MONITORING OF BERAGALA LANDSLIDE

A.K. DISSANAYAKE, A.G.H.J. EDIRISINGHE
H. N. SENEVIRATNE AND S. B. S. ABAYAKOON

*Department of Civil Engineering, Faculty of Engineering,
University of Peradeniya.*

ABSTRACT

Landslips occur in many parts of the world, specially in hilly or mountainous terrain. In Sri Lanka landslides are a major natural hazard. Out of many active landslides in the island, Beragala earthslip is particularly significant because of the possible disruption of the transportation system in the southern part of the central highlands. This paper describes the geotechnical instrumentation and monitoring carried out as a part of a major research project to study the behaviour of the Beragala landslide. The landslide is monitored using GPS method, extensometers and precise leveling of embedded markers. It is expected that interpretation of the results of this instrumentation would lead to the identification of the mechanism of the landslide and thereby enable the determination of suitable remedial measures if required.

Introduction

In many parts of the world, specially in hilly or mountainous regions landslips are often a common feature of the landscape. They usually have serious consequences on almost all constructions and have damaged property and caused death of many people on many instances. In Sri Lanka, landslide is a major natural hazard which occurs frequently in the central highlands during monsoon periods. Substantial damages have been caused by the landslides to the infrastructure and public utilities in the island. Out of the active landslides in Sri Lanka, Beragala landslide is considerably more important due to the magnitude of disruption it can cause to the transportation system in the island.

Beragala landslide is situated in the southern mountain slope of Ohiya - Idalgashinna - Haputale ridge in the central highlands that rises to an elevation of 1778m above mean sea level (MSL) (Fig. 1). According to the available information, this slope is composed of colluvial deposits and rock debris consisting of large boulders that have tumbled down from the ridge above. The first major failure at Beragala has taken place in June 1986 depositing large amounts of debris on Colombo - Wellawaya (A4) highway and on the area below it. The upper slope of the hill has been creeping continuously since this failure, affecting Beragala -HaliEla (A16) highway, which passes through the landslide area at a higher elevation than the Colombo - Wellawaya Road. In May 1987,a second landslide took place which made both A4 and A16 roads impassable for a number of weeks.

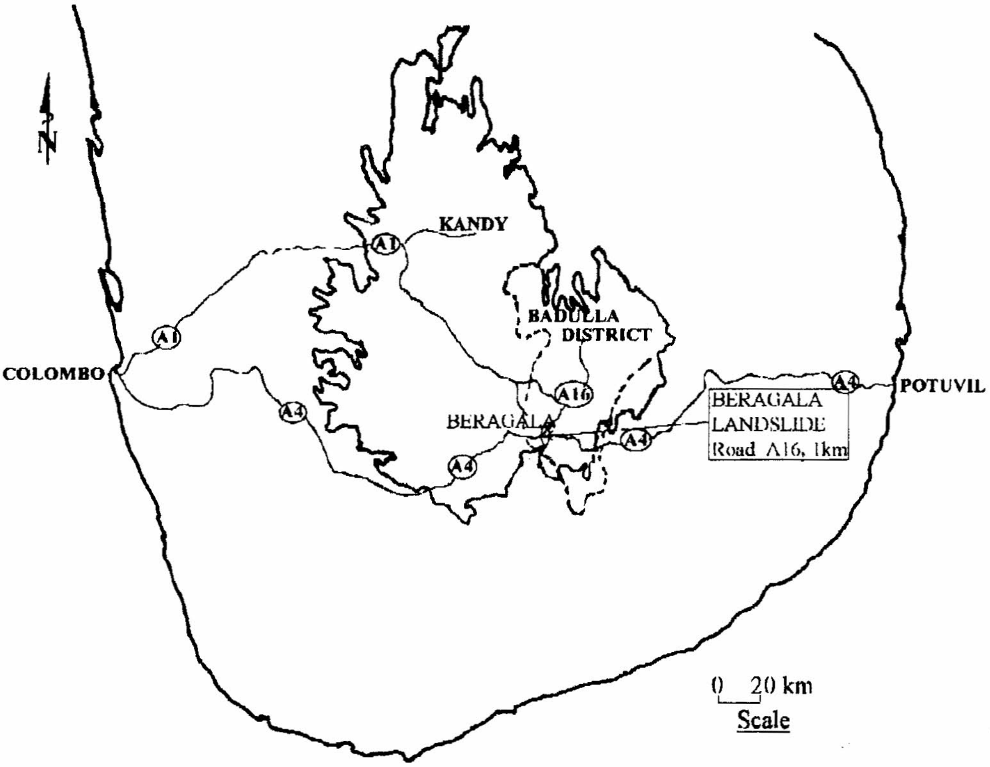

Fig. 1. Location of Beragala landslide

After the failure in 1987 the Road Development Authority of Sri Lanka has improved the surface and subsurface drainage by constructing trench and underground drains by the side of the A16 road, near the top of the landslide, and between 2/1 & 2/2 culverts. Surface drains were constructed using hume pipes of 0.9 m diameter and trench drains were constructed underneath them. Further, three horizontal drains have also been constructed across the A16 road between the same culverts as above (ADB 1989).

The stability of a slope could be monitored by measuring the surface soil movement of a potential landslide area. A forthcoming landslide is characterised by relatively large displacements and displacement rates which increase with time. Several methods are available to measure the surface and sub-surface lateral displacements in landslide areas. By monitoring landslides with proper measuring devices, potential landslides can be detected at an early stage and remedial measures can be undertaken (Loganathan et al 1992).

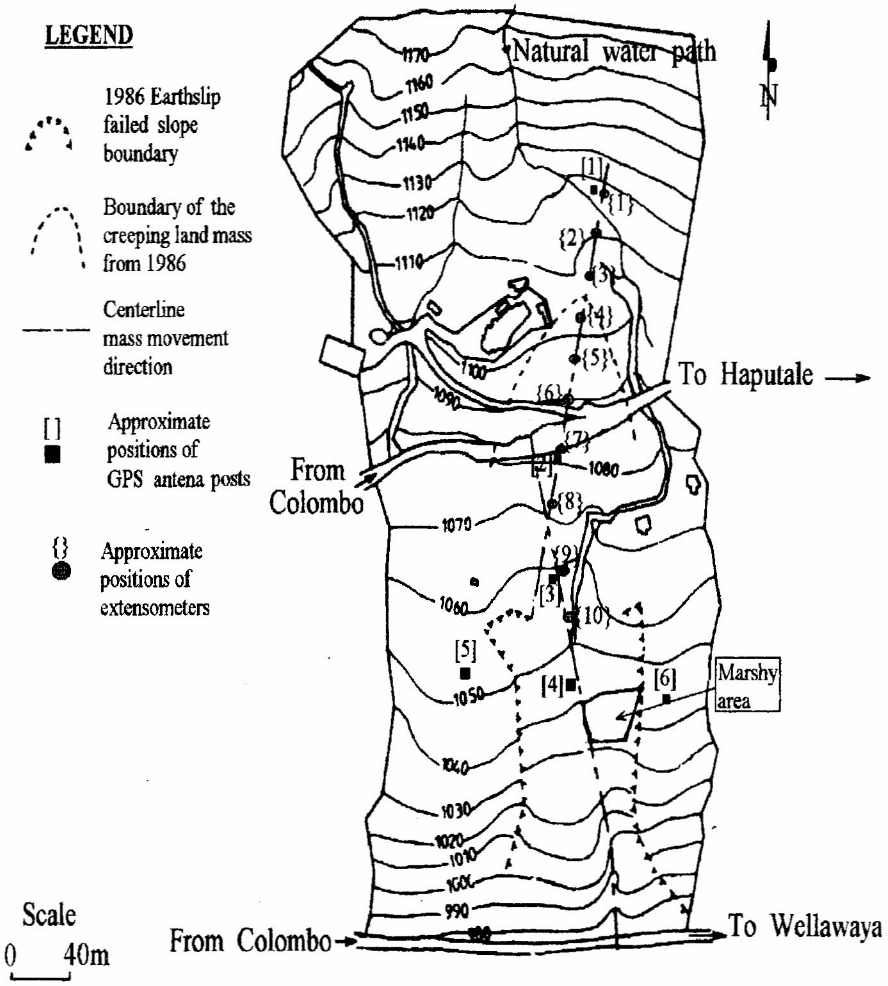

Fig. 2. Beragala earthslide postslide topography -1988

Beragala landslide is monitored with the use of Global Positioning System (GPS) survey (Sokobiki et al 1994) extensometers to measure the lateral displacements on the surface and, by a precise ground survey for subsidence. Approximate positions of the GPS antenna posts and extensometers are shown in fig. 2 . A detailed survey of the landslide area has not been completed yet.

Methods Adopted in Monitoring Beragala Landslide

Global Positioning System (GPS) survey

Observation of lateral displacements of a large scale landslide by conventional surveying methods involves a great deal of human labor. With recent advances in technology a survey technique using Global Positioning System (GPS) has become suitable for monitoring such landslides. This method uses satellites positioned at a higher elevation in space and its simplicity and efficiency attracted the attention of landslide engineers on a world - wide scale(Fig. 3 & 4).

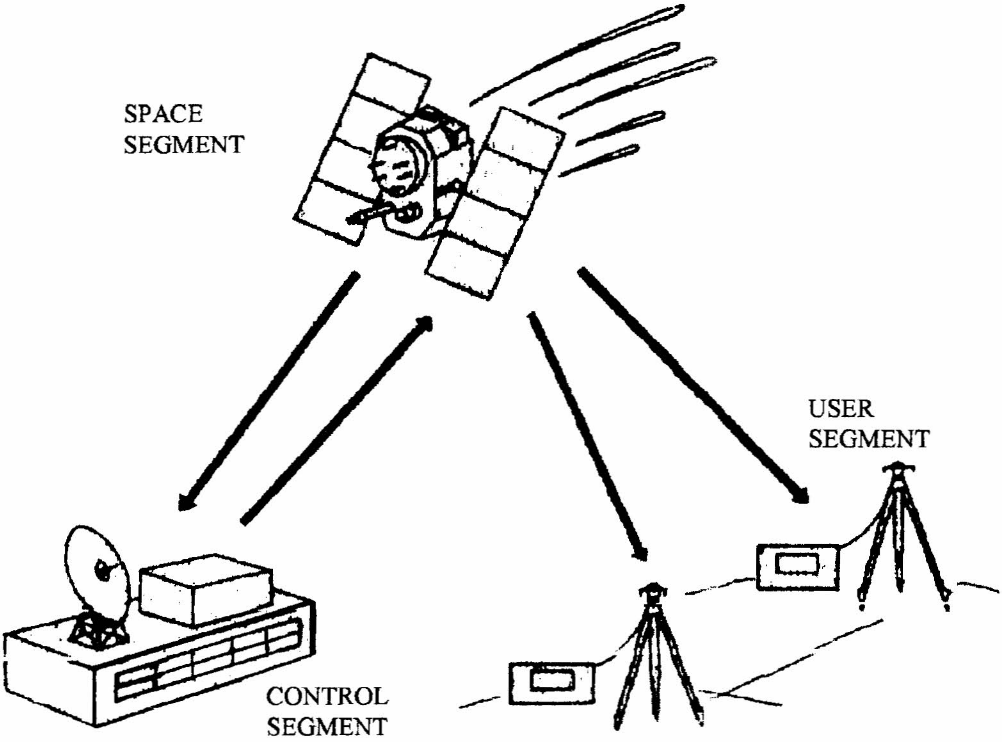

Fig. 3. Features of GPS

Figure 3, shows the components required for a GPS survey. The system comprises of a ground control segment which controls space segment, usually a satellite constellation, and a user segment, basically consisting of an antenna and a receiver. A conceptual display of landslide observation by GPS is shown in fig. 4. In general, a number of antennae is installed on the landslide and few others are set up around the landslide at stable points so that, relative to these stable points surface movements of the unstable points which are inside the landslide can be measured. At least four satellites must be visible from an antenna post to obtain an accurate reading.

The GPS satellite constellation is composed of 24 satellites in 6 orbits (4 satellites in an orbit) which are positioned in space at 20000 km away from the centre of earth. This positioning system has two modes. First mode is called "Point Positioning " which is used in navigation and the second is known as "Relative Positioning" which, in general, is used in surveying applications. The GPS method of landslide observation has the following major advantages over conventional surveying techniques.

(1) Visibility between measuring points is not necessary.

(2) Simultaneous measurements in three dimensional form is possible.

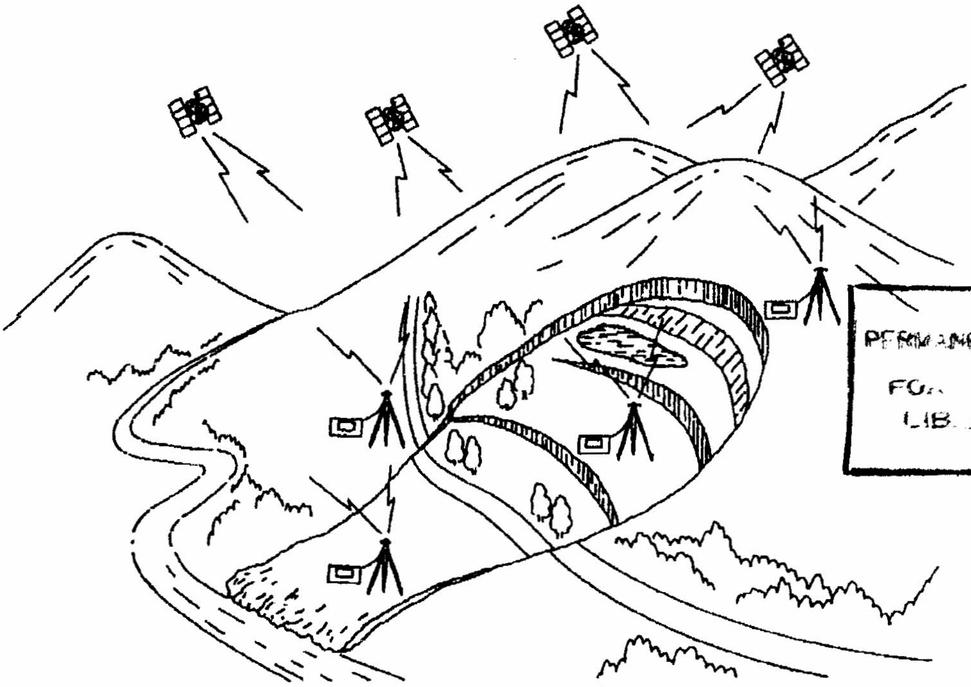

Fig. 4. Conceptual display of landslide observation by GPS

(3) Well trained surveyors are not required for GPS surveying.

(4) A GPS survey is not affected by a change of weather

Six numbers of antenna posts have been installed on Beragala site, three posts outside the area of the slip and, the other on the center line of the slide. The post at the topmost level is taken as the stable point and the distances between each post are measured relative to this stable point. Two successive sets of GPS measurements were taken during the investigation period. First set was obtained in October 1995 and the next in month of December of the same year. The results of these surveys are summarised (Table 1).

Table I. Coordinates of the GPS observation points

OCTOBER 1995			DECEMBER 1995		
X/(m)	Y/(m)	Z/(m)	X/(m)	Y/(m)	Z/(m)
0.0000	0.0000	1000.0000	0.0000	0.0000	1000.0000
-43.0845	-196.6000	983.1578	-43.0883	-196.5930	983.1776
-41.7950	-270.0290	964.1337	-41.7950	-270.0190	964.1555
-30.9475	-355.4130	940.1303	-30.9457	-355.4000	940.1496
-79.9398	-342.7270	950.5994	-79.9439	-342.7290	950.6169
21.8235	-374.4930	941.8928	21.8252	-374.4960	941.9089

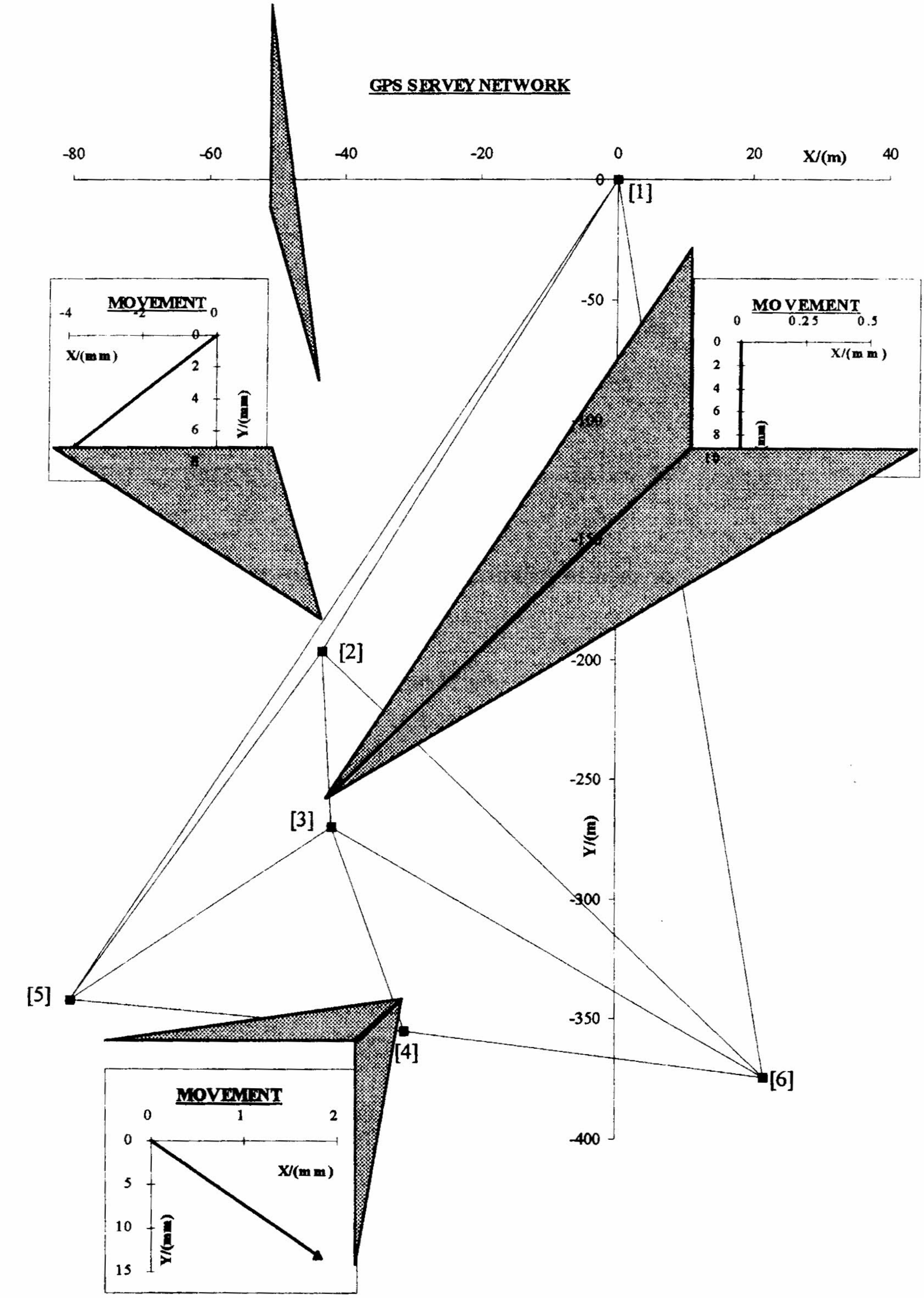

Fig. 5. GPS survey network at Beragala landslide and movements of the unstable points on the landslide

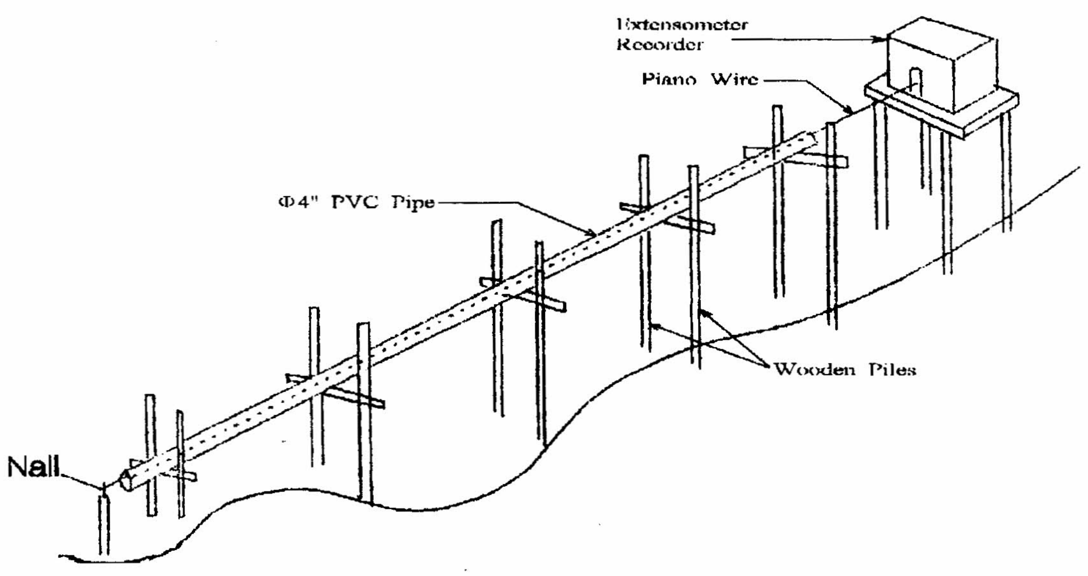

Fig. 6. An extensometer arrangement

Extensometers are used to measure time dependent surface displacements of a point relative to another point on the slope. Fig. 6, shows features of a typical extensometer system. It consists of a recorder, a piano wire and a nail. One end of the piano wire is fixed to the turning wheel of the recorder and the other end is fastened to a nail driven into a wooden pile half buried in the ground, after stretching the piano wire to its full length (30m in this case). The time dependent movement of the nail with respect to the recorder is plotted on a graph sheet drum as shown in Fig. 6. In landslide monitoring, extensometers are used to measure the variation of lateral displacements along the center line of landslides with time. Measurements could be taken at various time intervals in order to calculate the displacement rates. So far as the authors are aware of, this is the first time that extensometers of this kind are used to monitor a landslide in Sri Lanka.

Ten extensometers were set up along the center line of Beragala landslide as shown in Fig. 2. The distance between two consecutive extensometers is 30 m. The first extensometer at the top end is set up at a stable point above the crest of the landslide (on a rock outcrop). Data collection from the extensometers started in late October 1995 and the results obtained during the first fifteen weeks are given below in Table 2 and 3. Gaps in data on the table is due to the disturbance caused by animals to piano wires and due to mechanical failures on two instruments.

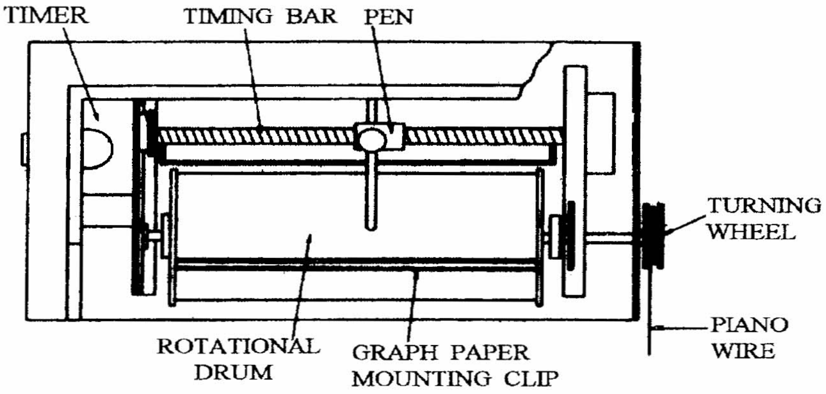

Fig. 7. Features of an extensometer recorder

One division refers to 0.2 mm and the relative movement is the movement within a week; the cumulative movement is the total movement at each point since the beginning of taking measurements.

Table II. Individual movements of each extensometer

TIME/ (WEEK)	OBSERVED RELATIVE MOVEMENT/div							
	1	*2*	*3*	*4*		*6*	*7*	*8*
1	-	-	-	-	8	-	0	0
2	0	0	0	2	6	-	0	0
3	1	1	0	0	0	-	0	0
4	0	3	2	0	2	-	1	-
5	0	0	2	-	3	-	-	-
6	0	-	1	2	7	-	0	-
7	-	-	-	-	-	-	-	-
8	0	4	0	2	0	4	1	-
9	1	0	1	-	7	-	0	-
10	0	1	2	0	0	0	0	0
11	0	0	0	-	-	0	0	-
12	0	1	0	-	-	-	0	-
13	0	0	0	0	0	0	0	-
14	0	4	0	0	0	0	-	0
15	0	3	0	1	0	0	-	-

Table III. Cumulative movements of each extensometer

TIME/ (WEEK)	OBSERVED CUMULATIVE MOVEMENT/div							
	1	2	3	4	5	6	7	8
1	0	0	0	0	8	8	8	8
2	0	0	0	2	16	16	16	16
3	0	1	1	3	17	17	17	17
4	1	5	7	9	25	25	26	26
5	1	5	9	11	30	30	31	31
6	1	5	10	14	40	40	41	41
7	1	5	10	14	40	40	41	41
8	1	9	14	20	46	50	52	52
9	1	9	15	21	54	58	60	60
10	2	11	19	25	58	62	64	64
11	2	11	19	25	58	62	64	64
12	2	12	20	26	59	63	65	65
13	2	12	20	26	59	63	65	65
14	2	16	24	30	63	67	69	69
15	2	19	27	34	67	71	73	73

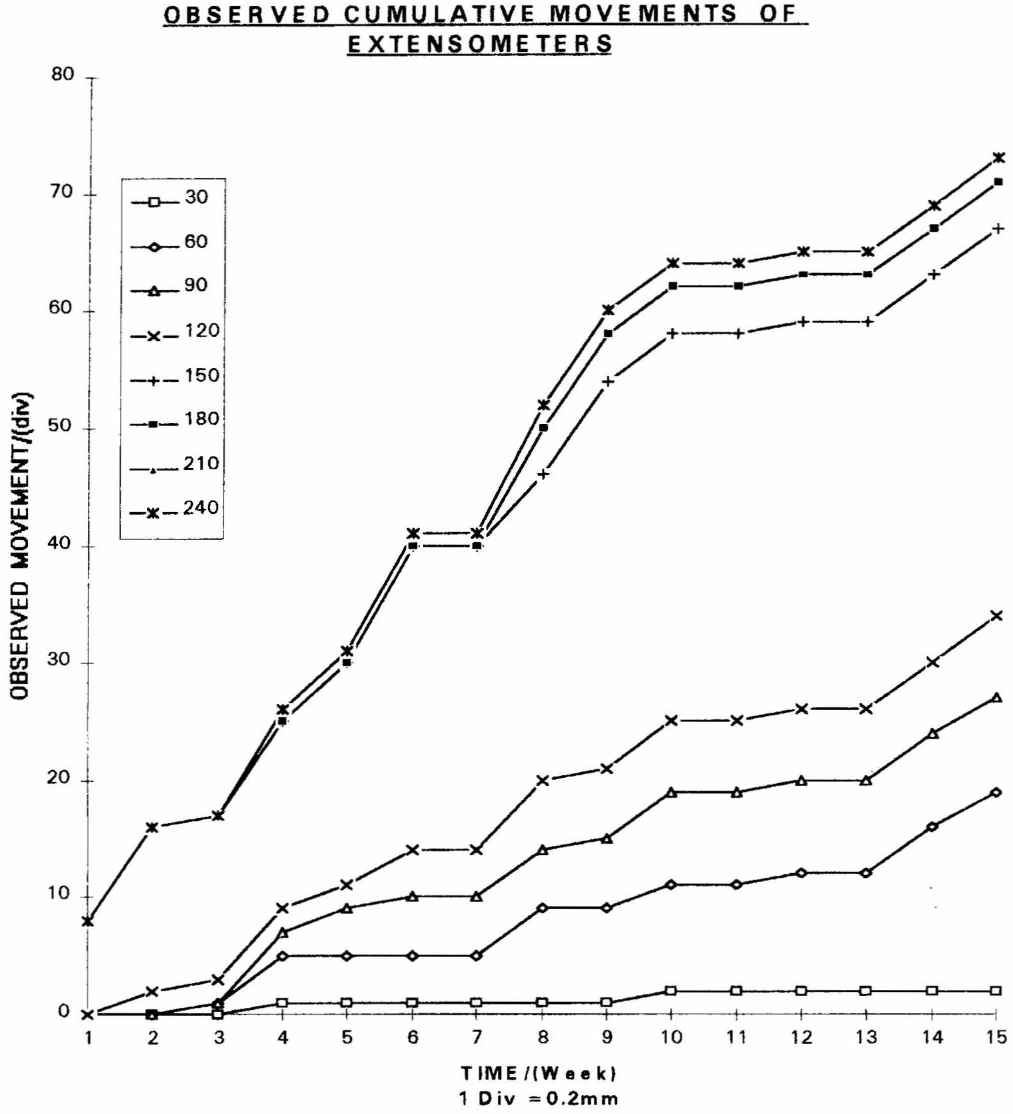

Fig. 8. Graphical representation of the movements of each extensometer

Figure 8, illustrates the variation of cumulative surface movement with time observed at eight extensometer locations. It is clear from this graph that there is a continuous increase of surface movements with time which accelerate and slow down with time probably with the variation of rainfall. The surface movements increase along the centre line of the slide. These observations indicate an average cumulative surface movement in the order of 100 mm/ year which is within the order of rate of movement given by Varnes (1973) for a slow moving landslide. This data is consistent with the GPS observations made so far.

Rainfall

Monthly rainfall figures obtained from the 'Stassen' tea estate which is situated very close to the landslide is given (Table IV) and displayed in Fig. 9.

Table IV. Rainfall figures at Beragala landslide from 1990

MONTH	RAINFALL/(mm)						
	1990	1991	1992	1993	1994	1995	1996
JANUARY	278.4	207	-	188	37.6	141	190
FEBRUARY	297.9	12.7	10.2	172.7	62	152.4	134.6
MARCH	326.9	346.7	38.9	16.3	35.1	135.9	
APRIL	121.9	381.8	466.3	224.9	480.8	578.1	
MAY	176.3	402.8	94	307.3	234.2	309.4	
JUNE	15.5	156.2	-	82.6	26.9	22.9	
JULY	31.2	15.2	154.9	116.8	1.5	17.3	
AUGUST	33	26.7	83.3	58.4	85.1	-	
SEPTEMBER	204.7	100.3	147.1	20.3	321.3	57.9	
OCTOBER	611.6	259.6	359.9	569	798.1	168.7	
NOVEMBER	351.9	343.2	785.6	842.3	529.1	403.1	
DECEMBER	95.3	410.2	161.3	708.8	250.4	82	
TOTAL	2544.6	2662.4	2301.5	3307.4	2862.1	2068.7	

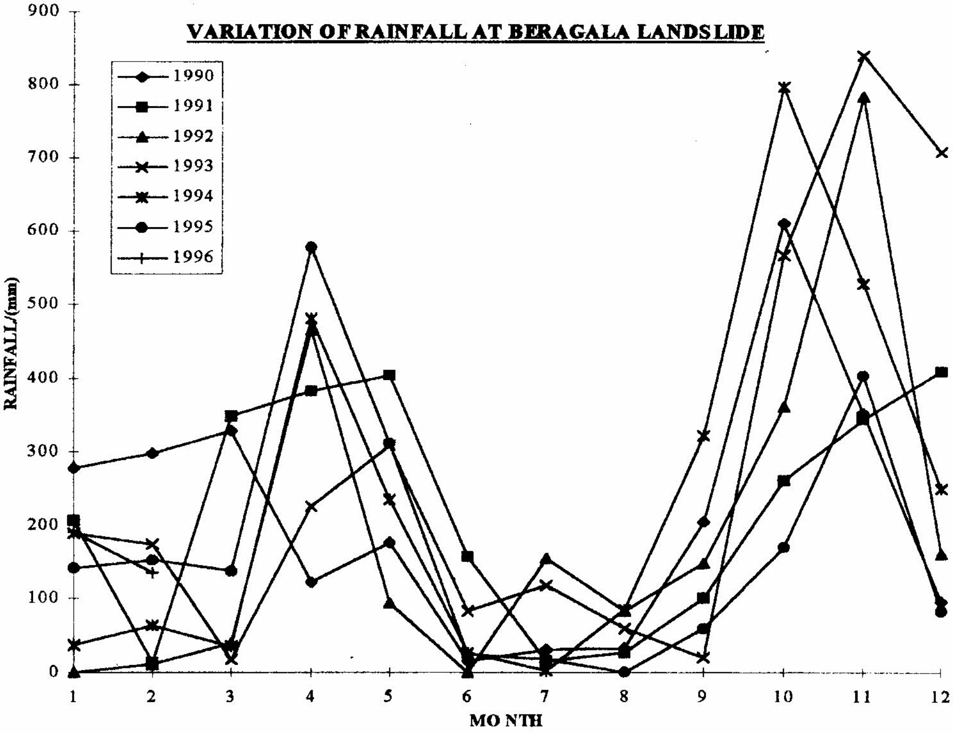

Fig. 9. Rainfall variation at Beragala landslide

According to Fig. 9, Beragala landslide receives heavy rainfall during the North-Easten monsoon period, from September to December. Comparing the last year rainfall figures of this period with the similar figures of the previous years, it is clear that the rainfall is much lower in

1995. Therefore, the measured movements of the landslide in 1995 are likely to be on the lower side.

Relation of ground movement with the rainfall

The variation of measured surface movement with the rainfall for six months starting from September 1995 is given below (Table V). The same data is shown graphically in Fig. 10. Though the data is clearly insufficient for a complete conclusion it is clear from this graph that the surface movements increase with rainfall.

Table V. Relation of the rainfall and the movement of the slide

MONTH	RAINFALL /(mm)	MOVEMENTS OF EXTENSOMETERS/(div)								TOTAL MOVEMENT
		1	2	3	4	5	6	7	8	/(Div)
SEP.'95	57.9	-	-	-	-	-	-	-	-	-
OCT.'95	168.7	-	-	-	-	-	-	-	-	-
NOV. '95	403.1	1	4	2	6	16	8	1	0	38
DEC. '95	82.0	0	4	3	7	14	10	1	0	39
JAN. '96	190.0	1	1	3	4	3	0	0	0	12
FEB. '96	134.6	0	1	0	0	0	0	0	0	1

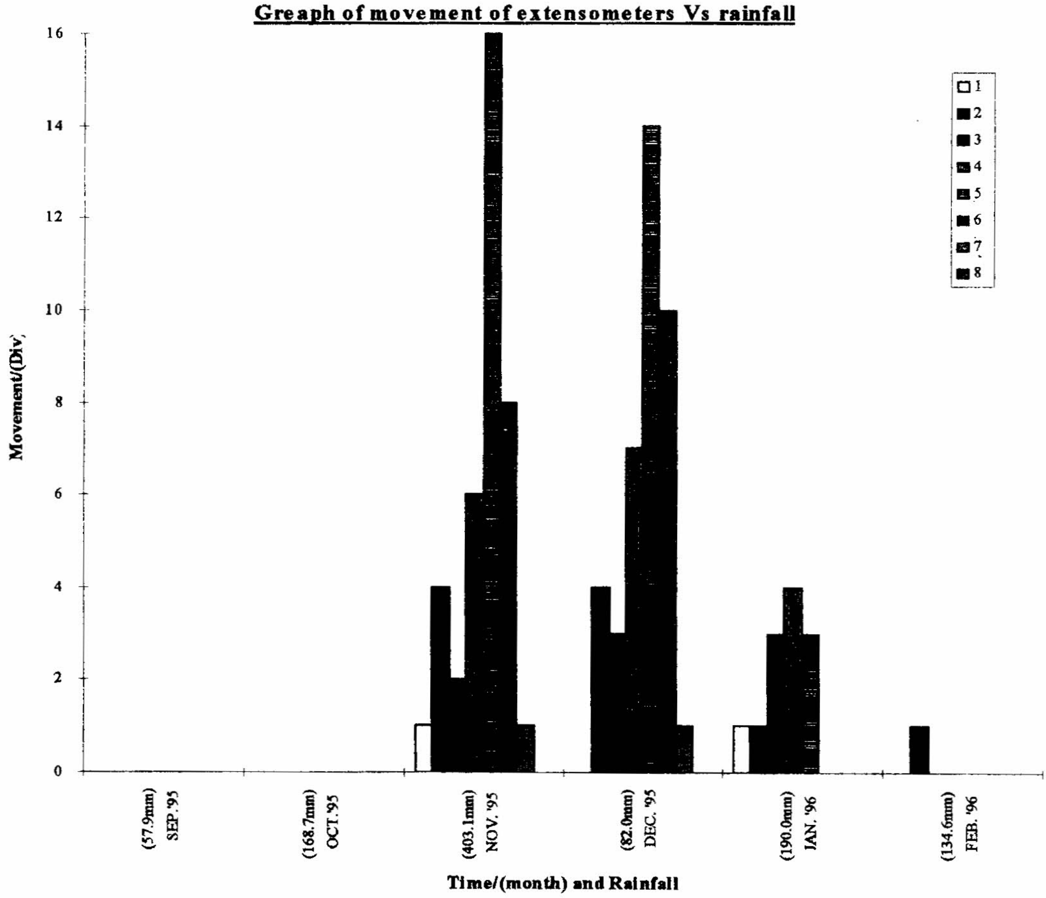

Fig. 10. Rainfall and surface movement relation at Beragala landslide

Ground survey

As a ground survey, leveling of markers is being carried out, starting from March 1996, to measure the subsidence within the landslide area. Fifty markers have been installed within and around the earthslip area so far. Precise leveling is being carried out at two weeks intervals.

Concluding Remarks

Monitoring of Beragala landslide has commenced in August 1995 and the measurements will be taken for a 12 month period, to cover a complete weather cycle. Data could then be analysed and thus suitable remedial measures (if necessary) could be proposed in order to stabilise the landslide. According to the limited data available at present Beragala landslide is moving at a rate of about 100 mm/year, a possible figure for a slow moving landslide. Despite the disturbance to instrumentation caused by animals, the available extensometer data seems to be consistent with GPS observations and rainfall figures indicating the reliability of instrumentation to a certain extent. The available data seems to indicate that it is worthwhile to continue monitoring this slide at least for another year to bring it to a satisfactory conclusion.

Acknowledgements

This project is carried out as a part of a joint research program established between Faculty of Engineering, University of Peradeniya and Faculty of Engineering, Hiroshima University. The authors are thankful to Prof. Osamu Kusakabe, the Japanese team leader and other members of the team, Dr. H Sokobiki, Dr. R. Kitagawa, and Dr. R. Yatabe for providing facilities and expertise to carry out the project. This project is also carried out with the collaboration of Road Development Authority of Sri Lanka having assistance from Mr. D. Mallawarachchi, Director (R&D), Mr. Jayamanne, Deputy Director(R&D), Mr. Thuraisamy, Provincial Director(Uva Province) Mr. R. Weerasekara, Chief Engineer & Mr. K. Karunaratne, Executive Engineer at Bandarawela. The authors wish to thank them for invaluable assistance received for the project. Finally the authors also would like to thank Mr. Gnanasekeram, the manager of "Stassen" tea estate, and his staff for their kind cooperation and assistance.

References

Asian Development Bank funded second road improvement project, Phase 1 report, 1989 (Road Development Authority of Sri Lanka).

Loganathan. N., De Silva. S., and Thurairaja. A. 1992 Strength correlation factor for residual soils, Journal of Geotechnical Engineering , 118, No 4, 593 - 610.

Sokobiki. H, Fukuoka. H., Sassa. K and Kodama. N. 1994 Observation of landslide movements by GPS survey, Proceedings of an International Conference on Landslides, Slope Stability and the Safety of Infrastructures , Kuala Lumpur, pp 333 - 340.