कर्नाटक राज्य के दक्षिण कन्नडा जिले में बेल्टनगाडी तालूक में नेरिया के किनारे भूस्खलन पर विस्तृत स्थल विशेष अन्वेषण

(क्षेत्र सत्र 2009-10 का प्रगति प्रतिवेदन)

कूट सं.: एल.एच.जेड./एस.आर./के/जी/2009/045

द्वारा

के.वी.मारुति, वरिष्ठ भूविज्ञानी

ए.के.मिश्रा, वरिष्ठ भूविज्ञानी

सारांश

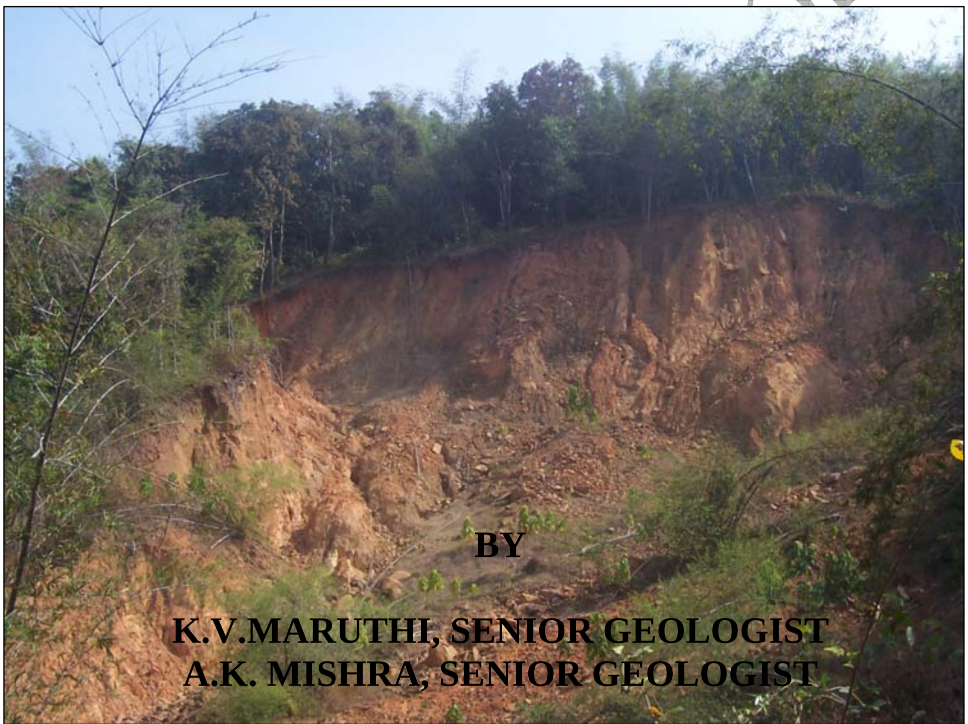
कर्नाटक में दक्षिण कन्नडा जिले के बेल्टनगाडी तालूक में अणियूर के पास नेरिया गाँव में दिनांक 13 अगस्त,2008 को भूस्खलन हुआ जिसमें चार घर नष्ट-भ्रष्ट हे गए. प्राथमिक पश्च आपदा अध्ययन दिनंक 18.08.2008 को किया गया एवं स्खलन विशेषताओं को जानने एवं दीर्घकालीन उपाय मार्ग के लिए प्रस्तावित करने हेतु विस्तृत अध्ययन का प्रस्ताव दिया गया. क्षेत्र सत्र 2009-2010 के दौरान सेवा मद के रूप में विस्तृत स्थल विशेष अध्ययन का आरंभ किया गया जो स्लाइड विशेषताओं, भूस्खलन के कारणात्मक घटकों को जानने के लिए एवं उपाय मार्गों को सुझाव देने के उद्देश्य से था. नेरिया भूस्खलन अणियूर के पास नेरिया गाँव के पास स्थित है एवं बेल्टनगाडी क्षेत्र के अश्म विज्ञान में बायोटाइट नाइस शामिल है जिसमें डोलेराइट का अन्तर्वेधन पाए गए है. स्खलन संस्तर में नाइस काफी अपक्षीण हुए है. 1:1000 प्रतिमान के स्थल योजना पर (0.15 km2 के क्षेत्र) तैयार किए गए एवं स्खलन के ज्यामितीय को आकलित करने के लिए तीन अनुप्रस्थ परिच्छेद खींचे गए. ढाल में मुख्यतया स्थमल (बजरी, गोलाश्मिका एवं गालेश्म) एवं तरुण वस्तु (मृत्तिका, साद एवं रेत) पाए गए है. इसीलिए वेर्नें के वर्गीकरण के अनुसार नेरिया के पास पाए गए स्लाइड. को " लार्ज डीप सीटेड डेर्बिस फ्लो'' के रूप में वर्गीकृत किया गया है. यह स्खलन एक नया स्खलन है. स्लाइडेड वस्तु के चलन की गति के अनुसार उस अति तीव्र "फ्लो'' के रूप में वर्गीकृत किया गया है. उच्च स्तर की अपक्षीण अवस्था,सरिता की दिशा की ओर अभिलम्ब नमन वाले प्रतिकूल प्रभाव वाले शिस्टोसिटी, अपक्षीण बायोटाइट/नाइस में मैफिक समृद्ध अन्तक्षेत्र (अवक्षय के संस्तर एवं " क्रौण'' भाग में) की मृत्तिका वस्तु यानि मोन्टनोलिनाइट एवं कायोलिनेट में परिवर्तन, सरिता में कम विसर्जन के कारण ढाल वस्तु की अतिसंतृप्ति एवं भारी वर्षा के साथ उच्च श्रेणी का अंत: स्यदन स्खलन के घटक हैं. स्थल अवस्था एवं भूतकनीकी आकलन के अनुसार "डेर्बिस फ्लो'' के उपाय मार्ग जैसे " वेटिवर" घास को उगाना, उचित जल-निकास व्यवस्था आदि का सुझाव दिया जाता है.

Classified as B (i)

GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA

DETAILED SITE SPECIFIC INVESTIGATION OF THE LANDSLIDE AT NERIYA, BELTANGADY TALUK, DAKSHINA KANNADA DISTRICT, KARNATAKA

(Progress Report for Field Season 2009-2010)
Code No.: LHZ/SR/KG/2009/045



BY

K.V.MARUTHI, SENIOR GEOLOGIST
A.K. MISHRA, SENIOR GEOLOGIST

Project: ENGINEERING GEOLOGY
Operation: Karnataka and Goa

BANGALORE
2011

Classified as B (i)

GOVERNMENT OF INDIA
GEOLOGICAL SURVEY OF INDIA

DETAILED SITE SPECIFIC INVESTIGATION OF THE LANDSLIDE AT NERIYA, BELTANGADY TALUK, DAKSHINA KANNADA DISTRICT, KARNATAKA

(Progress Report for Field Season 2009-2010)
Code No.: LHZ/SR/KG/2009/045

BY

K.V.MARUTHI, SENIOR GEOLOGIST
A.K. MISHRA, SENIOR GEOLOGIST

Project: ENGINEERING GEOLOGY
Operation: Karnataka and Goa
BANGALORE
2011

DETAILED SITE SPECIFIC INVESTIGATION OF THE LANDSLIDE AT NERIYA, BELTANGADY TALUK, DAKSHINA KANNADA DISTRICT, KARNATAKA
(Progress Report for Field Season 2009-2010)
Code No.: Code No.: LHZ/SR/KG/2009/045

BY

K.V.MARUTHI, SENIOR GEOLOGIST
A.K. MISHRA, SENIOR GEOLOGIST

CONTENTS

DETAILED SITE SPECIFIC INVESTIGATION OF THE LANDSLIDE AT NERIYA, BELTANGADY TALUK, DAKSHINA KANNADA DISTRICT, KARNATAKA

(Progress Report for Field Season 2009-2010)

Code No.: Code No.: LHZ/SR/KG/2009/045

BY

K.V.MARUTHI, SENIOR GEOLOGIST
A.K. MISHRA, SENIOR GEOLOGIST

ABSTRACT

The landslide that occurred in Neriya village near Aniyur, Beltangady taluk, Dakshina Kannada district, Karnataka on August 13th 2008, damaged four houses. The preliminary post disaster study was carried out on 18.08.2008 and detailed site specific study was proposed to know the slide characteristics and for proposing long term remedial measures. The detailed site specific study was taken up as a service item during the FS 2009-10 to get insight of the slide characteristics, causative factors of landslide and to suggest remedial measures. The Neriya landslide is located at Neriya village near Aniyur and is 15 kms from taluk head quarters Beltangady. The lithology of the Neriya-Beltangady area comprises of Biotite gneiss intruded by dolerite. The gneiss is highly weathered in the slide zone and partially weathered in the top of the crown. An area of about 0.15 km² of site plan on 1:000 scale was prepared and three cross sections were drawn to evaluate the geometry of the slide. The slope material predominantly consists of coarse (gravel, cobbles and boulders), and finer material (clay, silt and sand). Hence the slide at Neriya is classified as a large deep seated debris flow as per Verne's classification. This slide is found to be a new slide. As per the rate of movement of the slided material it is classified as an extremely rapid flow. The high degree of weathering, adversely oriented gneissosity dipping perpendicular to stream direction, conversion of weathered biotite/ mafic rich enclave in the gneiss (in the crown part and the zone of depletion) to clay particles viz., montmorillonite and kaolinite, over saturation of slope material due to less discharge to the stream and high infiltration along with heavy rainfall preceding the event are the main causes of the slide. As per the site condition and geotechnical evaluation of the factors responsible for the debris flow remedial measures proposed including plantations of vetiver grass, drainage facility etc.

DETAILED SITE SPECIFIC INVESTIGATION OF THE LANDSLIDE AT NERIYA, BELTANGADY TALUK, DAKSHINA KANNADA DISTRICT, KARNATAKA
(Progress Report for Field Season 2009-2010)
Code No.: Code No.: LHZ/SR/KG/2009/045

BY
K.V. MARUTHI, SENIOR GEOLOGIST
A.K. MISHRA, SENIOR GEOLOGIST

I. INTRODUCTION

Landslides is one of the main natural hazards causing enormous destruction in life and property, disrupting communication modes in landslide prone terrain of Western Ghats year after year during monsoon. With increase in population anthropogenic activity increased in Western Ghats resulting in unscientific way of slope modification first for plantation followed by housing and roads for communication. Landslides during every monsoon in Western Ghats are a common phenomenon and are of great concern for general public as well as local administration.

The landslide that occurred in Neriya village near Aniyur, Beltangady taluk, Dakshina Kannada district, Karnataka on August 13th 2008, around 11.00 pm damaged four houses. Preliminary post disaster study was carried out on 18.08.2008 and detailed site specific study was proposed to know the slide characteristics and for proposing long term remedial measure (Pradhan, 2008).

The detailed site specific study was taken up as a service item during the FS 2009-10 (Code No.: LHZ/SR/KG/2009/045) to get insight of the slide characteristics, causative factors of landslide and to suggest remedial measures.

I.1.LOCATION : The Neriya landslide area is located at latitude 13° 00′ 21″ N and longitude 75° 27′ 03″ E in Survey of India Toposheet No 48 O / 8, in Neriya village near Aniyur and is 15 kms from taluk head quarters Beltangady. (Plate- 1)

I.2.PREVIOUS WORK: Preliminary post disaster investigation of the landslide was carried out during 2008(Pradhan, 2008). The slide was described as a debris flow caused due to heavy rain and toe cutting by the streams. Grading of the slope with benches, construction of gabion wall with weep holes, planting vegetation on the slope was suggested to stabalise the slope. Detailed site specific study for suggesting long term remedial measures was also recommended.

I.3.SCOPE AND OBJECTIVE: The objective of the study was to evaluate the slide dimensions and morphomety, crack propagation if any, mechanism of failure, triggering mechanism, depth and type of failure circle, stability of the slope, risk associated with the slide in the area and to propose suitable long term remedial measures or precautionary measure to stabilize the slope.

I.4. NATURE AND QUANTUM OF WORK

Sl.No	NATURE OF WORK	TOTAL WORKLOAD ENVISAGED	WORK COMPLETED
1.	DM (1:1000 Scale) Sq.km	0.1 Sq.km	0.15 Sq.km
2.	Geological section a)Longitudinal section on 1:1000 b)Cross section on 1:1000	 2 Profiles 3 Profiles	 2 Profiles 3 Profiles
3.	Electrical resistivity Sounding	AN	Not required
4.	Drilling and SPT	AN	Not required

I.5. ACKNOWLEDGEMENTS: The authors extend their sincere thanks to Shri. R. Panduranga, the then Director EG Division, Op: Karnataka & Goa, GSI, Bangalore for his guidance during investigation, and to Dr.S.S.Nayak Director EG Division, Op: Karnataka & Goa, GSI, Bangalore for scrutiny of the report. They also extend their thanks to Deputy Director General, Op: Karnataka. & Goa, GSI, Bangalore for his encouragements and support. Thanks are due to, Tahsildar Beltangady taluk, village accountant and asst. village accountant Neriya village and other taluk administrative staffs for providing necessary help during the field work. Thanks are also due to residents of Neriya village for rendering co-operation during investigation.

II. PHYSIOGRPHY AND CLIMATE

II.1. TOPOGRAPHY: The Neriya landslide occurred on the Butada Gudda ▲368 trending NW-SE with Dense mixed Jungle (semi evergreen forest). The highest elevation in the area is 878m above MSL (Minji Kallu in Maniyala Gudda NE of Butada Gudda). Metalled road from Aniyur village to Neriya village runs at elevation of 110 m in NS direction perpendicular to flow direction. Relative relief from road is nearly 228m and till the nearest stream bed is 318 m.Distance from top to the nearest stream 1km and the original slope angle is nearly 14º. The average topography is undulating with the ridges and depressions parallel to the slide direction.

II.2. DRAINAGE: The area of investigation is drained by two major parallel streams Ilimalehalla in east and Aniyur hole in the west which drain toward SW. The drainage in the area shows subdendritic to trellis pattern. Smaller streams on either side of the water divide drain in to these two major streams. During rainy season when runoff is high the excess water from the slope drains out through the major depression.

III.3. LANDUSE AND LANDCOVER: The study area is a dense mixed jungle (semi evergreen forest) and slopes have been modified for rubber and cardamom plantations. Locally people have areca nut and coconut plantations also. The Agricultural land/populated flat land are mainly restricted to the valleys and the modified stream banks.

III.4. CLIMATE AND RAINFALL: The investigated area lies in the Western Ghats and has a tropical humid climate. Hence receives sumptuous rainfall during monsoon with a unimodal distribution. In general, the rainfall in this area is very high from June to September. The rainfall data from the nearest rain gauge station of Beltangady for the period 01-08-2008 to 18-08-2007, collected from the local authorities is given in Table 1:

Table 1: Rain fall data of the 7 days before and 7 days after the creep

Month	Date	Rainfall (in mm)
August -2008	1	39.0
	2	27.5
	3	23.0
	4	46.5
	5	53.5
	6	20.0
	7	41.5
	8	23.5
	9	77.0
	10	84.5
	11	100.5
	12	107.5
	13	143.0
	14	68.9
	15	33.8
	16	48.9
	17	45.8
	18	27.1

(Source- PWD office Beltangady)

III.5. GROUND WATER: The Ground water table fluctuation prevent ,the opening up of the joints in the hard jointed gneisses , dislodgement, development of clay bands and increase in depth of weathering, development of soil profile; hence increase the overburden and debris on the slope. The seasonal fluctuation of the ground water table is very high in the area coinciding with the variation in rainfall (as per the rainfall data shows that the area receives 70-80% of the total annual rainfall during the period from June to august). The ground water table at the site was observed in the dug well at the toe part of the slide. During the time of investigation standing water in this well was at a depth of ~1.5m indicating ground water table in general be at a depth of 1.5- 3.0m. Much variation is least expected as the major streams flowing in the study area are perennial.

III.GEOLOGY

III.1.REGIONAL GEOLOGY: The area exposes rocks belonging to Sargur Group and Peninsular Gneisses-I (PG-I). Sargur Group of rocks represented by amphibolite and kyanite-muscovite schist occur as minor lensoidal enclaves within PG-I .Peninsular gneiss represented by gneiss and older granitoid occupies vast area. Peninsular Gneiss is medium to coarse grained, mesocratic consists quartz, plagioclase and minor amounts of biotite. It is Migmatitic at places (Awasthi, 1980)

III.2. LITHOLOGY AT SITE: The lithology of the Neriya, Beltangady area exposes Biotite gneiss intruded by dolerite. The gneiss is highly weathered in the slide zone (photo 10,11,12) and partially weathered in the top of the crown.

III.2.1. BIOTITE GNEISS: The rocks are well exposed in the crown scarp, at the head portion behind the slide scarp around 240 R.L, at mid slope region and behind Janardhan shetty house at the toe region (Plate-2, 3) It is coarse grained, light grey, foliated granite gneiss with gneissosity varying from N21°W to N10°E dipping 42° towards south to vertical (Photo 9&10). The boulders of gneiss are also found in the debris as float mass. Six sets of joints are observed from gneiss in the slide zone (Photo 8 & 9) characteristics of these joints are given in Table-2.

Table2: The characteristics of the 6 set joints in gneisses.

Sl No	Place of Observation	Joint set	Attitude	Spacing	Opening / Filling	Characteristics
1	In mid slope in nala cutting(right bank)	Jt1 (foliation plane)	N10°E/71°NW	-	-	-
2	In mid slope in nala cutting(right bank)	Jt2	N35°W/65°NE	2-15 cm	Nil	Uneven, stained, seepage of water seen
3	In mid slope in nala cutting(right bank)	Jt3	N70°W/Vertical	10-15 cm	2mm/ soil	Smooth, uneven, stained, seepage of water seen
4	In mid slope in nala cutting (left bank)	Jt4(foliation plane)	N10°E/16°NW	-	-	-
5	In mid slope in nala cutting (left bank)	Jt5	N55°W/64°SW	5-15 cm	Tight	Smooth, stained, seepage of water seen
6	In mid slope in nala cutting (left bank)	Jt6	N76°W/Vertical	6-10 cm	Tight	Uneven, discontinuous

III.2.2. DYKES: A Dolerite dyke trending N39°W-S39°E is exposed below the crown of the slide on right flank and in centre of the slide. It is fine to medium grained, dark green to bottle green in colour consisting of pyroxene and plagioclase (Photo 7). Two sets of joints noticed in the dyke. The characteristics of these joints are given in Table-3.

Table3: The characteristics of the 2 set joints in dyke.

Sl No	Place of Observation	Joint set	Attitude	Spacing	Opening / Filling	Characteristics
1	Near crown	Jt1	N35°W/Vertical	10-30 cm	-	-
2	Near crown	Jt2	Horizontal	1-2 m	-	-

III.2.3. DEBRIS AND BOULDER UNIT: This unit consists of unconsolidated rock fragments of dyke and gneisses (gravel, cobble and boulder size) and sand, silt & clay. The size of blocks dispersed all over the slide zone ranges from 1to 4m. The size of debris may be classified as follows;

Big boulders: > 400 cm

Small boulders: <400 cm > 100cm

Pebble/cobble: <100 cm >10cm

Sand/silt: <10 > 1mm

Clay: <1mm

An attempt was made to classify the % distribution of above materials in the debris as a whole and is given in Table-4.

Table4: The % distribution of debris material.

Place	Big boulders (> 400 cm)	Small boulders (<400 cm > 100cm)	Pebble/cobble (<100 cm >10cm)	Sand/silt (<10 > 1 mm)	Clay (<1mm)
Between survey station 6 and 5 (near to Toe portion)	<5%	<5%	20%	10-15%	60%
Between survey station 5 and 4 (near to mid slope portion)	5%	5%	30%	10%	50%
Between survey station 4 and 3 (mid slope portion)	10%	10%	40%	10%	10%
Between survey station 3 and 2 (mid slope portion to near top slope portion)	10%	10%	50%	10%	20%
Between survey station 2 to toe of crown scarp (near top slope portion)	20%	20%	25%	5%	30%

It is clearly seen that the clay percentage increases in the toe portion because of the gully erosion which is continuing and the debris in the stream bed was eroded and causing more silt and clay deposition in the down stream. At the crown portion the percentage of boulders and pebbles increases considerably indicating the removal of blocks from the highly weathered gneisses.

III.2.4. CLAY UNIT: This unit consistently increases with the flow direction and at the middle slope to down slope onwards most of the debris consists of clay material. The clay formation is mainly due to conversion of weathered biotite gneiss and dyke material (in the crown part and the zone of depletion) to clay particles viz., montmorillonite and kaolinite.

III.3. WEATHERING: The type of litho units in the slope and nature and extent of weathering determine: a) the amount of pore space available and the permeability of the material present in the slope b) the clay content of the material in the slope and c) the retentivity and runoff of the slope material. The base failure (i.e. the slip failure with slip circle along the rock and debris contact) is controlled by the orientation of the weak planes in the rock. The gneissic rock wherever exposed in the slide zone is fresh to partially weathered. Dolerite dyke is also fresh to partially weathered at surface. The highly jointed nature of the rock in association with high rainfall dislodged huge blocks of the dyke and gneiss which have rolled down and are scattered all over the slope as float mass. Depth of weathering is estimated up to 25-30 m in the slide zone.

IV. LANDSLIDE CHARACTERISTICS

An area of about 0.15 km² of site plan on 1:000 scale was prepared (Plate-2) and three longitudinal and three cross sections were drawn to evaluate the geometry of the slide (Plates-3 and 4). As per the plan the geometry of the slide indicates crown scarp is on average 15 m high with highest point in the centre of 35 m. the scarp is vertical head scar exposing jointed biotite gneisses and dolerite dyke. No major cracks either longitudinal or tensional were observed. Gneisses with dolerite dykes occupy the slide area. The material in the slide zone is debris comprising of clayey soil and boulders of gneisses/ dyke. The original slope angle was 14 º. The modified slope angle of the slide zone varies from 18º-30º (Photo 5 & 6). The debris flow started from the zone of depletion and moved along the stream course which drains towards SW direction and turns towards West direction near the road. The slided debris accumulated near the road and the plantation area beyond the road in the down stream side, stopping just before engulfing two houses in its path (Photo 16). The lobate shaped slide formed a cuspate spreading foot near the toe overflowing the stream bank on the right side.

IV.1. MORPHOLOGICAL PARAMETERS

The morphological parameters of the hill slope were calculated from the contours of the 1:50000 scale toposheet and the slide morphometry was calculated from the plan and sections prepared in the field using total station on 1:1000 scale.

IV.1.1. HILL SLOPE MORPHOMETRY

a.	Length of the hill slope from water divide to river channel	(Ls)	:	~2.0km
b.	Vertical height between the heights of the water divide and of the stream	(Hs)	:	225m
c.	Plan distance of the slope from divide to stream	(HEs)	:	925mm
d.	Mean slope angle	(Bs)	:	13.67°

IV.1.2. SLIDE MORPHOMETRY

a.	Maximum length of the flow from crown to frontal lobe	(Lm)	:	790.30m.
b.	Maximum width of the slide zone from the left flank to the right flank boundary	(Wm)	:	70.0m
c.	Maximum depth of the failed mass from the surface of the slide to the failure surface	(Dm)	:	18 m
d.	Perimeter of the source of the solid fraction material		:	410 m
e.	Area of the debris flow in plan	(A)	:	~39500m²
f.	Debris flow Volume	(V)	:	~20,000m³
g.	Slope angle after failure took place	(β)	:	18º

IV.2. TYPE AND SIZE OF SLIDE MATERIAL: The slope material predominantly consists of coarse (gravel, cobbles and boulders), and fine material (clay, silt and sand) (Table 4). Hence it may be classified as debris following Varnes, 1978 and Cruden and Varnes, 1996.

IV.3. CLASSIFICATION: The factors used to classify landslides mainly are type of material involved, geomorphic attributes of the slope, landslide geometry, type of movement, climate, water content of the slided material, speed of movement of the slide, triggering mechanism etc. Landslides can be rapid or slow, and occur in a wide variety of geologic environments.

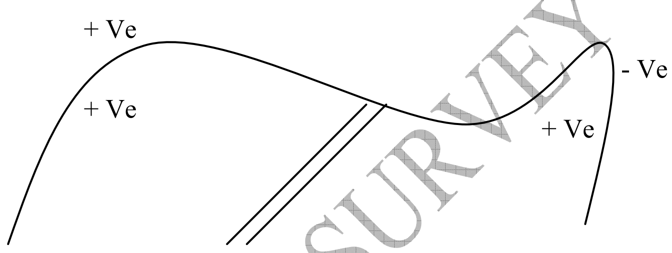
As per the observation the Neriya slide is found to be a new slide and is classified as a large deep seated debris flow as per Verne's classification (Vernes 1978). As per the rate of movement it is classified as an extremely rapid flow. As per Fell,(1994) size classification for landslides, the Neriya slide can be grouped in class 3. The Neriya debris flow can also be classified as a Class 3 debris flow with volume as per Jacob (2005).

V. CAUSES AND TRIGERRING MECHANISM

The initiation of a debris flow is a landslide which contributes to the solid fraction of the debris flow material. Instability of any slope increases over a period of time due to various factors like slope modification, quality and density of slope forming material, weathering depth and conditions, ground water table variation etc. affecting independently or simultaneously. These factors are difficult to quantify but there are a number of factors which may be operating either to increase the shear stress or to decrease the shearing resistance of the material (e.g. by decreasing the normal shearing resistance because of pore pressure increase) causing the slope failure. There are also other causes that affect both the parameters of safety factor hence decreasing the safety factor, allowing the slope to fail.

V.1.CAUSES: The main causes for the Neriya debris flow can be summarized as follows

1. The high degree and depth of weathering, wherein the biotite gneiss has been kaolinised (Photo 10, 11 & 12).
2. The lateritization of gneissic rock (as seen in debris) with clay particles.
3. The adversely oriented gneissosity dipping perpendicular to stream direction.
4. The weakened contact between gneiss and the dolerite dyke due to weathering and soil/ laterite formation.
5. Part of the slide took place in a negative slope in the right flank where the volume of material is less and failed from the top of the slope.



8. The conversion of weathered biotite/ mafic rich enclave in the gneiss (in the crown part and the zone of depletion) to clay particles viz., montmorillonite and kaolinite.
9. The over saturation of slope material due to less discharge to the stream and high infiltration.

V.2.TRIGERRING MECHANISM: Rainfall is the immediate triggering factor for almost all the slides in Western Ghats (Mishra & Pradhan 2010, Mishra & Dharuman 2010). The unprecedented and incessant rainfall in the area during the monsoon of 2008 shows a sharp rise and have a positive correlation to the slope failure. Hence the triggering factor of this slide was the heavy rainfall preceding the event. The low permeability of the slope material was the cause for increased pore pressure due to high clay content (as observed in debris through out valley) thus reducing the soil strength thus causing the highly saturated slope forming material to fail. High stream recharge due to rainfall and as the stream is perennial and ground water table is shallow, the overbank failures mixed up with the high volume of water flowed down stream as a semi viscous mass.

VI. RECOMMENDATIONS

VI.1. Recommendations

As per the site condition and evaluation of the factors responsible for the debris flow (both causes and triggers) the following remedial measures are proposed.

1. At the source of the failed mass : High rise deep rooted plants are to planted in the stream bed in the failed mass zone in five to six rows closely spaced in staggered pattern to reduce the flow velocity and flow density of the future slide rock mass in the area. These will act as restraining structure for the future possible slide. This measure is to be provided between section lines GH and IJ (Plate4).
2. Deep rooted plants/vetiver grass is to be planted on the scarp face (soil) of the over bank failures between section lines GH and IJ (Plate4). So as to reduce the volume of material added from the over bank failures.
3. At the mid section of the flow: The gully erosion is continuing and the debris in the stream bed will be eroded and could cause more silt and clay deposition in the down stream hence plantation of vetiver grass all along the mid section can be done till survey station 4 as the depth of debris does not exceed 3 m. The grass can reduce further erosion and will also help people in the vicinity an economical benefit.
4. Besides the above between station 3 and 4 where course of the flow changes plantation is to carried out to reduce the impact of deflection. High rise deep rooted plants are to be planted in the stream bed in the failed mass zone in five to six closely spaced rows in staggered pattern.
5. Providing drainage facility: for effective control of surface drainage lined catch water drain may be provided above the crown of the slide.
6. The toe part beyond the road: the heaped up debris material will not move except gully erosion/ rill formation as the debris height is more than 2m. Plantation can stop erosion and this material won’t move beyond the place of accumulation.
7. The two houses in front of the toe area may experience slurry/ erosion material getting deposited in their houses. It is best for them if they vacate that houses and if at all they are not willing then they may be advised to grade the frontal lobe and plant vetiver grass/ deep rooted plants in the accumulated mass.
8. If ever the slope at the upper reach fails in future this accumulated debris will act as a restraining structure for movement of the material by reducing the gradient.
9. Enough space/ draining facility is to be erected/ constructed near the road so as to give way to the flow of water from the stream as presently it has been blocked by accumulated debris. This should be done by taking in to account the possible maximum discharge from this stream so that structure erected should be capable enough to discharge the same volume of water down stream.

VII. SUMMARY AND CONCLUSIONS

As per the size classification of the debris flow the Neriya debris flow can be classified into a class 3 slide Which may have a decadal return period as this is a supply limited watershed and can have a destructive potential with peak discharges of up to 200 m3/s and 90,000 m2 area inundated. (Jacob 2005).which can be destructive and can cause damage to the buildings, habitations and human lives. The debris flow path is restricted to the stream and the source lies in the unhabitated area. The sparsely habitated area in the fringe of the debris flow zone has an advantage of giving localized biogeotechnical measures for containing the future flow.

The detailed site specific study of landslide that occurred in Neriya village near Aniyur, Beltangady taluk, Dakshina Kannada district, Karnataka was taken up to get a insight of the slide characteristics, causative factors of landslide and to suggest remedial measures. The detailed mapping on 1:1000 scale was carried out in slide zone. After detailed mapping of the site the following conclusions could be drawn.

1. The slide at Neriya is classified as a large deep seated debris flow.
2. The slope material predominantly consists of coarse (gravel, cobbles and boulders), and finer material (clay, silt and sand). Hence may be classified as debris.
3. The lithology of the area comprises of Biotite gneiss intruded by dolerite.
4. The high degree of weathering, adversely oriented gneissosity dipping perpendicular to stream direction, conversion of weathered biotite/ mafic rich enclave in the gneiss (in the crown part and the zone of depletion) to clay particles viz., montmorilonite and kaolinite, over saturation of slope material due to less discharge to the stream and high infiltration along with the triggering factor of heavy rainfall preceding the event are the main causes of the slide.
5. The low permeability of the slope material due to high clay content was the cause for increased pore pressure thus reducing the soil strength and causing the highly saturated slope forming material to fail.

<table>
<tr><td>Sd/-
(K.V.MARUTHI)
Senior Geologist</td><td></td><td>Sd/-
(A.K.MISHRA)
Senior Geologist</td></tr>
<tr><td colspan="3">SCRUTINISED BY
Sd/-
(Dr. S.S NAYAK)
Director</td></tr>
<tr><td colspan="3">APPROVED BY

Sd/-
(R.N. PATRA)
Director – in - Charge</td></tr>
</table>

REFERENCES

Awasthi, S. K., 1980. Geology of parts of Puttur and Suliya taluks, South Kanara district, Karnataka Unpublished GSI report F.S.1979-80.

Cruden, D.M., Varnes, D.J., 1996. Landslide types and processes In: Turner, A.K., Schuster, R.L. (Eds), Special report 247 Landslides: Investigation and Mitigation. Transportation Research Board, National Research Council, Washington D.C., pp 36-75

Fell, R., 1994. Landslide risk assessment and acceptable risk.Canadian Geotechnical Journal 31, 261– 272

Jacob, M., 2005. A size classification for debris flows, Engineering Geology Vol. 79 pp. 151–161

Mishra, A.K., Pradhan, U.K., 2010. A Report on Landslide Inventory along NH &SH of Ghat roads in Karnataka, Unpublished GSI report F.S.2007-08.

Mishra, A.K., Dharuman. R., 2010. A report on detailed site specific study of Biligeri landslide, Somwarpet taluk, Coorg district, Karnataka, Unpublished GSI report F.S.2006-07.

Pradhan, U.K., 2008. A geotechnical note on post disaster study of the landslide at Neriya, Beltangady taluk, Dakshina kannada district, Karnataka Unpublished GSI report F.S.2007-08.

Varnes, D.J., 1978. Slope movement types and processes. In: Schuster, R.L., Krizek, R.J. (Eds.), Special Report 176 Landslides: Analysis and Control. Transportation Research Board, National Research Council, Washington D.C., pp. 11 – 33.

SYNOPSIS OF WORK DONE

<table>
<tr><td>1</td><td>Title of the report</td><td colspan="2">Detailed Site Specific Investigation of the Landslide at Neriya, Beltangady Taluk, Dakshina Kannada District, Karnataka</td></tr>
<tr><td>2</td><td>Item No.</td><td colspan="2">Code No.: LHZ/SR/KG/2009/045</td></tr>
<tr><td>3</td><td>Field Season</td><td colspan="2">2009-2010</td></tr>
<tr><td>4</td><td>Date of commencement</td><td colspan="2">18.02.2010</td></tr>
<tr><td>5</td><td>Date of completion</td><td colspan="2">27.02.2010</td></tr>
<tr><td>6</td><td>Officers Associated with investigation and No. of days spent in the field</td><td>K.V.Maruthi, Senior Geologist
A.K.Mishra Senior Geologist</td><td>10 Days</td></tr>
<tr><td>7</td><td>Quantum of work done
(i) LHZ (1: 25000 scale)</td><td colspan="2"></td></tr>
<tr><td></td><td colspan="3">
<table>
<tr><th>Sl.No</th><th>NATURE OF WORK</th><th>TOTAL WORKLOAD ENVISAGED</th><th>WORK COMPLETED</th></tr>
<tr><td>1.</td><td>DM (1:1000 Scale) Sq.km</td><td>0.1 Sq.km</td><td>0.15 Sq.km</td></tr>
<tr><td>2.</td><td>Geological section
a)Longitudinal section on 1:1000
b)Cross section on 1:1000</td><td>2 Profiles
3 Profiles</td><td>2 Profiles
3 Profiles</td></tr>
</table>
</td></tr>
<tr><td>8</td><td>Analysis carried out
1) AAS-MIBK for Au
2) ICP-AES</td><td colspan="2">NA</td></tr>
<tr><td>9</td><td>Elements analysed</td><td colspan="2">NA</td></tr>
<tr><td></td><td>Expenditure
(1) POL
(2) Wages
(3) Misc.</td><td colspan="2">8,925/-
3220/-
2126/-</td></tr>
<tr><td>10</td><td>Other information if any</td><td colspan="2"></td></tr>
</table>

<table>
<tr><td>Sd/-
(K.V.MARUTHI)
Senior Geologist</td><td></td><td>Sd/-
(A.K.MISHRA)
Senior Geologist</td></tr>
<tr><td colspan="3">Sd/-
(Dr. S.S NAYAK)
Director</td></tr>
</table>

PHOTOGRPHS OF NERIYA DEBRIS FLOW

Photo 1: Scarp of the Neriya debris flow with small water channel formed in the zone of depletion of the slide (Photo Pradhan, 2008)

Photo 2: Scarp of the Neriya debris flow with small water channel formed in the zone of depletion of the slide (Photo Pradhan, 2008)

Photo 3: The heaped up debris material at toe part day after slide on 14.08.08. (Photo courtesy Village Panchayat Neriya)

Photo 4: The heaped up debris material/ slush at toe part day after slide on 14.08.08.(Photo courtesy Village Panchayat Neriya)

Photo 5: Down stream view of present day Neriya debris flow from the crown portion.

Photo 6: Crown portion showing distinct scarp of Neriya debris flow.

Photo 7: Dislodged blocks of dyke rock exposure just below crown portion

Photo 8: Major joint planes in gneiss.

Photo 9: Major joint planes in gneiss.

Photo 10: Highly weathered gneiss converted to clay particles.

Photo 11: Highly weathered gneiss converted in to clay particles.

Photo 12: Highly weathered gneiss converted in to clay particles.

Photo 13: Nala cutting through the debris material.

Photo 14: Gully erosion in the zone of depletion.

Photo 15: Heaped up material at toe may act as natural barrier for future.

Photo 16: Heaped up material at toe may act as natural barrier for future for two houses.

Photo 17: Tilting of trees above crown portion suggesting distress.

Photo 18: Survey work of Neriya investigation is in progress.