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SALIENT ASPECTS OF LANDSLIDES IN SRI LANKA

GLISSEMENTS DE TERRAIN AU SRI LANKA – ASPECTS PRINCIPAUX

K.S. Senanayake[1] *P.M. Sithamparapillai*[2] *N.W. Herath*[3]

[1]Formerly Head, Geotechnical Engineering Division, National Building Research Organisation, Colombo, Sri Lanka
[2]UN National Consultant, Engineering Geology, National Building Research Organisation, Colombo, Sri Lanka
[3]Head, Geotechnical Engineering Division, National Building Research Organisation, Colombo, Sri Lanka

ABSTRACT: The central highlands of Sri Lanka are prone to landslides. Frequent and disastrous landslides have caused loss of many lives, and damage to property to the tune of several million dollars apart from rendering tens of thousands of people homeless. A study was therefore undertaken by the Government with the objective of identifying the causes and mechanism of landslides. Besides the inherent geotechnical characteristics, the consequences of human activities leading to environmental deterioration were found to be the major causative factors. As almost all the past landslides considered had occurred during or after unusually heavy rains, it may be concluded that rainfall is the main triggering factor of landslides in Sri Lanka. Arising from these studies, a Landslide Hazard Mapping Project is now in progress in two Landslide prone districts of the hill country viz:Badulla and Nuwara Eliya.

NATURAL CONDITIONS

Physiographical Characteristics

Sri Lanka consists of a central mountainous mass stepping down in three peneplains towards the sea. The highest of these has an elevation of 1500m to 1800m with a few peaks rising to 2000m or 2500m above sea level. The altitude of the middle plain varies from about 700m to 900m, and the lowest peneplain has general levels less than 30m, but rises to about 100m in some locations. It is mostly in the highest peneplain, and somewhat less in the middle peneplain that landslides are a frequent phenomenon.

Geological Characteristics

Rocks found in the hill country are composed of two main types; (a) metamorphosed sediments like garnetsillimanite schists and gneisses, quartz and quartz schists, quartzfeldspar granulites, garnetiferous gneisses, crystalline limestones (marbles) and calcgranulites, graphitiferous schists, and (b) charnockites. The tropical rainfall and temperature intensify the weathering of these rocks (Cooray 1966).

A complex distribution of lineaments, some of which may be currently active, and geological evidence of sheared zones have been observed by Vitanage (1983, 1986).

Soil Characteristics

Different types of earth cover observed are; (a) residual soils (b) colluvial soils and (c) mixed hill slopes.

Residual soils are the result of in situ weathering of the metamorphic rocks found in the region. The upper layers of the residual rocks which have undergone a greater degree of weathering contain soil minerals such as quartz, mica, clay and iron oxide. Clay minerals are mainly kaolinite and illite.

Colluvial terrain occurs at the foot of rock scarps or steep mixed hill slopes. Colluvium is generally composed of mixtures of rock boulders and soil masses which fall or roll down. In the mixed hill slopes, soil mantles co-exist with outcrops of bedrock. Surface slopes where stones and boulders are enclosed in the soil or laid on its surface may also fall into this type.

Rainfall Characteristics

Different parts of Sri Lanka receive rains during the south-west and north-east monsoons, and also duing the two inter-monsoon periods.

The annual rainfall is as low as 750mm in some parts of the dry zone, but as high as 5000mm at some locations in the hills of the wet zone. The annual precipitation in the hill country is generally above 1700mm. In the south-western parts of the country, the average annual rainfall is about 3750mm to over 5000mm.

The distribution of landslides is characterised by the direction of monsoons: ie, on the north eastern hill slopes during the n-e monsoons, and on the south-western hill slopes during the s-w monsoons. When tropical cyclones pass through the Island, they bring with them unusually heavy rains with storms. Some recent cyclones had direct influence on the hill country causing disastrous landslides.

LANDSLIDE STUDIES-SRI LANKA

Past Studies

Until a few years ago, literature available on landslides in Sri Lanka was limited to adhoc studies of some catastrophic landslides or potential failure of slopes which posed risk to human life and property. Most of such studies had been conducted by the Geological Survey

Department of Sri Lanka, which maintains such records. Only a small amount of published literature had been exposed outside the country and the overall state-of-the-art of landslide control had been considered poor in Sri Lanka (Brand 1984).

Present Study

Since 1985, in the background of frequent recurrences of landslides in the recent past, the National Building Research Organisation (1) identify major causative and contributory factors
(2) formulate guidelines to identify potentially hazardous slopes
(3) determine criteria for selection of land for development, and
(4) develop early warning systems.
Some salient aspects of landslides observed from this study (NBRO 1990) are discussed below. Arising from the results obtained in this study during 1986-90, a detailed Landslide Hazard Mapping Project was commenced in 1990 in two landslide prone districts (Badulla & Nuwara Eliya) in the central highlands, and is in progress half-way towards completion.

Distribution of Landslides

Distribution of past landslides in Sri Lanka suggest that practically most hill slopes in the wet zone are prone to landslides. Based on past records, seven hilly districts have been identified as specific areas which are most vulnerable. Fig.1 shows the distribution of reported/known landslide occurrences over the past five decades. These are only the ones which have affected life and property, or which have otherwise received the attention of man.

The influence of meteorological conditions is clearly evident in that; (a) landslides have always occurred during the monsoon periods, or during unusually heavy intermonsoon rainfall, (b) events of a particular year and month are distributed in clusters and (c) events in different monsoon periods are as discussed in section 1.4.

Simple Data Base Analysis

Data Base

Of over 200 past landslides reconnoitred, 64 locations were selected for detailed study. A computerised data base was compiled with relevant information collected for each selected landslide on the location & time of occurrence, history, scale, type and mode of failure, possible contributory and causative factors, prior warning signs, extent of damage and degree of risk, land use and vegetation, rainfall, soil types, lithology, tectonics and structure, geomorphology, hydrogeology etc. Some results of analyses are given below.

Land Use and Vegetation Before the Slide.

A majority of landslides have occurred in plantation areas on slopes, with 36% in tea, 20% in rubber and 10% in coconut. A significant number were on irrigated slopes with 13% in rice terraces and 8% in vegetable cultivation. Vegetation in 51% of the locations was low bush, tobacco or crops of shifting cultivation. High bush was in 11% of the landslides and house garden in 22%. Streams ran through or adjacent to 57% of the landslides.

Geology

70% of the landslides were on midslopes, 13% in benches on slopes and 8% in natural terraces. Inclination of the surface slope before failure was in the 16-30 deg. range for 64% of the slides, 31-45 deg. range for 22% and less than 15 deg. slopes in 14% of slides.

32% of the slides were on dip slopes, 22% on scarp slopes and the balance were on intermediate slopes. At 57% of the locations, quartzite or quartzitic gneiss was present as the main rock type, and in 51% as the secondary rock type. Charnockites or charnockitic gneiss were the main rock types in 19% of the slides, and in 31% as the secondary rock type. Biotite gneiss represented the rest.

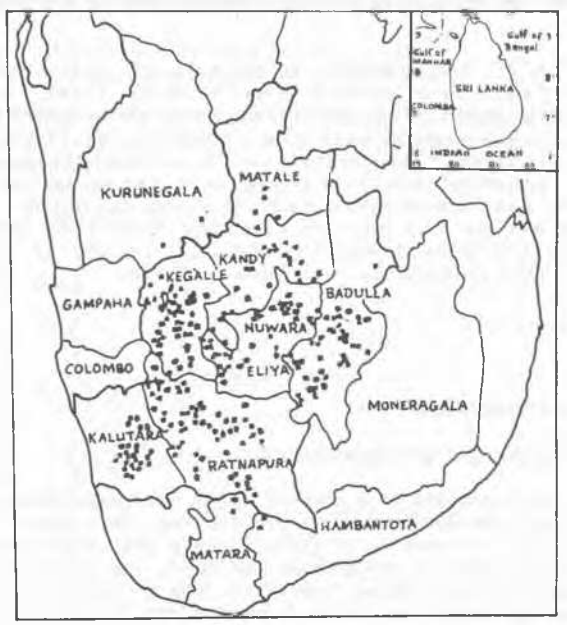

Fig. 1 Distribution of Landslides in Sri Lanka

In all the locations at least one predominant joint plane was clearly visible, though 2 or 3 joint planes were seen in some. Many of the joint planes are vertical or nearly vertical. Spacing between two joints was less than 1m in 77% of the cases, and less than 0.3m in 24%. Complete weathering has advanced to 1/3 of the regolith depth in 48% of the locations, to the middle third in 58% and to full depth in the rest. Depth to bedrock was less than 5m at 78% of the locations, with 10m being the maximum. In 40% of them, the bedrock was deeper than 3m.

RAINFALL

From the analysis of intensity of rainfall for the 28hr, 48hr and 72hr periods prior to the event, it was found that 80% of the slides occurred when the 3-day cumulative precipitation exceeded 200mm. The number of landslides for each range of antecedent rainfall is shown in Fig.2. This, and the observation of rainfall pattern at many other past landslides helped to derive a thumb rule for early warning as follows:- "if more than 200mm rainfall had occurred on the hill slopes in a period of 3 days, and if wet weather was continuing, then the possibility of landslides looms ahead."

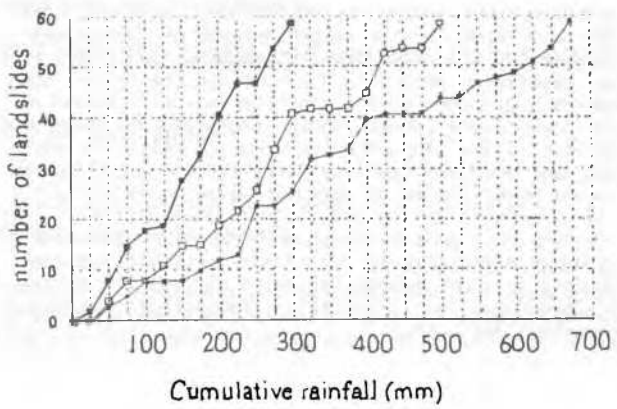

Fig. 2 Number of landslides vs-antecedent cumulative rainfall during 24,48 and 72 hours

This is borne out by the following analysis of the rainfall intensities for the preceding 72 hours at 62 of the locations studied :-

mm	Locations
0 - 50	03
50 - 100	05
100 - 200	06
200 - 400	27
400 - 600	12
600 - 700	09

The undermentioned information would be of additional interest :
Pussellawa - 1024 mm, 5 day rainfall in January 1986
Laxapana - 645 mm, 3 day rainfall in May/Jun 1989

Table 1 : Antecendent Daily Rainfall (mm) at the 10 sites referred in Fig.3. No automatic rain gauges were fixed here.

RAINFALL

	24 hr	48 hr	72 hr	4 dy	5 dy	6 dy	7 dy	Ft msl
KY06 Denapitiya	30	33	84	84	84	83	83	2500
BD08A Blackwood	25	28	29	30	46	101	136	3400
BD49 Agaratenna	53	115	187	257	321	410	418	3000
NW17 Unique View	34	73	98	120	150	156	161	6400
BD06 Westmoreland	154	254	379	400	400	402	402	3500
NW10A Wellagiriya	130	261	487	640	676	676	676	3000
KT05 Panthiya	298	388	391	408	410	408	434	3000
BD46 Keenagashena	299	499	545	548	545	552	546	3500
BD13 Ledgerwatte	203	419	673	888	910	918	918	4000
NW07 Kurupanawela	160	414	559	612	610	612	612	5300

The rainfall pattern for 7 days prior to the failure in typical landslides is shown in Fig.3. As observed in these Figures, however, there are landslides which have occurred when the 3-day cumulative rainfall was as low as 50mm. There were some cases where even the daily rainfall intensity during the 3 days has been well surpassed by previous daily rainfall during the season without causing any significant stability problems. Predicting of landslides based on rainfall alone is therefore not a reality, but may yet help in saving lives from landslide disasters.

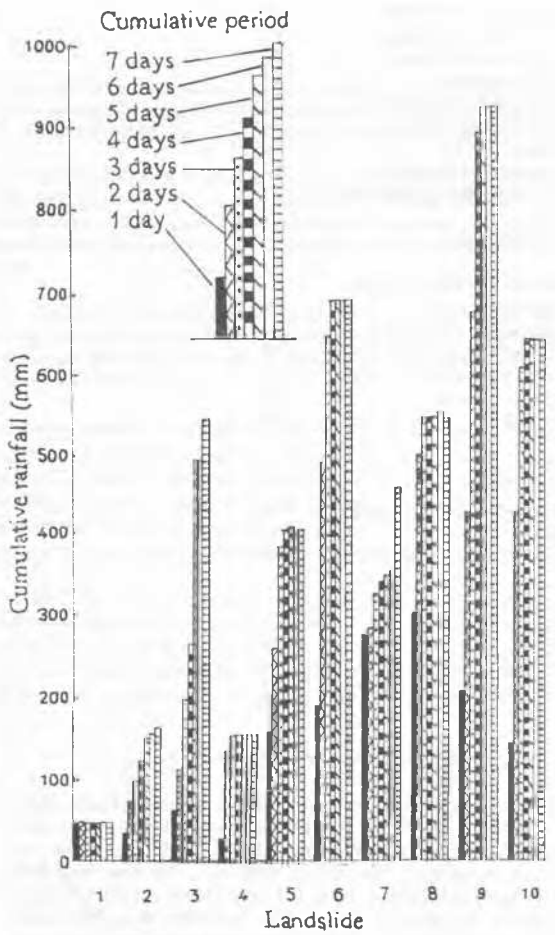

Fig. 3 Rainfall pattern during 7 days prior to failure in 10 typical landslides

MODE OF FAILURE

On a broad classification of the mode of failure, 15% of the landslides were grouped under rock and earth falls, 50% as slides and 15% as creep. 60% of the slides were translational, the rest being rotational. Creep was obvious on slopes which were rain fed, or almost perennially irrigated for rice or vegetable cultivation.

Causes of Landslides

The landslides studied were often influenced by contributory or causative factors, and it was not possible to isolate one as the main factor. Adverse human activities and neglect of proper slope management have contributed to the increased occurrence of landslides. The contribution of rainfall as a key triggering factor remains significant. Different causes of landslides are given below as percentages of the landslides which were observed in this study:-

Geomorphology, Geology & Soils	%
Recurrence of old slides	37
Steep slopes 31 - 45 deg.	22
16 - 30 deg.	62
Dip of foliation planes	37
Dip of joint planes	47
Having fault/shear planes	02
Having clay seams/layers	14
Having clayey soils	70
Having micaceous minerals	12
Having rounded sands/pebbles	11
Water and Drainage	
Ponds/reservoir/rice fields	31
Contour irrigation	08
Overflow of water courses	15
Trenches trapping sediments	09
Blocking natural water flows	11
Rise of water table	53
Rapid drawdown	06
Construction	
Excessive loading of slopes	06
Toe removal	21
Vibration by rock blasting	04
Others	
Thunderstorm	06
Impact of landslides	26
Removing forest/other cover	15

Landslide Hazard Mapping Project, 1990-1994

In view of the Government's decision to continue more detailed studies on the landslide hazards in the two districts of Badulla and Nuwara Eliya, a total area of 4525 sq.km. rising up from about 300m El. to the highest mountain, Pidurutalagala (2524.7m) was taken up for study, giving priority to about 1200 sq.km. considered vulnerable to human life ad property. Work was commenced in 1990 and is scheduled to be completed in 1994.

The scope of this project is to do field mapping and mark off zones of high, medium and low landslide hazards, using ozalid prints of base maps to the scale of 1:10,000 and aerial photos having scales varying from 1:20,000 to 1:50,000.

This Project which is multi-disciplinary in nature takes into its ambit not only physical geology, geomorphology, engineering geology, and engineering soil science, but also environment, land use planning and human settlements.

CONCLUDING REMARKS

Of over 200 landslides reconnoitred, only 64 locations were considered in the simple analysis. Limited resources and time were constraints for in-depth studies involving detailed geotechnical investigations and monitoring ground movement except at a few selected locations.

The studies indicated that the presence of clay minerals, rise of the water table and its fluctuation, occurrence of steep hill slopes, and steep dips of foliation and joint planes were some of the major causes of landslides. Recurrence of old landslides, impounding of water in ponds, reservoirs or for cultivation on the hills, toe removal on cut slopes during construction, and removal of forest cover were other causes that led to several landslides. These indicate definite pointers to main causes, and the investigations necessary for updating and improving them. The man triggering factor is rainfall.

The studies also gave an opportunity to local scientists to develop methodologies for field geologic mapping, monitoring of slope movements, early warning and better instrumentation for rainfall, subsurface geology, hydrogeology and soils.

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* UNCHS - United Nations Centre for Human Settlements
* UNDP - United Nations Development Programme