GOVERNMENT OF INDIA

GEOLOGICAL SURVEY OF INDIA

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REPORT ON GEOTECHNICAL INVESTIGATION FOR LANDSLIDE NEAR MANGALORE, DAKSHINA KANNADA DISTRICT, KARNATAKA

(Field Season: 1997-98)

by
M.Chakradhar
B.K. Bhandaru
Geologists (Sr)
&
K.Bulli Raju
Geologist (Jr)
ENGINEERING GEOLOGY DIVISION

PROJECT: ENGINEERING GEOLOGY
SOUTHERN REGION
HYDERABAD

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ABSTRACT

A landslide occurred at 10 km northeast of Mangalore on 26.6.98 damaging a stretch of 100 m state highway. Granite gneiss capped by varying thickness of laterite is exposed in this area. Torrential rains of the order of 1100mm for about 10 days activated sliding. The causative factors and the morphology of the slide has been discussed in detail. The physical properties of the material involved in sliding have been determined and the theoretical slope angle is worked out. The necessity for adopting the slope stabilization measures and the nature of the measures have been discussed.

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I. INTRODUCTION

1. A massive landslide ($12^0$55'20": $74^0$54'30"; 48L/13) had occurred on 26.6.98 near Omanjur at 10 km northeast of Mangalore ($12^0$52'00": $74^0$50'30"; 48L/13) Dakshina Kannada District, Karnataka. The slide had damaged about 100m stretch of the Hospet - Mangalore state highway between 364.3 and 364.4 km (Plate - I). Geotechnical investigation had been proposed to be taken up soon after receiving the communication from Director (C&T), OME Division, GSI, Mangalore. Subsequently a request had also been received from Superintending Engineer, PWD, Mangalore.

2. The investigation was taken up as an Additional Item during the period from 22.7.1998 to 31.7.98 and an intern note was issued immediately (Appendix-I) after the visit. The work carried out include i) detailed geological mapping of an area of 50,000 sq.m on 1:500 scale, ii) identification of different components of the landslide and iii)collection of undisturbed soil samples and bulk samples from the slided mass to determine the physical properties. Surveying of the slide area was carried out considering the bench mark given at the southern slope of the road into consideration. Taking the level of the bench mark as 51.2m, the level, as surveyed on the crown is 83.588m. A study of the toposheet indicates that the level at the crown is of the order of 100m. Thus, this appears to be a level difference which is of the order of 32.7m.

3. **Acknowledgements:** The authors are thankful to Shri P. Balakrishnan, Director (C&T), OME Division, GSI, Mangalore for providing all the necessary logistic support during the course of field work. They thank S/Shri G.R.M. Rao, Geologist (Sr) and N.K. Sinku, STA (G) for testing the physical properties of the soil samples and Shri G. Rama Rao, Geophysicist (Sr), Mineral Physics Division for carrying out X-ray analysis of the soil samples. The authors gratefully acknowledge the help extended by Shri A.V. Satya Kumar, Geologist (Jr), Engineering Geology Division, GSI in the preparation of slope stability charts. The work was carried out under the guidance of Shri G.S. Murthy, Director, Engineering Geology Division, GSI. The authors are thankful to him for scrutinising the report.

II. GEOLOGY OF THE AREA

4. The area in and around the slide has been mapped by Shafeeq Ahmed "Geology of parts of Mangalore and Bantwal taluks, South Kanara district, Karnataka" by Shafeeq Ahmed, Unpublished report of GSI for FS 1984-85. The slide area forms part of Western Ghats characterised by plateau with moderate slopes of colluvial pediment in general and occasionally steep escarpments and valley flats. Westerly flowing Gurpur river which joins the Arabian Sea lies at a distance of 1.5 km north of the landslide. Detailed geological mapping of an area of 50,000 sq.m was carried out on a scale of 1:500 scale. Granodiorite gneiss, granitic gneiss and migmatite of Peninsular Gneissic Complex with enclaves of amphibolite and pyroxene granulite intruded by dolerite and gabbro are the litho units around the landslide area. The strike of foliation in granodiorite gneiss varies from ENE-WSW to NW-SE. Two sets of joints viz., i) foliation joints and ii) vertical joints in NE- SW direction are well developed.

5. Ferruginous/aluminous laterite capping the lithounits is generally a heterogenous mixture of lithomarge underlain by duricrust varying in colour from deep red to brownish red.

III. MORPHOLOGY OF LANDSLIDE

6. The present landslide is an integral part of a major 250m wide paleoslide. Within this reach landslide occurred at 60m left i.e towards east of the present one in 1997 which was stabilised to a certain extent by constructing a retaining wall.

7. Laterite plateau forming "the breakaway zone" continues beyond "the crown". Transverse cracks with openings varying from a few millimeteres to 5 cm

occur close to the arcuate crown and extend beyond the crown. A steep surface, 10.7m high, forms "the main scarp" exposing lithomarge on the undisturbed ground around the arcuate crown. A number of "transverse and longitudinal fissures" trending in $N60^0W$ - $S60^0E$ and NNE-SSW direction were developed in "the zone of transportation". Some of the fissures are as wide as 1.5m. "Minor scars" in the zone of transportation were obliterated due to the downward movement of "the units" of the earlier slide mass consequent to sliding of "the head" along the main scar.

8. The highway which registered maximum downward throw of the order of 5m, .as reported by PWD authority, lies just above "the foot". Continuous sliding has resulted in bulging and upheaval of laterite in " the zone of accumulation" Taking into consideration the morphology of the present slide and the palaeoscars, this slide may be classified as "multiple rotational slide".

IV. CAUSATIVE FACTORS OF SLIDING

9. The Mangalore-Hospet road was laid by cutting the laterite ridge which was left unsupported for decades causing the instability of slopes. Due to the disruption of equilibrium the area has been subjected to sliding. The involvement of the area in successive sliding is evidenced by paleoscars on the flanks, movement of mass in the adjacent reaches and gradual rise in the toe portion, as observed and reported by local residents for the past few years.

10. Rainfall data prior to sliding from three rain gauge stations nearby the landslide area had been analysed. These rain gauge stations located at 10km $S50^0W$ (Mangalore), 5km $N20^0W$ (Bajpe Airport) and 10 km $N60^0E$ (Kuppe Padavu) of the landslide area recorded cumulative rainfall of 1085mm, 1036mm and 1172 mm respectively. Incidentally this heavy rain between 17th and 30th June triggered the landslide. Increase in water pressure due to rising water table due to rainstorms is the most important single factor reactivating the event. Rain water percolation through interconnected joints in laterite resulted in super saturation of the entire laterite profile including the bottommost lithomarge which ultimately might have increased pore water pressure. This has resulted in the reduction of effective stress with a consequent reduction in resistance to shear and caused the slide.

V. RESULTS OF THE ANALYSIS OF PHYSICAL PROPERTIES

11. A total of 9 samples were collected at various locations (Plate-II) in the slide area for the determination of physical properties and the mineral constituents. The physical properties viz., specific gravity, variation in grain size, void ratio, porosity, cohesion (C), angle of internal friction (ϕ), liquid limit (LL), plastic limit (PL), shrinkage limit (SL) and plasticity index of the undisturbed soil samples and bulk samples collected from the landslide were determined.

12. The test results obtained from the laboratory has been tabulated (Table No. 3) and a graph has been drawn with liquid limit in the abscess and plasticity index as ordinate.

13. On examination of soil fractions smaller than 425 micron, the manual identification tests viz., dilatency, toughness and dry strength are not considered necessary for the purpose of soil identification. So the identification and classification of soil samples

TABLE-3

PHYSICAL PROPERTIES OF THE SOIL SAMPLES FROM THE LANDSLIDE AREA TESTED IN GEOTECHNICAL LABORATORY, SOUTHERN REGION, GEOLOGICAL SURVEY OF INDIA

Sample No.	Sp. Gr.	Gravel %	Sand %	Silt %	Clay %	Void ratio	Porosity %	Cohesion Kg/cm2	Angle of internal friction	LL %	P.L %	S.L %	P.I %	Identification
S-l	2.66	16	51	21	12	0.7733	43.61	0.24	22	59	31	26	28	CH
S-2	2.74	26	41	21	12	0.8266	45.25	0.24	28	66	34	30	32	CH
S-3	2.61	5	48	30	17	0.7401	42.53	0.18	30	62	30	26	32	CH
S-4	2.6	18	61	14	7	0.7334	42.31	0.17	17	41	32	28	9	MI
S-5	2.74	3	69	21	7	0.8266	45.25	0.18	19	64	39	35	25	CH
S-6	2.76	19	66	21	7	0.8602	46.24	0.17	17	56	28	23	28	CH
S-7	2.49	13	72	11	4	0.8676	46.45	0.18	25	63	30	25	33	CH
S-8	2.47	12	79	8	1	0.8526	46.02	0.22	14	72	31	26	41	CH
S-9	2.49	8	68	16	8	0.8676	46.45	0.12	21	70	26	30	34	CH

Boundary conditions:

1. The samples were compacted to a density of 1. Gr/c.c
2. The degree of saturation is 100%
3. The test is quick and undrained test
4. The rate of strain applied is 0.625 mm/minute

is based mainly on laboratory tests. Sample No. 4 shows very low plasticity index with low liquid limit, classified as "MI" is anamolous as compared to the other samples. This may probably due to contamination of the local sample.

14. As per the laboratory classification criteria for classifying the soils given in the plasticity chart (Fig. 1) soil samples 1,3,6,7 and 8 lie above A-line whereas soil samples 2,5 and 9 lie below A- line. The soils, in general, are "fine grained consisting of silts and clays with high compressibility and liquid limit greater than 50"

15. The soil samples possess characteristics of both silt and clay in particle size distribution and as such do not strictly fall under a single group. Bouldery classification between silt and clay assigning the group symbol "MH-CH" is more appropriate. Specific gravity ranges from 2.47 to 2.74. Void ratio of these samples varies from 0.7334 to 0.8676 whereas porosity (percent) varies from 42.31 to 46.45. Porosity, in general, exhibits an increasing trend with respect to the increase in void ratio.

16. **Slope analysis:** Critical height (H Cr) corresponding to the angle of the slope (i) has been calculated employing the equation given below:

$$H\,Cr = \frac{4C}{r} \times \frac{\sin i.\cos\phi}{1-\cos(i-\phi)}$$

Cheng Liu and B. Evelt, "Soils and Foundations" 1981, p.p. 293-311

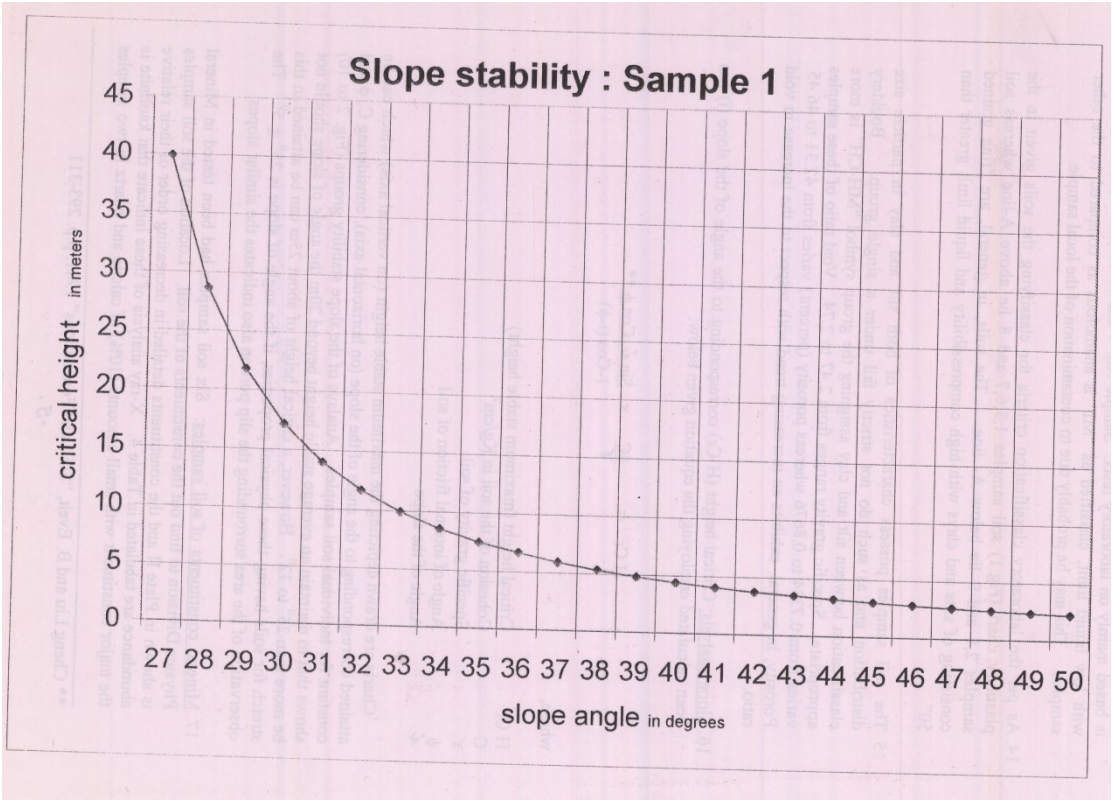
where,

H Cr : Critical height (maximum stable height)
C : Cohesion of the soil iin Kg/cm^2
r : Specific gravity of soil
ϕ : Angle of internal friction of soil
i : Angle of slope

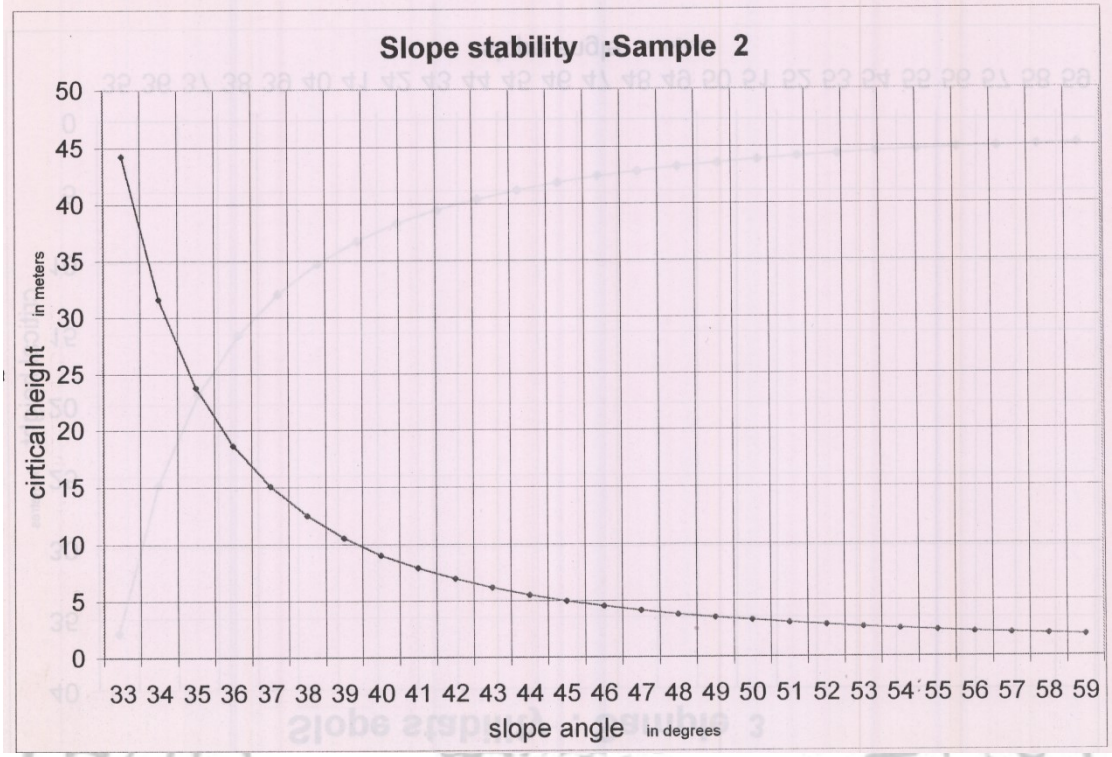
Charts are drawn depicting the maximum stable height (on vertical axis) which can be attained corresponding to the angle of the slope (on horizontal axis), considering C, ϕ) and constant for individual soil samples. Analyses of the slope stability groups (Fig. 2 to 10) shows that to maintain an average stable height beyond 20m the angle of slope should not be more than 25^0 to 32^0. However, a critical height of about 25m can be attained in this stretch for soils having these physical properties, if the angle of slope is $25^0 \pm 5^0$. The observation of the area surrounding the slip portion also indicates the similar slopes.

17.**Mineral constituents of soil samples:** Six soil samples had been tested in Mineral Physics Division to find out the constituents of the soil. Location of the soil samples is shown in Plate II and the constituents detailed in decreasing order of their relative abundance are tabulated in Table 4. X-ray analysis of these indicate that kaolinite is the major constituent with small amounts (10%) of calcite and quartz in two samples

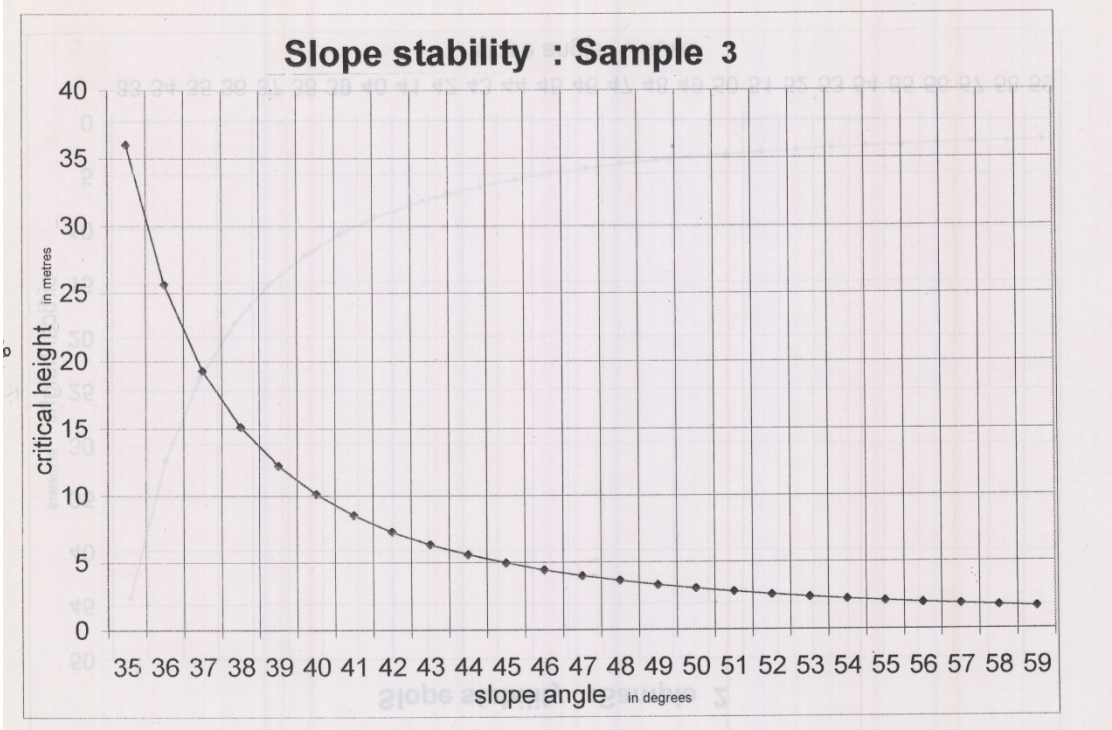
Slope Stability : Sample 1



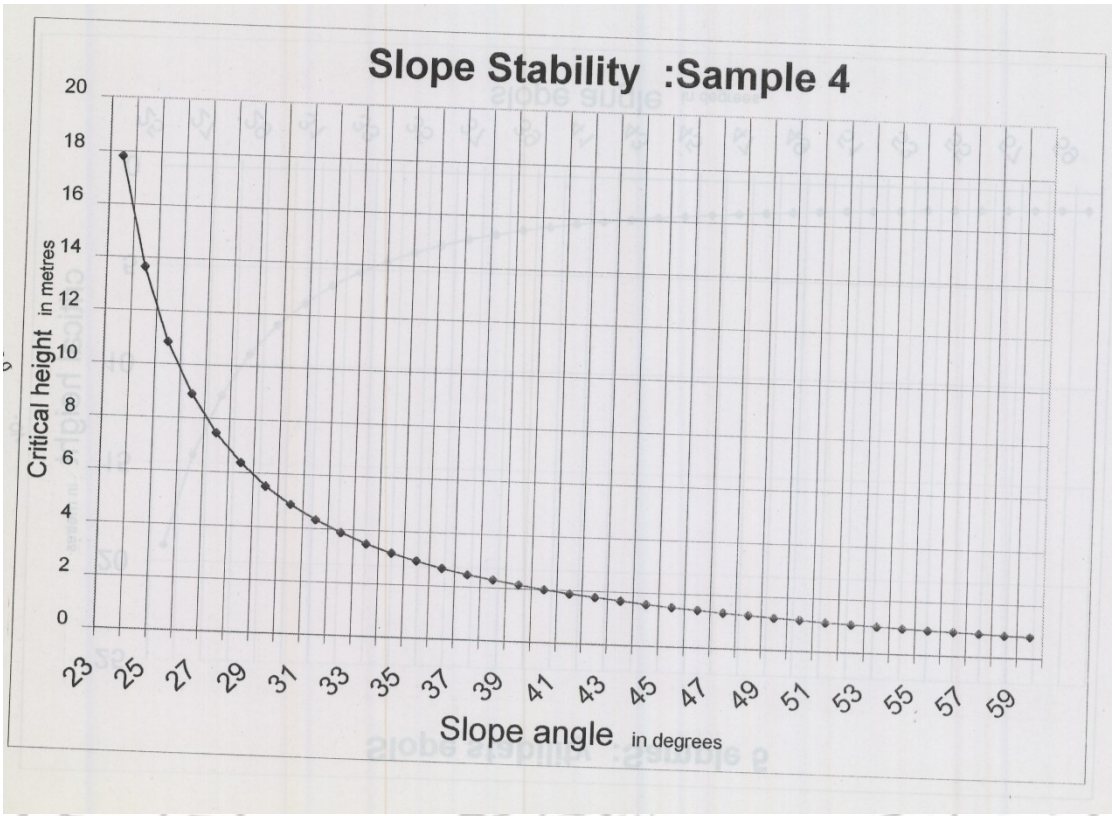
Slope Stability : Sample 2



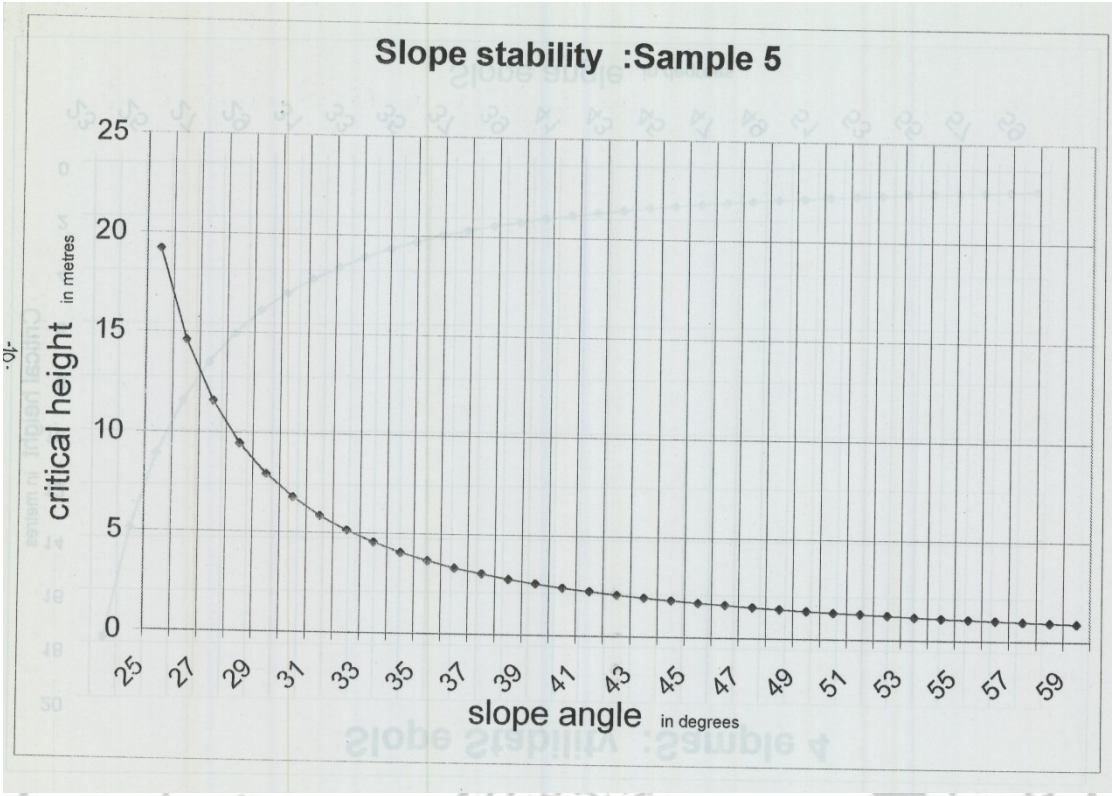
Slope Stability : Sample 3



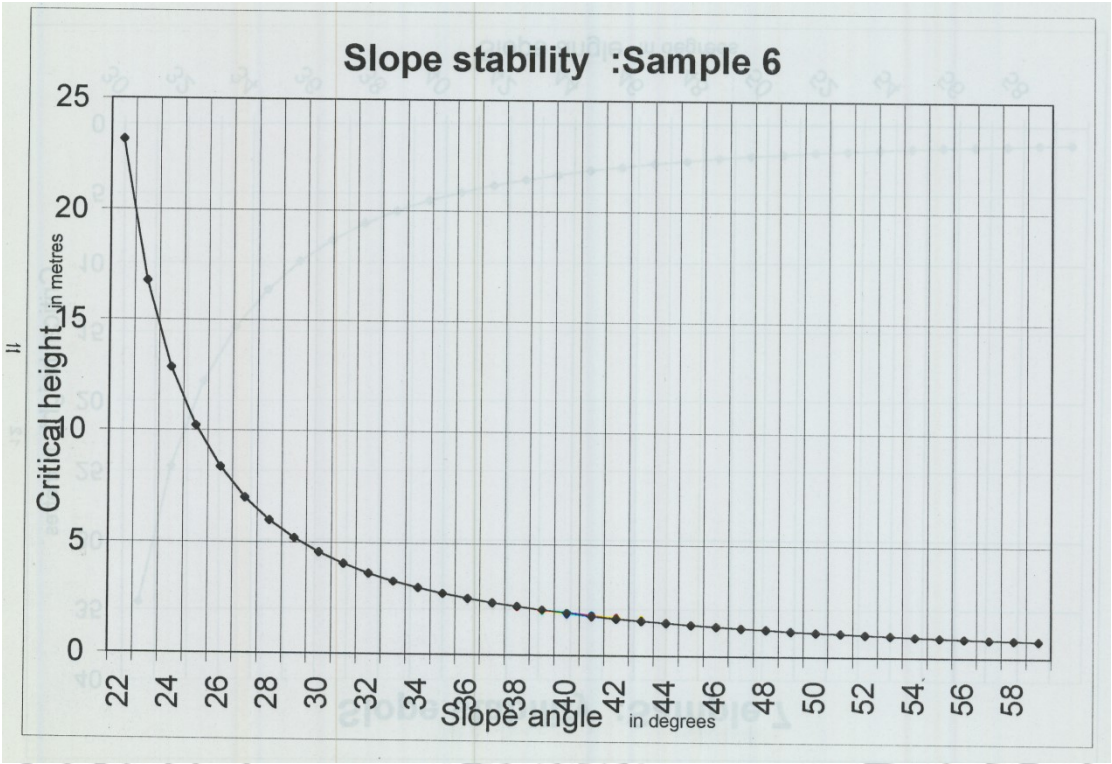
Slope Stability : Sample 4



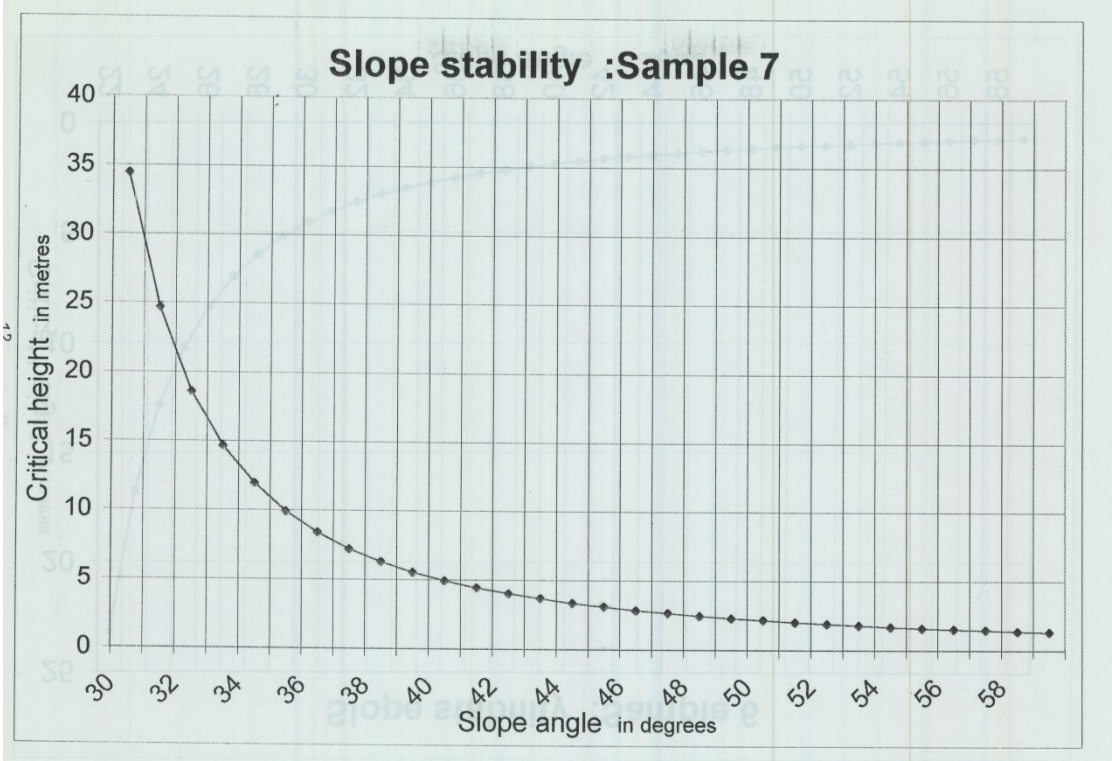
Slope Stability : Sample 5



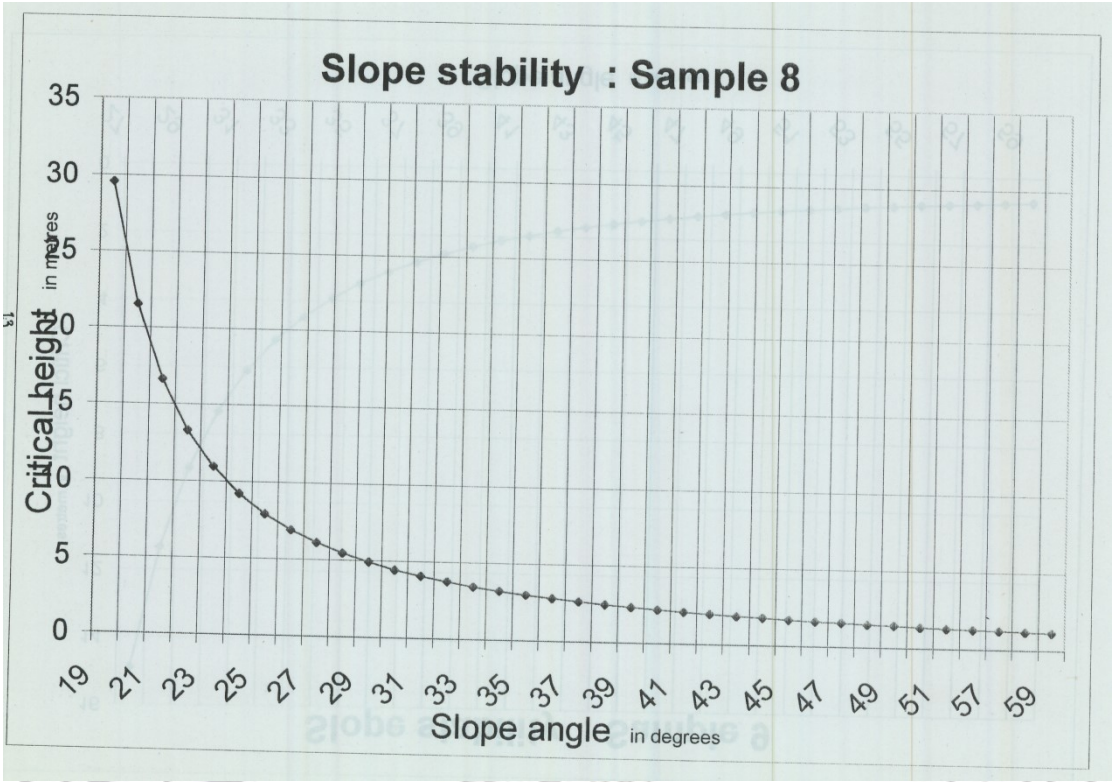
Slope Stability : Sample 6



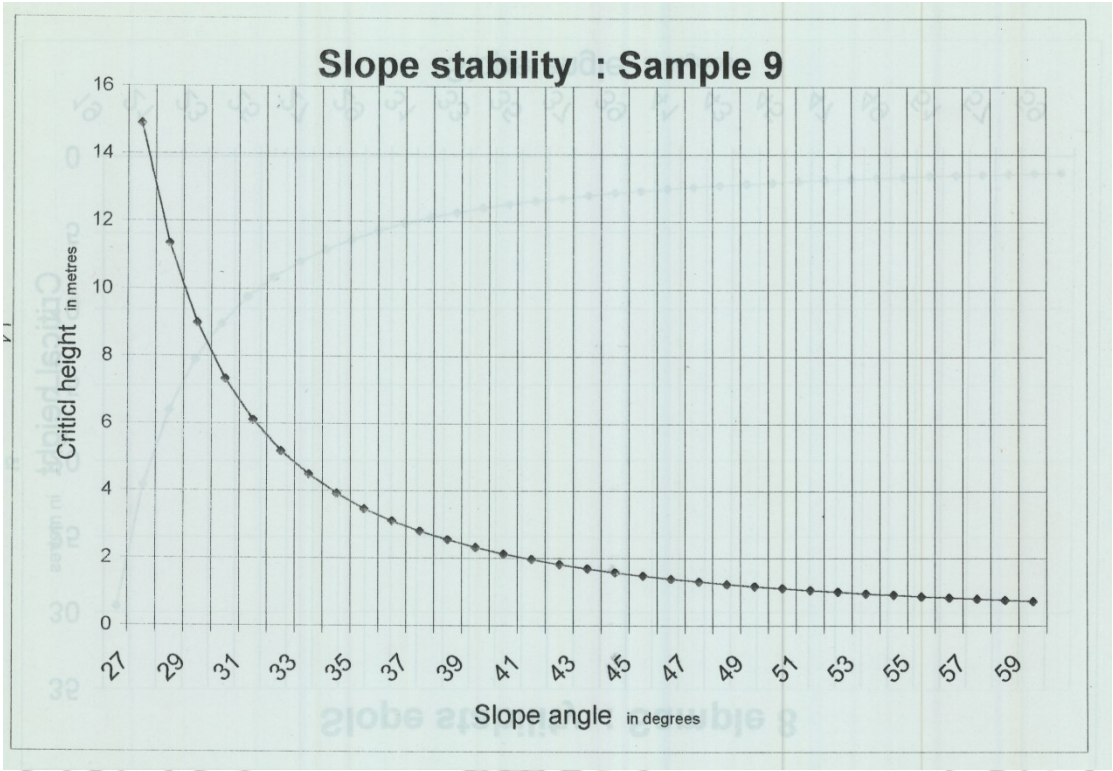
Slope Stability : Sample 7



Slope Stability : Sample 8



Slope Stability : Sample 9



(5 and 6); and contain traces (5%) of gibbsite in two samples (3 and 6) Hematite, mica and pyroxene are the likely traces (<5%) in these samples. Expansive minerals which are prone to swell with changes in water content are not reported to constitute the soil samples (Table 4).

VI. CONCLUSIONS AND RECOMMENDATIONS

18. Granite gneiss capped by laterite is exposed in the area near Omanjur where a massive land slide occurred on 29th June. 1998. Incessant rain and excessive percolation of water below the duricrust resulting in super saturation might have induced the landslide. Based on the evaluation of the physical properties, it is estimated that the critical height of 25m can be achieved provided the slope angle is $25^0 \pm 5^0$

19. In order to stabilise the present slope it is recommended to i) provide effective drainage by constructing the channels intercepting the surface flow, ii) remove loose and detached blocks above the neutral line and iii) provide afforestation measures in the zone of transportation.

20. However, the permanent measures for slope stabilisation like easening of the slopes, construction of retaining walls, etc will be suggested after the receipt of the topographic plans as suggested earlier.

TABLE 4: REPORT ON X-RAY ANALYSIS OF SOIL SAMPLES

Sample No.	Description & Locality	Constituents detected (in decreasing order of their relative abundance)				
		Major	**Considerable amount**	**Small amount**	**Trace amount**	**Trace likely**
1) SM-1	Soil Samples, Landslide areas, Mangalore, Karnataka	Kaolinite	-	-	-	Gibbsite, Hematite
2) SM-2	-do-	Kaolinite	-	-	-	Gibbsite, Hematite
3) SM-3	-do-	Kaolinite	-	-	Gibbsite	-
4) SM-4	-do-	Kaolinite	-	-	-	Gibbsite, Quartz
5) SM-5	-do-	Kaolinite	-	Calcite	-	Hematite, Mica, Pyroxene, Gibbsite
6) SM-6	-do-	Kaolinite	-	Calcite, Quartz	Gibbsite	Hematite-Pyroxene

Major : >50%
Considerable amount around : 30%
Small amount : 10%
Trace amount : 5%
Trace likely : <5%

} Percentage are arbitrary in character by volume

FIG 1: PLOT OF THE TEST RESULTS OF SOIL SAMPLES ON PLASTICITY CHART AS PER IS CODE No 1498 – 1970

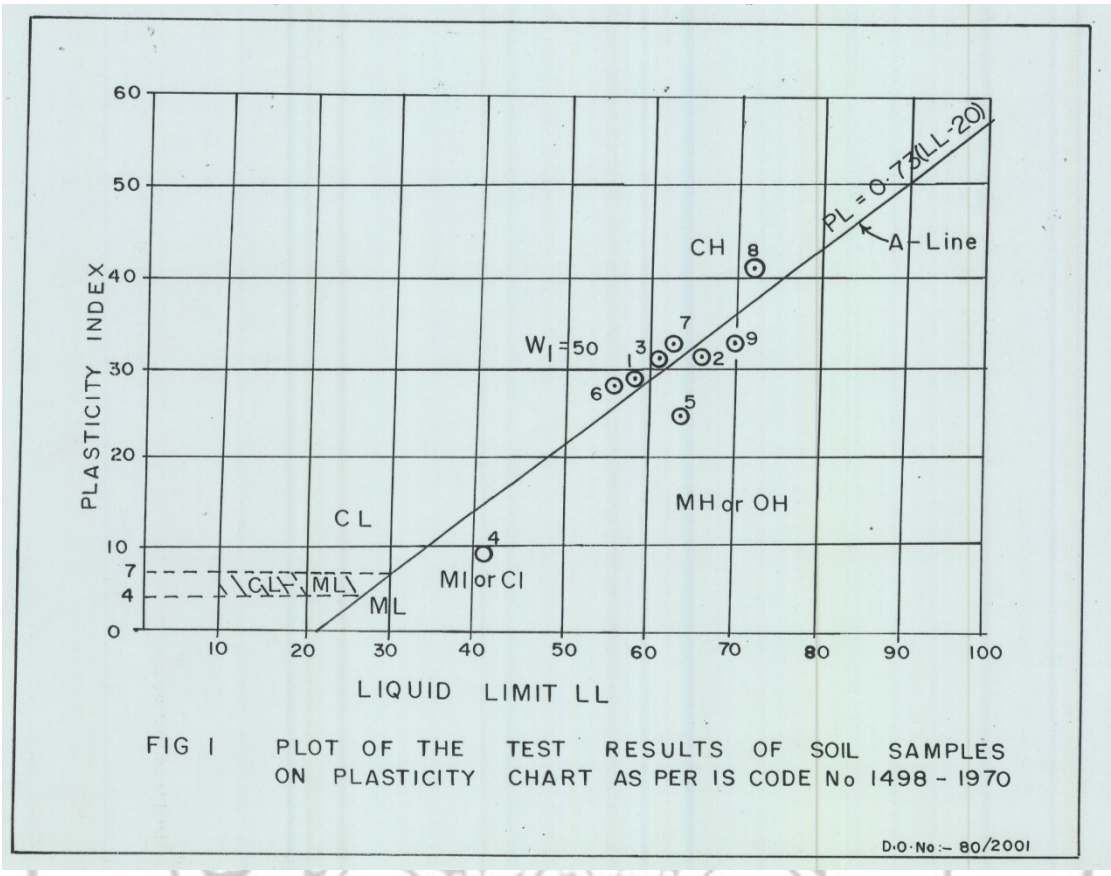


FIG I PLOT OF THE TEST RESULTS OF SOIL SAMPLES ON PLASTICITY CHART AS PER IS CODE No 1498 - 1970

D·O·No:- 80/2001

APPENDIX

I. Interim report on geotechnical investigations carried out for landslide, 10 km NE of Mangalore, Dakshina Kannada, Karnataka

APPENDIX – I

GOVERNMENT OF INDIA

Geological Survey of India
Southern Region
Engineering Geology Division
Bandlaguda
HYDERABAD

No. 79/Slides/EGD/Kar/98 Dt: 7.8.1998

To

Deputy Commissioner
Dakshina Kannada District
MANGALORE

Sir,

I am herewith forwarding the note entitled "An interim report on the investigations carried out for landslide at Omanjur, 10 km north-east of Mangalore, Dakshina Kannada district. Karnataka" for your kind information.

Yours faithfully,

Sd/-
(G.S.MURTHY)
Director

Encl: As above

Copy forwarded for information to:

Shri P. Balakrishna, Director (C&T), GSI, OME Wing, Mangalore

Sd/-
(G.S. MURTHY)
Director

AN INTERIM REPORT ON THE GEOTECHNICAL INVESTIGATIONS CARRIED OUT FOR LANDSLIDE AT OMANJUR, 10 KM NORTH-EAST OF MANGALORE, DAKSHINA KANNADA DISTRICT, KARNATAKA

By
M. Chakradhar
B.K. Bhandaru
K. Bulli Raju

Engineering Geology Division
Geological Survey of India

INTRODUCTION

1. With reference to the fax message from the Director (C.T.), Marine Geology Wing. Geological Survey of India. Mangalore the geotechnical investigations of the landslide occurred near Omanjur ($12^0$55'08" : $74^0$54'36"; 48 L/13) were taken up on priority basis during the period 22nd to 31st July, 1998. Subsequently, a fax message has also been received from Superintending Engineer, P.W.D., Mangalore on 28th July, 1998.

2. There was a sudden spurt in the rain fall in this area from 17th June and continued upto 30th June. The rain fall data provided by P.W.D. authorities indicate that the amount of rain occurred is of the order of 1020 mm. This has resulted in a massive landslide between 365.75 and 364.50 km on Hospet - Mangalore road disrupting the entire road traffic.

3. Mangalore - Hospet road in this reach had probably been laid, by cutting the left side laterite ridge, thereby disrupting the equilibrium of the stable slope. Subsequently it was reported that there was a land slip during 1997 in the adjacent reach towards Hospet. This slip had been treated by constructing a retaining wall.

GEOLOGY OF THE LANDSLIDE

4. Granite gneiss capped by ferrugeneous/alluminous laterites are the rock types exposed near the slide. The strike of the foliation of the rock is in E-W direction with steep northerly dips becoming vertical at places.

5. In the zone of transportation mostly laterite and blocks of laterite are seen. In the breakaway zone lithomarge is overlain by duricrust. In the toe portion, in the zone of accumulation a bulge had developed in lateritic soil. In the zone of transportation a number of transverse and longitudinal cracks are observed in N60^0W - S60^0E and NNE-SSW directions. The width of the transverse cracks is as wide as 1.5m. Beyond

the breakaway zone, the laterite plateau continues further. Transverse cracks ranging from a few milli meters to 5 cm occur upto about 10m from the crown indicating landslide is probably active. Soil samples from the landslide area have, however, been collected to determine their geotechnical properties. It is to be mentioned here that paleoscars are present in this area indicating that this site has been subjected to landslides earlier.

6. Incessant rains and excessive percolation of water below duricrust resulting in super saturation might have induced the landslip. As the zone of transportation is obscured with slided material, it is not possible to arrive at the actual dimensions of lithomarge, at present. Taking into consideration the morphology of the present slide and the paleoscars this slide may be classified as "multiple rotational slide".

RECOMMENDATIONS

7. The area has been surveyed for a detailed assessment of the slide taking the bench mark of the southern slope of the road into consideration. Taking the bench mark as 52.1 m, the level as surveyed on the crown is 83.588m. A study of the toposheet indicates that the level at the crown is of the order of 100m indicating a level difference of about 50m from the road. But the survey carried out indicates that the level difference is of the order of 32.7m. Therefore, it is suggested to furnish a detailed contour plan of the area, including the area of the landslide occurred in 1997 to have a comprehensive assessment.

8. As the present slide is expected to continue due to various factors mentioned in the paragraph-5 it is not possible to come to any conclusion regarding long term measures. Geotechnical investigations will be carried after the detailed contour plan is furnished and the mass movement is stabilized.

9. However, the following temporary measures may be implemented during the monsoon for effectively draining the area:

1. The surface run off from the plateau may be diverted away from the periphery of the slide in the crown portion and its immediate vicinity to minimize the possibility of further sliding.

2. There are a number of water pools in the zone of transportation. The water accumulated in the pools may be drained effectively by adopting suitable and quick measures.

3. As far as possible, the slope may be regraded to attain a gentle, natural slope

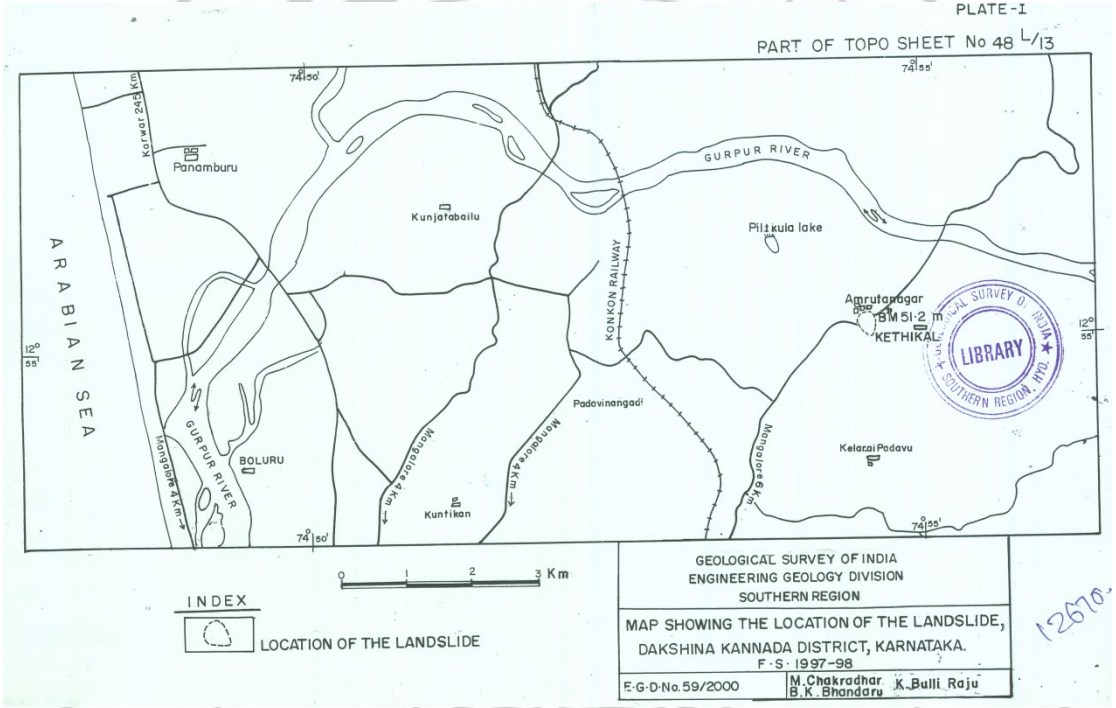
4. As a precautionary measure, it is suggested that the residents of the area at the bulge portion i.e in the zone of accumulation and in the immediate vicinity

of the crown portion of the slide may be shifted to a safer place as and when there is heavy rain which may induce further slides.

10. Long term measures like provision of effective drainage, construction of retaining walls etc. will be suggested after the monsoon and receipt of the topographic plans.

LIST OF PLATES

I. Map showing the location of the landslide.



II. Detailed geological map of the landslide.