
13.	40 Km slide	27^0 08′ N 88^0 30.45′ E	Become vulnerable	Sinking zone. State- Reactivated, expanding and complex.
14.	42.4 Km. Slide	27^0 08.12′ N 88^0 30.84′ E	Become vulnerable	Rock cum debris slide/complex slide. State- Reactivated, confined and complex.
15.	Sangoe/Tar Khola slide	27^0 08.468′ N 88^0 31.325′ E	Not vulnerable	Debris slide. State- Fossil/relict, confined, single.

TABLE – 5: MAJOR LANDSLIDE ALONG **NATIONAL HIGHWAY- 55**

SL.NO	LANDSLIDE	LOCATION	VULNERABILITY	NATURE OF SLIDE
16.	64.5 Km. Slide	26^0 49′ 13″ N 88^0 20′ 43″ E	Not vulnerable	Rock cum debris slide/complex slide. State- Dormant, confined and single.
17.	61 Km. Slide	26^0 49′ 31″ N 88^0 20′ 21″ E	Not vulnerable	Sinking zone. State- Dormant, diminishing and single.
18.	Kopahigrows slide	26^0 50′ 49″ N 88^0 20′ 19″ E	Not vulnerable	Rock cum debris slide/complex slide. State- Dormant, confined and single.

19.	54.5 Km. Slide	26^0 52.035′ N 88^0 18.309′ E	Vulnerable	Rock slide. State- Active, retrogressive, successive.
20.	14 Mile slide (Pagla Jhora-II)	26^0 52′ 15″ N 88^0 18′ 30″ E	Vulnerable	Rock slide. State- Active, retrogressive, successive.
21.	Pagla Jhora sinking zone	26^0 52.7′ N 88^0 18.46′ E	Highly vulnerable	Sinking zone, State- Active, enlarging, and complex.
22.	Upper Pagla Jhora slide	26^0 52.89′ N 88^0 18.51′ E	Vulnerable	Rock cum debris slide/complex slide. State- Active, enlarging, and successive.
23.	Giddapahar slide	26^0 52′ 20″ N 88^0 17′ 45″ E	Vulnerable	Rock slide. State- Dormant confined and single.
24.	Kharav-Khola slide	26^0 53′ 52″ N 88^0 17′ 19″ E	Vulnerable	Debris slide/ debris avalanche. State- Suspended, enlarging and single.
25.	Tung slide	26^0 55′ 45″ N 88^0 18′ 06″ E	Vulnerable	Debris slide. State- Dormant confined and single.
26.	Devisthan Jhora slide	26^0 57′ 19″ N 88^0 17′ 21″ E	Highly vulnerable	Rock cum debris slide. State- Active, confined, single.
27.	Sudhapatal slide	26^0 53′ 15″ N 88^0 16′ 41″ E	Vulnerable	Rock cum debris slide. State- reactivated, confined and single.
28.	Nimkidhara slide	27^0 01′ 26″ N 88^0 15′ 42″ E	Not so vulnerable.	Rock cum debris. State- active, confined and single.

TABLE – 6: MAJOR LANDSLIDE ALONG **STATE HIGHWAY- 12 A**

SL.NO	LANDSLIDE	LOCATION	VULNERABILITY	NATURE OF SLIDE
29.	5.5Km. slide	26^0 49′ 25″ N 88^0 14′ 03″ E	Not vulnerable	Rock cum debris slide/complex slide. State- Dormant, confined.
30.	9 Km. Slide	36^0 49′ 27″ N 88^0 13′ 58″ E	Not vulnerable	Debris slide. State- Fossil confined and single.
31.	Gayabari slide	26^0 50′ 30″ N 88^0 13′ 52″ E	Not so vulnerable	Debris slide. State- dormant confined and single.
32.	14.75 Km. slide	26^0 50′ 30″ N 88^0 13′ 52″ E	Not so vulnerable	Sinking zone. State- dormant, confined and single.

- Active Slide

Source: Special Publication No. – 94, GSI, EASTERN REGION, KOLKATA, 2009.

The roadways specially national and state highway is very much landslide vulnerable due to unique geological setting of young Himalayan terrain and increased motor vehicle day after day. The several time earthquake and frequent rain during monsoon period accelerated or triggered landslide vulnerability. Out of total landslide took place in this three highways today about 37% are not so vulnerable. But due to unscientific use along and around highways most of the dormant and not so vulnerable landslide area about 9% again becomes vulnerable. Almost 24% areas are determined as highly vulnerable and another 24% landslide area is subjected to vulnerable landslide zone in the study route.

TABLE – 7: TYPE OF VULNERABILITY SCALE AND THEIR FREQUENCY.

SL. NO	TYPE OF VULNERABILITY SCALE	FREQUENCY (%)
1.	HIGHLY VULNERABLE	24
2.	VULNERABLE	24
3.	MODERATE VULNERABLE	03
4.	DORMANT	03
5.	BECOME VULNERABLE	09
6.	NOT SO VULNREABLE/ NOT VULNERABLE	37

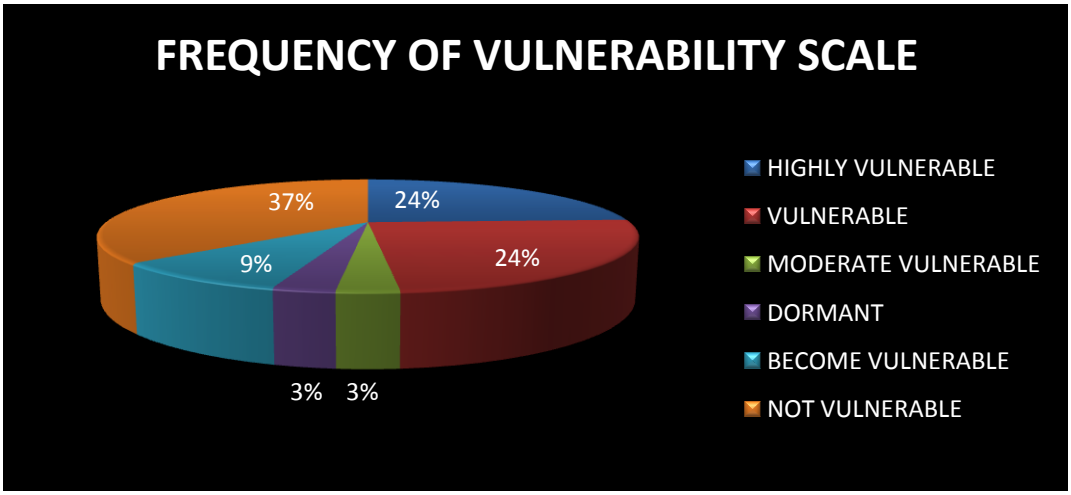

Fig: 2– Frequency of Landslide Vulnerability in the study area.

During the landslide masses of rocks, debris, sometimes rock cum debris move down on slope by a share zone or slip surface where as some places may sink. On the basis of Nature of slide 21% and 18% respectively are rock slide and debris slide in nature took place in and around the study route. Almost 31% are complex slide in nature that means rock cum debris slide together took place. About 30% of the landslide zones are sinking zone in nature.

TABLE – 8: FREQUENCY OF LANDSLIDE ACCORDING TO NATURE OF SLIDE.

SL.NO	NATURE OF SLIDE	FREQUENCY (%)
1.	ROCK SLIDE	21
2.	DEBRIS SLIDE	18
3.	ROCK CUM DEBRIS SLIDE/ COMPLEX SLIDE	31
4.	SINKING ZONE	30

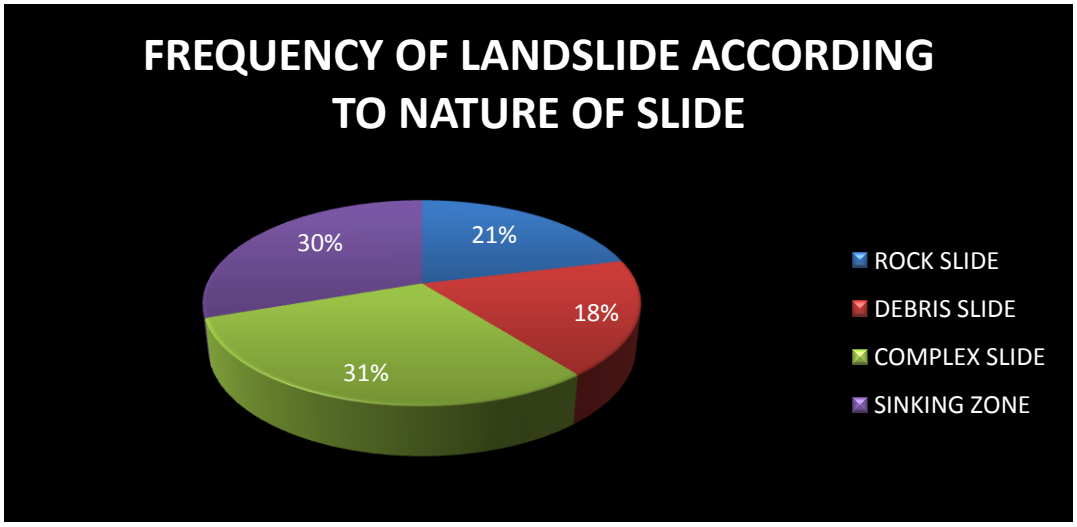

Fig: 3– Frequency of Slide according to Nature of Slide.

An active landslide is currently moving. A reactivated landslide is an active landslide which has been inactive. A suspended landslide has moved within the last 12 months, but is not active at present. An inactive landslide has not moved within the last 12 months and can be divided into 4 states: Dormant, Abandoned, Stabilised and Relict/Ancient/ Fossil. A dormant landslide is an inactive landslide which can be reactivated by its original causes or other causes. An abandoned landslide is an inactive landslide which is no longer affected by its original causes. A stabilised landslide is an inactive landslide which has been protected from its original causes by remedial measures.

A relict landslide is an inactive landslide which developed under climatic or geo morphological conditions considerably different from those at present. In the study route most of the slide zones (almost 43%) are subjected to active slide and almost 12% of landslide zone become reactivated. Only 06% of landslide zone has move within the last 12 months but is not active at present that means these are suspended landslide zone. Rest of 39% are belonging to inactive landslide zone where slide has not moved within or above the last 12 months.

TABLE – 9: FREQUENCY OF LANDSLIDE ACCORDING TO TYPE OF SLIDE ACTIVITY.

SL.NO	TYPE OFACTIVITY OF SLIDE	FREQUENCY (%)
1.	ACTIVE SLIDE	43
2.	REACTIVE SLIDE	12
3.	SUSPENDED SLIDE	06
4.	DORMANT	33
5.	FOSSIL/ ANCIENT/ RELICT	06

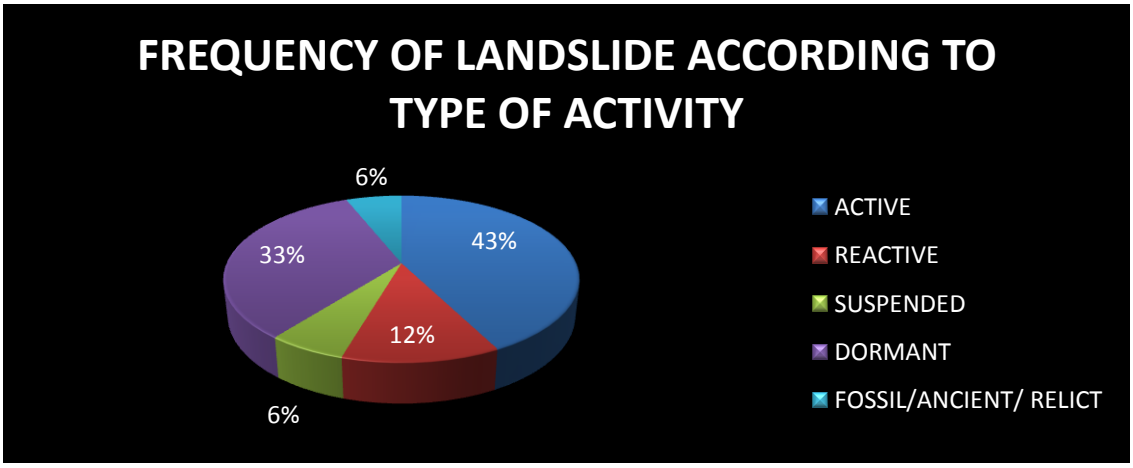

Fig: 4– Frequency of Landslide according to Type of Activity in the Study area.

In an advancing landslide the rupture surface is extending in the direction of movement. In a retrogressive landslide the rupture surface is extending in the direction opposite to the movement of the displaced material. In an enlarging landslide the rupture surface of the landslide is extending in two or more directions. In a diminishing landslide the volume of displaced material is decreasing. In a confined landslide there is a scarp but no rupture surface visible at the foot of the displaced mass. In a moving landslide the displaced material continues to move without any visible change in the rupture surface and the volume of the displaced material. In a widening landslide the rupture surface is extending into one or both flanks of the landslide. In the three highway study route most of the landslide areas are confined (59%). About 22% are enlarging landslide and 10% are retrogressive landslide in nature of the study route. About 3% are advancing landslide where the rapture surface is extended in the direction of movement. About 10% landslides are retrogressive in nature where rupture surface is extending in the direction opposite to the movement of the displaced materials.

TABLE – 10: FREQUENCY OF LANDSLIDE ACCORDING TO TYPE OF DISTRIBUTION.

SL. NO	TYPE OF DISTRIBUTION	FREQUENCY (%)
1.	ADVANCING	03
2.	RETROGRESSIVE	10
3.	ENLARGING	22
4.	DIMINISHING	06
5.	CONFINED	59

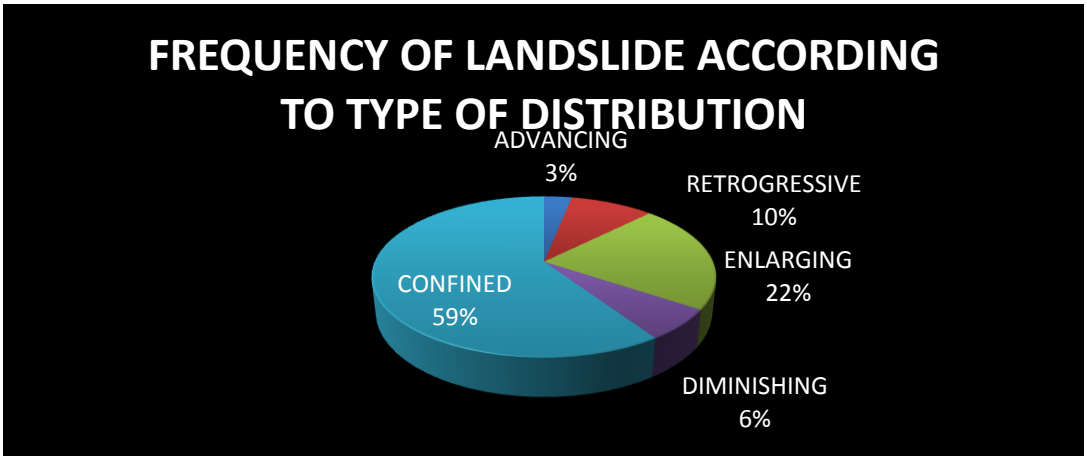

Fig: 5– Frequency of Landslide according to Distribution in the Study area.

A complex landslide exhibits at least two types of movement (falling, toppling, sliding, spreading, flowing and sinking) in sequence. A composite landslide exhibits at least two types of movement simultaneously in different parts of the displacing mass. A multiple landslide shows repeated development of the same type of movement. A successive landslide is the same type as a nearby, earlier landslide, but does not share displaced material or rupture surface with it. A single landslide is a single movement of displaced material. In the study route most of the landslides about 65% are belong to single landslide where a single movement of displaced materials took place. About 16% of landslide are complex and another 16% are successive in nature means these landslide exhibits at least two type of movement in sequence or the landslide is as same as earlier slide but does not share displaced material or rupture surface in it.

TABLE – 11: FREQUENCY OF LANDSLIDE ACCORDING TO TYPE OF STYLE.

SL. NO	TYPE OF STYLE	FREQUENCY (%)
1.	COMPLEX	16
2.	COMPOSITE	03
3.	MULTIPLE	00
4.	SUCCESSIVE	16
5.	SINGLE	65

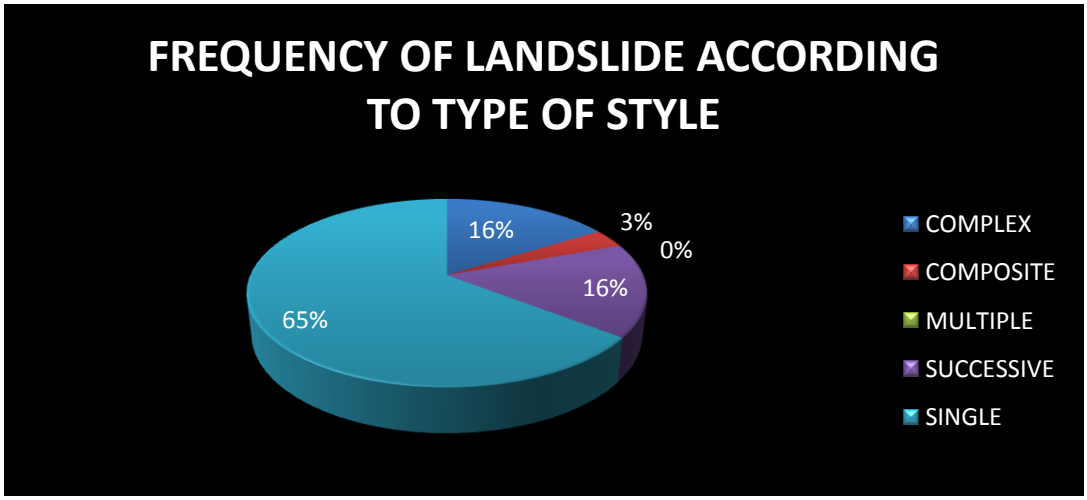

Fig: 6- Frequency of Landslide according to Type of Style.

IV. CONCLUSION AND RECOMMENDATION

Apart from all measure are taken previously in the study route landslide is continue in different form and different magnitude with untold suffer of inhabited and tourist along the study highways. The following recommendation may helpful to save the lifeline of transportation of northern most landlocked district of West Bengal-

Recent measure such as-

i. Rescue operation as early as possible.
ii. First aid and hospitalised the injured people.
iii. Removal of debris to overcome breakdown situation of transportation system.

Structural measure such as-
i. Treatment of slope and drainage system.
ii. Afforestation programme.
iii. Scientific engineering construction of human settlement.
iv. Wide expansion of Tea plantation, Urbanisation, Unscientific mining and Cultivation, Construction, Large dam in river channel for Hydroelectricity should not be welcome.

Non structural measure such as-
i. Data mining and hazard zonation mapping.
ii. Geological and geotechnical investigation.
iii. Awareness.
iv. Landslide monitoring and forecasting.
v. Human man power capacity building.
vi. Proper land uses planning and its rules, regulation and its proper implementation.
vii. Village wise training programme for elders and landslide management education from school level.
viii. National and inter-state co-operative programme should lunch to save the lifeline highways (NH-31 A, NH- 55 and SH 12 A) of landlocked district- Darjeeling.

All three national and state highways are become much more vulnerable day after day. During massive calamity such as earthquake or frequent massive rain in monsoon period trigger landslide in three highway breakdown all the transportation system of hilly Darjeeling terrain. For the daily need for inhabited the northern most district of West Bengal depend on Siliguri town but when landslide took place in the study route as no alternative route the district is isolated from rest of the state. So, by knowing the importance of study route and nature of a specific landslide zone right scientific measure should be taken to minimise this hazard on lifeline of landlocked Darjeeling district.

V. ACKNOWLEDGEMENT

This paper could not have been completed without significant valuable support of following people and organisation.

- My heartfelt thanks to (a) Prof. Sujit Kumar Mandal, Department of Geography, Gour Banga University and (b) Prof. Malay Bhattacharya, Department of Botany, Kalimpong College, NBU for provide me valuable inputs from their highly enriched sources.
- I also thankful to all the Institution and Organisation who co-operated with me more or less for conducting the study.

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