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Monitoring the Earth Movements at the Recent Earth-Slip Affected Area Using Surveying Techniques

E.P.N.U. Kumara, A.W. Wijeratne, W.N.N.K. Perera, S.R.C. Ranaweera, R.M.I.J.B. Ranatunga and R.P. De Silva[1]

Sabaragamuwa University of Sri Lanka, P.O. Box 02
Belihuloya, Sri Lanka.

ABSTRACT. The study was based on the recent earth-slip that occurred in Puwakgahawela. A devastating earth-slip took place at the above hamlet, on the 5th of October 2002, causing copious environmental and socioeconomic impacts. This was one of the major natural disasters in this part of the island. The study area is located in Imbulpe divisional secretariat, Balangoda electorate in the Ratnapura district, and is in close proximity to the Sabaragamuwa University of Sri Lanka. The earth-slip hit area comprises about 60 households with 342 family members. The Sabaragamuwa University Centre for Environment and Sustainable Development (SUCEDS) implemented a research study to monitor the earth movements at the earth slip affected area using surveying techniques. Primary data were mainly used for this study. Having inspected the earth-slip struck area; suitable locations were identified for the detection of possible earth movement (i.e. 16 observation points). Readings were taken to the 16 points at regular intervals (once a month) with respect to the established ground control points (i.e. 3 ground control points) on either sides of the causeway of the stream. The resultant displacements of earth were then calculated using Euclidiance distance. This research disclosed that all the observation points showed significant earth movements within a short period of time.

INTRODUCTION

At present, it is known that major regions of seven administrative districts of Sri Lanka consisting of the central hills are subjected to landslide hazards. This area is estimated as approximately 12000 sq Km comprising nearly 20% of the area of the country. The inventory of landslides indicates that highest record of landslides have occurred in Badulla, Nuwara Eliya, Ratnapura and Kegalle regions during the period 1955 to 1996 with the highest recorded intensity during the period of 1986 to 1990 (Dias, 2002).

The catastrophic earth-slip under study took place on the 5th of October 2002 at Puwakgahawela (168950mN, 202500mE) hamlet of Balangoda in Rathnapura district causing numerous environmental and socio- economic impacts. This was one of the major natural disasters in this part of Sri Lanka. Primary reasons for this type of earth-slip are forest fires, mismanagement of watersheds, wonton destruction of forests etc.

The area is located in Balangoda electorate, Imbulpe divisional secretariat and close proximity to the Sabaragamuwa University of Sri Lanka. Earth-slip affected area consists of about 60 households and includes 342 family members (Edirisooriya,

[1] Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

2000).he area is situated in the Intermediate Zone (IZ), the mean annual temperature is about 27^0 C and annual rainfall ranges between 1750mm to 2500mm (Fig. 1). The bimodal rainfall pattern can be seen clearly in this area (Udaya Kumara, 2002).From May to September the constant wind also accounts for the depletion of the ground water level (Udaya Kumara, 2002).

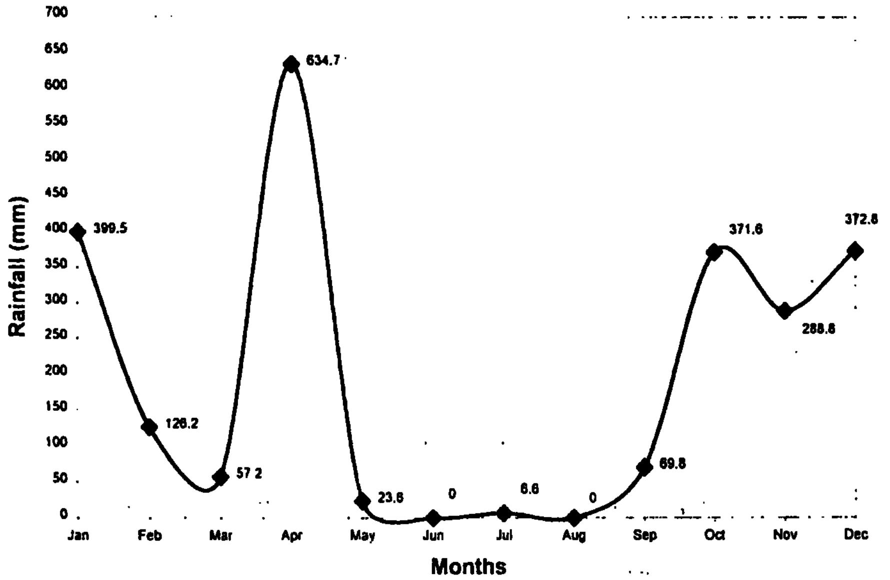

Fig. 1. Rainfall at Sabaragamuwa University Premises at Belihuloya in 2002.
Source: Meteorological station at the Sabaragamuwa University Centre for Environment and Sustainable Development (SUCEDS).

The objective of this study was to monitor the earth movements at the earth-slip affected area (Puwakgahawela) using surveying techniques. Then to study the earth movements using two-dimensional views and to make available this methodology and findings to identify similar land slide proven areas in the future and to develop a disaster early warning system.

MATERIALS AND METHODS

By means of the surveying principles the new positions of the monitoring stations with respect to a local reference system were determined. Further the total extent of the earth-slip-affected area was calculated. Total Station with its necessary accessories and Levelling Instrument and staves were used for surveying. The earth-slip ravaged area is about fifty hectares in extent. In this study necessary observations were taken by using the Total Station, although presently more precise surveying techniques are available.

Procedure

Sixteen observation points were identified as suitable locations for possible earth movements. (Fig. 2). Monitoring stations were established at these locations to study the earth movements in any direction. These monitoring stations were connected to the ground control points (i.e. 3 Ground Control Points) using basic surveying principles. The ground control points were selected at the locations, where the possibility of the earth movements would be minimum; hence they had to be located outside the earth-slip affected area. The variations of already identified earth movements were monitored at regular intervals (once a month) for the period of three months.

In this study, three Ground Control Points were established on either sides of the water stream (two points were established on the left bank and one point was established on the right bank of the water stream). Sixteen Observation Points were placed along the earth-slip affected area at about 50m intervals. (See fig. 3).

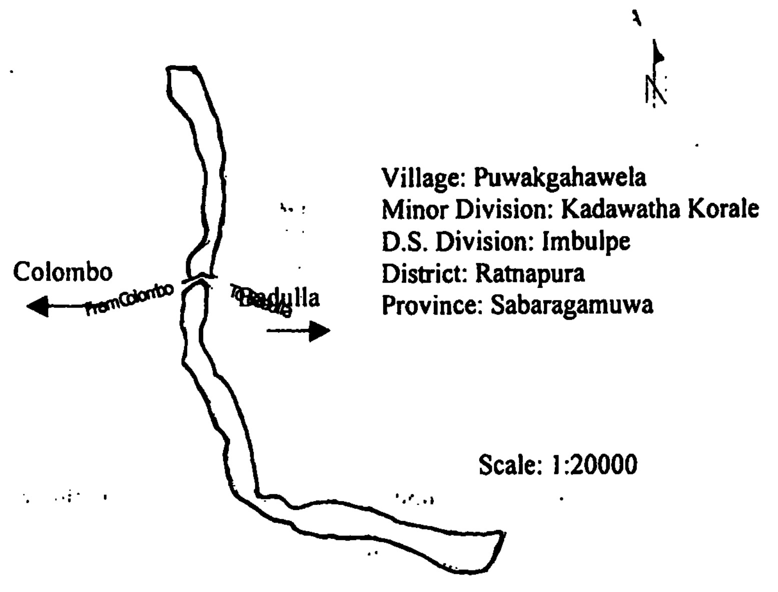

Fig 2. Earth slip affected area –Puwakgahawela.

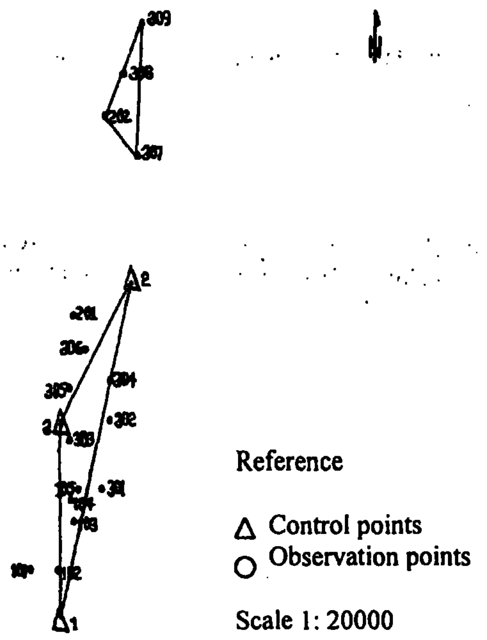

Fig. 3. Locations of ground control points and observation points.

Calculations

With reference to the established three-ground control points the x, y coordinate (north and east) of the monitoring points were determined at regular time intervals. The earth movements were calculated using the Euclidiance distance for the given time interval as follows (Fig. 4).

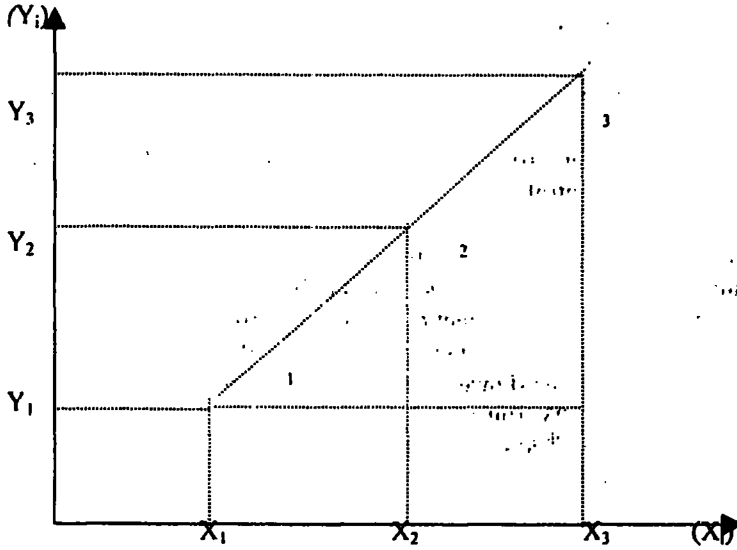

Fig. 4 Calculation of displacement of earth movements using X, Y coordinates.

(X_1, Y_1) = Coordinate of East and North at first observation day for particular observation point;

(X_i, Y_i) = Coordinate of East and North at i^{th} observation day for particular observation point;

Where i =1,2,3...

Displacement of each X, Y coordinate was calculated using Euclidean distance in order to view the earth movements of the earth-slip affected area.

$$D_i = \sqrt{(X_1 - X_i)^2 + (Y_1 - Y_i)^2}$$

Where,

D_i = Displacement from the 1^{st} day to the i^{th} observation day for a particular observation point.

Correction factor for the instrument error of the Total Station was calculated using the following equation (*Sokkia* Co Ltd, 1999)

$$E = \pm(3 + 2ppm \times d)mm$$

Where, E = Instrument error (mm); 3,2= Constants; ppm = Parts per million; d = Measured distance (mm).

RESULTS AND DISCUSSION

At the commencement of this study sixteen observation points were established with respect to the three-ground control points. Subsequently, observation point number 101 had been removed by the villagers. A major earth movement had occurred in close proximity to point 308 and so it was not available for further study.

Observation point numbers 102,105,302 and 303 showed significant earth movements (i.e. away from the control points) for the period of 8th April 2003 to 25th June 2003 (Table 1 and 2). Observation point numbers 103,202 and 305 showed significant earth movements in the opposite directions. (i.e. towards the control points). Observation point numbers 104,201,301,304,306,307 and 309 showed irregular earth movements. Some observation points mentioned above (104,201,301) showed increasing earth movements during the time period of 9th May 2003 to 29th May 2003 and thereafter those observation points showed decreasing movements from the period of 29th May 2003 to 25th June 2003. But the rest (304,306,307) showed decreasing earth movements for the period of 9th May 2003 to 29th May 2003 and after that those points again showed increasing earth movements (i.e. from 29th May 2003 to 25th June 2003).

Table 1. Displacement of earth and corrected values for + or – error (mm) from 8th April to 29th May 2003.

Observation Point No	Earth Movement (mm)	Correction factor Error (+)	Correction factor Error (-)	Earth Movement (mm)	Correction factor Error (+)	Correction factor Error (-)
102	395.1	398.1	392.1	1431.7	1425.7	1428.7
103	85.4	88.4	82.4	79.6	73.6	76.6
104	9.4	12.4	6.4	17.8	11.8	14.8
105	9.4	12.4	6.4	16.6	10.6	13.6
201	4.4	7.4	1.4	13.8	7.8	10.8
202	14.3	17.3	11.3	6.1	0.1	3.1
301	17.4	20.4	14.4	24.2	18.2	21.2
302	2.2	5.2	-0.7	9.3	3.3	6.3
303	2.8	5.8	-0.1	7.1	1.1	4.1
304	57.2	60.2	54.2	8.0	2.0	5.0
305	4.4	7.4	1.4	6.0	0.0	3.0
306	22.3	25.3	19.3	13.7	7.7	10.7
307	28.1	31.1	25.1	19.1	13.1	16.1
309	30.8	33.8	27.8	29.2	23.2	26.2

Table 2. Displacement of earth and corrected values for + or – error (mm) from 8th April to 25th June 2003.

Observation Point No	Earth Movement (mm)	Correction factor Error (+)	Correction factor Error (-)
102	4168.7	4171.7	4165.7
103	72.6	75.6	69.6
104	13.4	16.4	10.4
105	14.1	17.1	11.1
201	8.9	11.9	5.9
202	1.0	4.0	-2.0
301	10.6	13.6	7.6
302	23.3	26.3	20.3
303	6.7	9.7	3.7
304	9.2	12.2	6.2
305	1.4	4.4	-1.5
306	11.7	14.7	8.7
307	30.8	33.8	27.8
309	35.0	38.0	32.0

In surveying techniques there are mainly three types of errors, they are instrumental errors, personnel errors and error due to the natural causes. There are two types of instrumental errors namely; error due to the instrument being out of adjustment and systematic errors of the instrument. In order to eliminate the first error (mentioned above) permanent adjustments were performed and the latter errors such as zero error, scale error and cyclic error were found out by calibrating the instrument. There are two types of personnel errors namely error of manipulation and error of sighting and reading. These errors were minimized by using experienced personnel.

Applicability of the existing temperature and pressure at the site minimized some natural errors, which affected the observations. However the effect of environmental conditions like wind, humidity and correction for refraction were neglected .In this study vertical movements of the observation points were not taken, on account of the difficulty to measure instrument height and target height accurately. According to the specification instrumental accuracy was $\pm(3+2ppm\times d)mm$. During the period of this study a few observation points had been removed, therefore in place of the removed observation points, new observation points were replaced at the previous locations.

CONCLUSIONS

The earth slip affected area showed significant earth movements within a very short period of time (3 months).There were three patterns of earth movements i.e. irregular, increasing trend and decreasing trend in the earth slip affected area.Researches based on earth movements will immensely help to forecast earth slips at earth slip vulnerable areas in Sri Lanka. Therefore these studies should be carried out with commitment of the authorities concerned.

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