National Building Research Organisation

Newsletter

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Technical Co-operation for Landslide Mitigation Project

In This Issue

Landslide occured in *Wedamulla Estate, Kotmale on 25th September 2015*

Dear Readers

National Building Research Organisation (NBRO) as the national entity committed to landslide risk reduction in Sri Lanka considers it as its priority to strive for the capacity building of its staff.

Japan International Cooperation Agency (JICA) has been long assisting our country to strengthen its development needs and economic policy framework. With NBRO - JICA collaborations, National Building Research Organisation has been able to reach greater heights in its quest for a disaster reduced Sri Lanka. Disaster Management Capacity Enhancement Project adaptable to Climate Change (DiMCEP) put forth in April 2010 was a similar collaborative effort.

The Technical Cooperation for Landslide Mitigation Project (TCLMP) was initiated in 2014, upon the request of the Sri Lankan government from JICA. The main objective of the project is to build the capacity of NBRO in landslide mitigation.

This special edition of the official newsletter of NBRO features the various activities and benefits reaped out of TCLMP. With this issue marking the closure of yet another eventful year, we welcome the dear readers to enjoy the contents and let us know your valuable feedback to be incorporated in our future activities.

Best Wishes,
Eng. (Dr.) Asiri Karunawardane
Director General
National Building Research Organisation

Both Sri Lanka and Japan are island countries and share experiences of devastating natural disasters.

Through its own experience, Japan has accumulated knowledge and technology for disaster risk reduction and has committed in promoting cooperation to reduce as much as possible, the number of disaster victims, as well as their suffering, in the international community.

One of the good examples of such cooperation is Sri Lanka. Since the Indian Ocean Tsunami hit the island on 26th of December 2014, Sri Lanka has developed its own capacity in disaster risk management. I believe, JICA has contributed to this development under the Program for Climate Change and Disaster Prevention. We have been working together with NBRO as well as Disaster Management Center, Meteorological Department and all other stakeholders engaged in disaster risk management.

This newsletter covers JICA's current cooperation with NBRO. On behalf of JICA I wish for enhanced partnership between NBRO and JICA to make Sri Lanka further more resilient.

Best Wishes,
Kiyoshi Amada
Chief Representative
Sri Lanka Office
Japan International Cooperation Agency (JICA)

The Technical Cooperation for Landslide Mitigation Project started in October 2014, and two years have elapsed since its initiation. I, along with the consultant team, J.O.C.V. Okamura, and many other related persons including short-term experts have been exchanging techniques of sediment disaster countermeasures of Japan with the NBRO staff. Large-scale sediment disasters have occurred more than four times in the last two years. It is my sincere belief that the NBRO staff have gathered a great deal on Japanese sediment disaster countermeasures, including field survey methods through TCLMP.

The project is planned up until October 2018. I believe it is prudent for both parties to share good practices with each other. It is my intention to conceive up far better ways of which the TCLMP team and NBRO could make use of Japanese and Sri Lankan experience in disaster management.

I highly appreciate this opportunity to introduce TCLMP, one of the many technical collaborations between JICA and NBRO, through this issue.

Best Wishes,
Mr. Kenichi Handa
Chief Advisor
Technical Corporation for Landslide Mitigation Project
Japan International Cooperation Agency (JICA)

Editor's thoughts: Towards a Safer Sri Lanka

Landslides in their very essence signify destruction, and each year, Sri Lanka faces a fair share of it. Every time relentless rains run havoc within the country, National Building Research Organisation finds itself in a whirlwind like state, stretched to its extreme with the dead weight of woes and anxieties of ten landslide prone districts.

Being an island nation and with central highlands in its midst, Sri Lanka experiences localized rains. 20% of the total area of the country is under landslide threat while 30% of the total population has long settled in these regions, making it practically impossible to go for straightforward solutions. Therefore, it is more or less a never-ending battle against the cruel side of the nature.

Established in 1984, NBRO has grown into one strong body of professionals coming from a number of disciplines, all dedicated for one dream – a safer Sri Lanka. NBRO believes TCLMP to be a fresh start in achieving this, blending its existing technologies and know-how with that of a strong nation. Given its own long history of natural disasters, Japan has learnt many lessons the hard way. Therefore, their insights, extensive studies and attention to every minute detail regarding this natural disaster would certainly prove to be invaluable assets to NBRO in its mission of creating a disaster free built environment in the years to come.

Technical Cooperation for Landslide Mitigation Project

R. M. S. Bandara
Director, Landslide Research and Risk Management Division
National Building Research Organisation

The Technical Cooperation for Landslide Mitigation Project (TCLMP) is a fruitful outcome of National Building Research Organisation's continuous effort to elevate its standards and for the capacity building of its staff. The ultimate goal of the project would be to contribute towards social and economic development of the country as a whole while mainly achieving the following five objectives.

- To strengthen the capacity of investigation, planning and evaluation for sediment disaster (landslide) mitigation measures
- To strengthen the capacity of designing, construction supervision, and monitoring of landslide mitigation measure
- To strengthen the capacity of designing of slope failure mitigation measures
- To strengthen the capacity of designing, construction supervision, and monitoring of rock fall mitigation measures
- To improve the knowledge and know-how of landslide mitigation measures

JICA contributes to the project by providing their experts, training opportunities for NBRO staff in Japan or in other countries, machinery, equipment and other materials.

Four pilot sites were selected initially in Kandy, Udamadura, Badulusirigama and Alagumale, out of which the pilot site at Kandy Nursing School was removed from the project later on, while the construction works are currently being carried out at the rest of the three sites. The project is scheduled for approximately three years from March 2014.

The direct beneficiaries of TCLMP are the NBRO staff members while indirectly it is expected to benefit the Sri Lankan community as a whole. Undoubtedly, NBRO also has an important role to play in reaping the fullest benefit out of the project. At each phase, starting from preliminary investigations, detailed investigations, monitoring up to mitigation of each pilot site, smooth transfer of the knowledge and technology - where necessary - is essential. NBRO appreciates this opportunity to embrace the new possibilities opened up as a result of the project.

Hiroki Hashimoto
Representative, JICA Sri Lanka Office
Japan International Cooperation Agency

Sri Lanka is vulnerable to landslides caused by heavy rain as the island is widely influenced by monsoon. In addition, it is observed that the change of rainfall pattern due to the climate change tends to make the vulnerability even more severe. Areas under high landslide risk exist in hilly and mountainous regions of the country and covers about 20% of the total land area where 30% of the population have settled. Japan International Cooperation Agency (JICA) considers Disaster Risk Reduction as one of the high priority areas in its cooperation strategy and one of the main focus is landslide mitigation in cooperation with National Building Research Organisation (NBRO).

In March 2013, Japanese ODA Loan Agreement for "Landslide Disaster Protection Project of the National Road Network (LDPP)" was signed. LDPP carries out countermeasure construction on slopes on major national roads having a high risk of landslides, in order to alleviate the risk of disaster and making the road network and lives of the nearby residents safer. LDPP is jointly conducted by RDA and NBRO.

Even though NBRO has been improving its capacity of landslide mitigation, there is still more room to improve the capacity on countermeasures based on accurate topographic analysis harmonized with technical standards and countermeasures in Sri Lanka. Under these circumstances, the Government of Sri Lanka requested the Government of Japan to implement technical cooperation to enhance the capacity of NBRO through on-the–job training, preparation of the technical guidelines and manuals, and construction of mitigation measures.

Responding to above request, and after a series of discussions on the detailed design of the project among relevant authorities including NBRO, JICA commenced "Technical Cooperation for Landslide Mitigation Project (TCLMP)" in March 2014. The objective of TCLMP is to improve the landslide management capacity of NBRO through application of appropriate mitigation measures with Japanese and other technology in the pilot project sites.

Mr. Kenichi HANDA, Chief Advisor, from Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in Japan, the team of Japanese Experts from ESS (Earth System Science Co. Ltd.) and the short-term experts from MLIT are working with NBRO staff on day-to-day basis to achieve its objectives.

Pilot Sites	Location	Type of disaster
School of Nursing - Kandy	Kandy District	Slope Failure
Alagumale	Matale District	Rock fall
Badulusirigama	Badulla District	Landslide
Udamadura	Nuwara-Eliya District	Landslide

Pilot sites of the Technical Cooperation for Landslide Mitigation Project

"THE ULTIMATE OBJECTIVE OF TCLMP IS TO IMPROVE THE LANDSLIDE MANAGEMENT CAPACITY OF NBRO"

A New Outlook for Landslide Investigation, Instrumentation and Monitoring Techniques with TCLMP

Ravindra Balasooriya
Senior Scientist, Geotechnical Engineering Division
National Building Research Organisation

A landslide is a complex phenomenon that requires extensive information on its behavior, mostly for prolonged periods, to characterize and accurately identify its dynamics. For the predictions and conclusions drawn out of this information to bear any significance, they have to be reliable and consistent as well, necessitating the use of sound landslide investigation methods. Bearing this in mind, NBRO, the national entity responsible for landslide risk reduction in Sri Lanka, sought to incorporate Japanese technology into its existing investigation and monitoring methods.

Especially, the Technical Cooperation for Landslide Mitigation Project has enabled NBRO to explore new avenues in landslide investigation and monitoring techniques.

Enhanced Landslide Investigation Techniques

For accurate assessment and controlling of stability conditions of a slope and prediction of its future movements, subsurface investigations and landslide monitoring programs are powerful tools for landslide specialists. While indirect investigation methods like geophysical explorations could prove to be quite valuable in subsurface profiling, NBRO predominantly concentrates on direct in-situ and laboratory-testing methods as the latter provides both quantitative and qualitaative information important for mitigation design purposes.

Geotechnical boring is commonly used at NBRO as a sampling method in order to obtain specific information about a given landslide, including subsurface geological formations, soil type, stratification and most importantly, depth and geotechnical parameters of the slip surface(s).

However, the customary core-drilling techniques practiced at NBRO using its five rotary drilling machines were not quite up to the task. For one thing, NBRO did not have the technique of continuous sampling. In order to get some form of continuous samples, NBRO had to resort to slightly 'modified' version of the regular standard penetration test so that core-samples could be obtained virtually over the whole 1m depth interval, allowing the scientists to get an approximate subsurface profile of the soil mass in question. Rock core sampling was ineffective and mostly brought little to no recovery. This had more than a little to do with the fact that proper techniques or machinery was not being utilized and lack of proper guidance during the process.

Techniques in obtaining good quality and high recovery of core samples in terms of equipment, control of drilling fluid and drilling under problematic geological and groundwater conditions have been shared with NBRO during the project.

In particular, the drilling machine equipped with SPT assembly, continuous sampler assembly for soils and coring tools (single-tube, double-tube and double-tube swivel-type) with different grade bit types for rock core sampling acquired through TCLMP has helped NBRO in improving its drilling performance. The double-tube swivel-type core barrel systems, insures borehole stability and good core reecovery during drilling and coring. The new machine allows extracting higher quality and continuous soil and rock core samples that enables a clearer and more accurate identification of the geological structure and failure surface(s)

NEW ROTARY DRILLING MACHINE THROUGH TCLMP:

- Inject Water Pressure Controlling
- Continuous Soil Sampling
- Sampling of Moderately to Highly Weathered Rocks and Fresh Rocks
- Enhanced Recovery and Sample Quality

There is much room to improve, and the core samples from the new machine from borehole No 6 at pilot site Badulusirigama with a significant increase in recovery could be considered as a good sign.

Core recovered from existing techniques (40% recovery)

Core recovered from the new rig (60% recovery)

Japanese expert assistance in core sample inspection

Another important outcome of TCLMP is the technical know-how on visually identifying the rupture surface from core samples. The technical knowledge has been shared with NBRO during the investigation works at pilot sites. Identification and determination of the rupture surfaces of a landslide is critical in performing stability analysis of a landslide and for subsequent planning and designing of mitigation works. It is quite important to obtain high-quality core samples for identifying the position of rupture surfaces or zones along which landslide movement has occurred. Improvement of coring techniques to help NBRO drillers obtain high-quality cores has been given much thought and effort through this project.

"TECHNICAL KNOW-HOW ON VISUALLY IDENTIFYING THE RUPTURE SURFACE FROM CORE SAMPLES"

Studies are being carried out on core observation methods for identifying and determining of the rupture surfaces or zones of various types of landslides, mainly based on the experience of landslide investigations in Japan, as a part of TCLMP activities.

New Rotary Drilling Machine

Innovations on Instrumentation and Monitoring Techniques

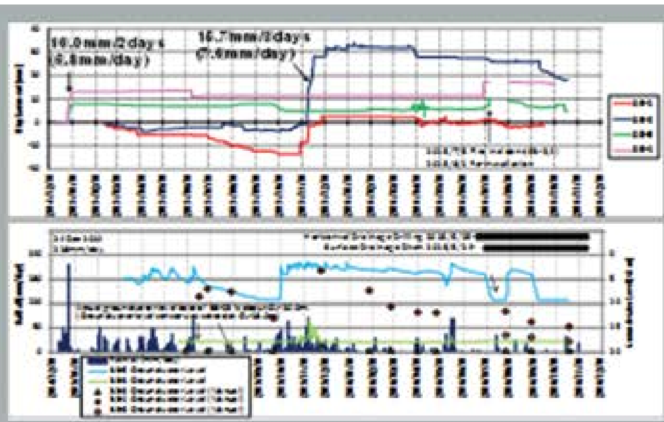
JICA has played a huge part in current instrumentation and monitoring practices in Sri Lanka. Up until year 2007, the monitoring of landslides were carried out manually, and with the technological involvement of JICA, NBRO introduced three monitoring instruments – strain gauges, inclinometers and extensometers - into its system at Mahawewa and Nildandahinna landslides, the first of their kind in Sri Lanka. This enabled NBRO to verify actual slip surface of a landslide. No later than 2012, automated water level gauges were added to the list, under the expert guidance of JICA - TCLMP.

With relevant improvements in traditional and experience based forecasting methods, the new approaches to landslide monitoring based on extensometers, inclinometers, pipe strain gauges and water level meters were introduced to Badulusirigama and Udamadura pilot sites of the project.

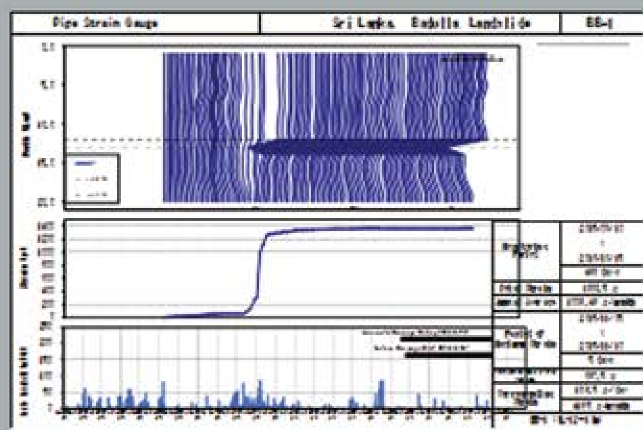
JICA consultants provided the technical consultancies and expert assistance for the project, especially in accurately installing monitoring equipment. Software and techniques has been transferred to NBRO scientists, which help them identify the slip surface of a landslide using monitored data. With the combined effect of monitoring data from strain gauges, extensometers, inclinometers and water level gauges NBRO is able to have a comprehensive idea of ground movement rate, slip surface(s) depth with respect to ground water levels.

LANDSLIDE MONITORING WITH DATA FROM:

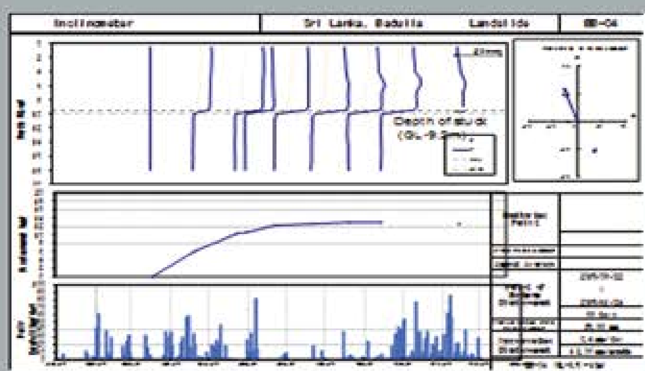
- STRAIN GAUGES
- INCLINOMETERS
- EXTENSOMETERS
- WATER LEVEL GAUGES



Extensometer and groundwater level data distribution with daily rainfall – Monitoring data from Badulusirigama



Pipe strain gauge data distribution with daily rainfall – Monitoring data from Badulusirigama



Inclinometer data distribution with daily rainfall - Monitoring data from Badulusirigama

For instance, clear activity could be identified at the Badulusirigama pilot site with the help of the data from the installed monitoring instruments. From the graphs, the groundwater table could clearly be seen to fluctuate in close conjunction with the rainfall. The rainfall event at the end of September and the beginning of November 2015 has brought groundwater level significantly up, which is well reflected in monitoring data from extensometers installed at the lateral area of the lower landslide blocks (SB1 and SB2). The area shows active movement during the period. The movement velocity was measured to be 15.7 mm/3 days (Max. 7.6 mm/day). The total displacement was 29.0 mm during 10 days between 8th and 17th Nov. The movement is observed to be slow since December 2015.

According to the extensometer data from the upper area of the landslide (SB3 and SB4), active movement could be observed (10.0 mm/2days, Max. 5.8 mm/day) during and after heavy rain (total cumulative rainfall; 652 mm/18 days) at the end of December 2014. The movement has not been active during a rainfall event of May 2016. The monitoring data reveals that the landslide increases its moving speed when the cumulative rainfall exceeds 400 mm.

Inclinometer data collected from the site also displays definite cumulative displacement, especially during the latter part of September 2015 to the end of November, falling in line with the heavy rainfall events during the period. The inclinometer guide pipe of BB-4 was stuck at GL-9.20 m depth on November 2015 due to the bending caused by landslide movement. Definite cumulative displacement has been observed at the depth of GL-12.0 m - 13.0 m of BB-1 based on strain gauge data as well. The movement has increased from the end of October 2015 to the middle of November 2015, but has been slow since the end of November 2015.

Likewise, a clear picture of the landslide dynamics could be achieved with the data collected from these monitoring instruments.

Future Improvements

Since NBRO now possesses a robust landslide monitoring system, implementing site-specific early warning systems and accessing, observing, and monitoring the accumulated data remotely from a base station, ideally at NBRO head office, real-time is a highly sought after outcome of this project. All these, ultimately, have resulted in improved performance and enabled NBRO to come up with far better design decisions. However, the shared technical knowledge, while being empirical, may not quite match with the Sri Lankan context. Therefore, they should be further revised and updated based on landslide investigation practices in Sri Lanka.

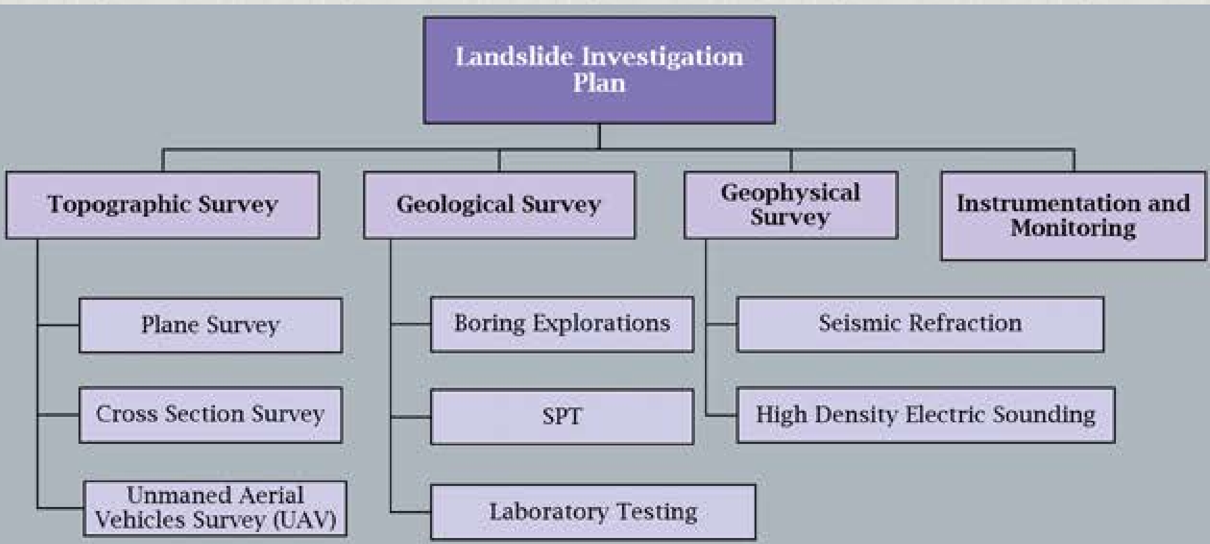
With these investigation and monitoring techniques, NBRO has been able to increase its design capacity owing to the enhanced and boosted performance achieved through JICA - TCLMP involvement. Naturally, NBRO eagerly waits to reap the benefits of this novel standpoint and has high expectations towards a sustainable future for the country.

Design Concepts Adapted from TCLMP for Landslide Mitigation

Thushari Thilakarathne
Engineer, Landslide Research and Risk Management Division
National Building Research Organisation

Landslide mitigation design concepts, though inherently similar in terms of the ultimate objective, show subtle differences from country to country and Sri Lanka is no exception in this regard.

However, mingling of 'design cultures' is always good as there is much to gather from a country of high disaster awareness like Japan. One major output expected from TCLMP is strengthening the capacity of slope disaster (landslides, slope failures and rock fall) mitigation measures of NBRO. The investigation and design activities of TCLMP pilot sites provided a good platform for the engineers and scientists at NBRO to obtain hands on experience of the Japanese techniques.



Landslide investigation plan of pilot sites at Badulusirigama, Udamadura and Alagumale

Investigation and Monitoring

The Japanese design concepts for landslide mitigations have a very systematic approach. Due consideration is given to data gathered from both investigation and monitoring. Greater effort is given to collect more realistic and reliable data at both investigation and monitoring periods using sophisticated technology. Different techniques are used to obtain topographical data. Investigation data and core samples are carefully analysed to identify indications of failure surface. After the completion of detailed investigations, automated monitoring instruments are installed at the site for further verifications of test data (ex: depth of slip surface/s) and to gather further data for the design of countermeasures (Ex: groundwater behavior of the site alongside rainfall, rate of landslide movement). The automated monitoring systems are used to establish relationships between the rainfall and ground water level and movements of landslide which are essential information for design work.

Design of Countermeasures

Based on the descriptive idea formulated from different landslide surveys, landslide mechanisms are identified as accurately as possible so that stability analyses could be carried out to determine the scale and quantity of landslide countermeasures required to maintain the stability of the landslide.

Stability Analysis and Factor of Safety

Three types of safety factors are defined and used in the designing of countermeasures namely, critical safety factor, current safety factor and design safety factor.

Critical safety factor (FOS=1)	When landslide starts to move and the FOS at that moment is called the critical safety factor. Ground water level at the moment is called critical water level
Current safety factor (FOS<0.95-1.0)	The current safety factor can be obtained from the analysis when high water table is recorded. It is less than the critical safety factor (the worst-case scenario)
Design safety factor (FOS>1.2)	The design safety factor is obtained by applying of countermeasures for analysis starting from the worst-case. An acceptable value should be achieved based on design considerations. (Ex: people, roads, public facilities)

Back Calculations for Analysis

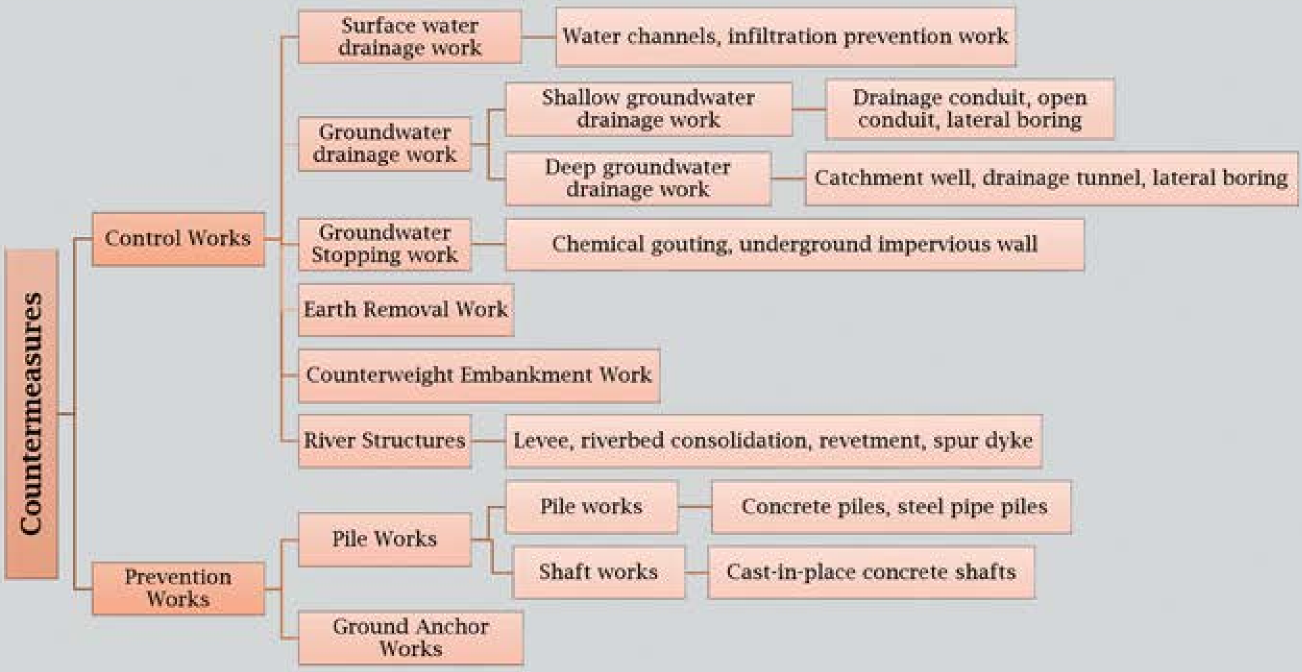
This method is very useful in slope stability analysis. Even though some laboratory tests are carried out for undisturbed samples obtained from the site, they may not represent the whole area of the landslide, particularly when the area in question is large. In such cases or in the absence of field and laboratory test data, back calculation of stability analysis could be put into use. This could also be put to good use when the slip surface cannot be clearly defined.

In this method, either of the shear strength parameters (c or φ) are determined with the predetermined value of the other, assuming the Critical Safety Factor (i.e. FOS=1). The predetermined value can be chosen from the tables specially developed for the purpose. Appropriate parametric analyses may be performed at this stage. A notable feature in Japanese approach is that different analyses are performed to establish a representative set of shear strength parameters to be used in the design of countermeasures.

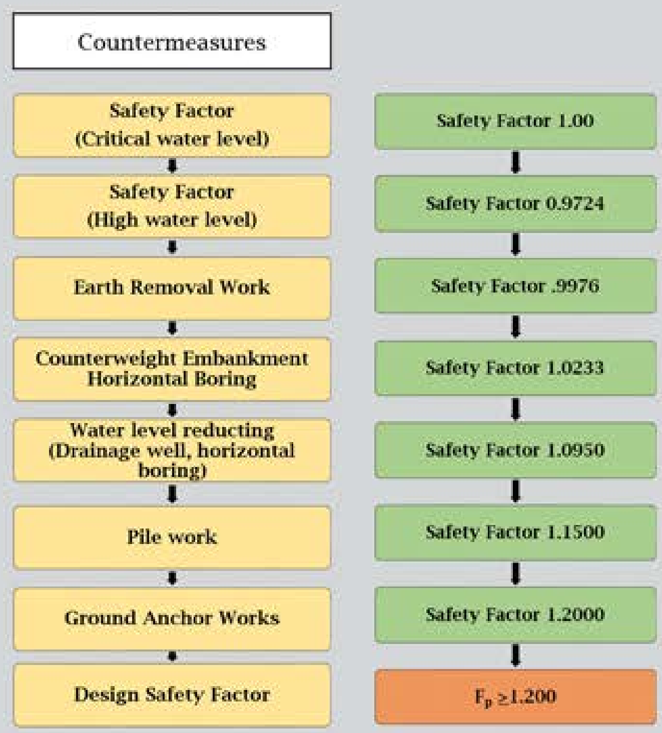
Selection of Countermeasures

Selection of suitable countermeasure work depends on technical effectiveness, financial viability, environmental impacts and amount of maintenance required. As for the pilot sites, JICA specialists provided guidance to NBRO teams through meetings and seminars, and the most appropriate countermeasures were selected as a collective effort. A wide range of countermeasures such as change of geometry, surface drainage, sub surface drainage, counterweight embankments, piling and ground anchors are considered.

Unlike conventional practices, several combinations of countermeasures are considered based on the stability analysis. Each is examined to decide a couple or more appropriate combinations of countermeasures in terms of both economic efficiency and design requirements. From the more appropriate combinations of counter measures, an optimum combination is selected through careful examination and comparison.



Sediment Disaster Countermeasures

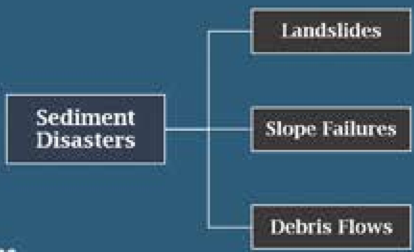


An example of selecting the appropriate countermeasure by repetitive stability analyses until the satisfactory safety factor is achieved

Sediment Disasters

Thamali Mampitiyaarachchi
Engineer, Landslide Research and Risk Management Division
National Building Research Organisation

Having number of definitions to begin with, 'landslides' by no means is a simple and straightforward term that fits into one specific category. However, slope failure incidents in Sri Lanka are given the generic name 'landslides', mostly due to the inherent similarity in what triggers them – by excessive rainfall. Meanwhile in Japan, the term 'sediment disasters' is preferred, as revealed at the TCLMP seminar and workshop carried out by JICA experts. These sediment disasters are considered as three distinct categories: landslides, debris flows and slope failures; their reason being, the countermeasures for each depend on the type of the disaster.



Landslides

A landslide is defined as 'a slow movement of mass along the slip surface under the influence of elevated ground water or a similar cause'. The agent of mass transfer is gravity. The preventive measures suggested for a 'landslide' are much similar to the concepts put into practice at Sri Lanka including soil removal work, drainage tunnel works, horizontal drainage boring, channel works, steel pipe pile works and anchor works.

Slope failures

Compared to landslides, slope failures are abrupt and occurs when soil masses or rocks loses its ability to self-retain due to the influence of rainfall or an earthquake.

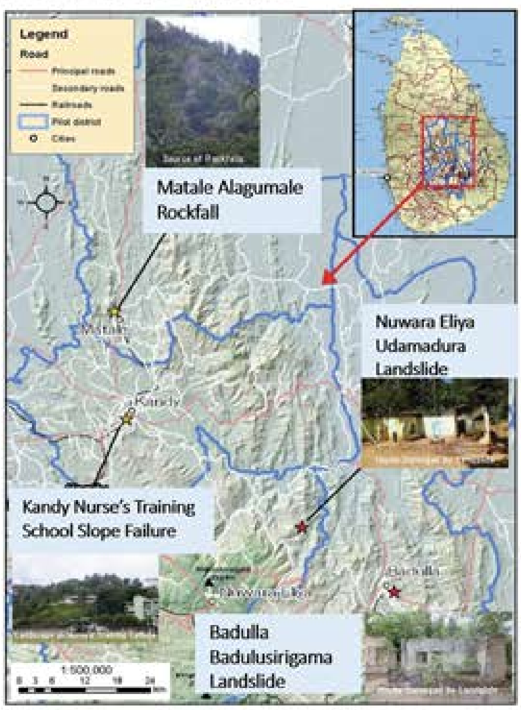
Debris Flows

A debris flow forms when "part of soil, stone and rock making up a hillside and river bed is mixed with water from localized rainfall etc. and is carried downstream at a dash". A debris flow will propagate forward until it reaches down to a level where the ground has 2 degrees inclination and turn into bedload, and the spatial pattern of slope angle has been identified as one of the key parameters that govern debris flow propagation. Three mechanisms of debris flow initiation are identified: collapse, failure of a natural dam and fluidization of sediment deposited in a valley. Type 1 debris flows initiate as a landslide and turns into a debris flow, given the right conditions - a situation similar to Aranayake. Type 2 occurs when a natural landslide dam is breached due to a landslide, setting off a debris flow. Type 3 debris flows can occur when sediments in a valley are fluidized, without the influence of an initiating landslide.
As for the preventive measures for a debris flow disaster, 'sabo dams' and erosion controlling of hillsides prone to the threat are recommended. Systematic approaches have been formulated to identify Yellow Zones (areas under the risk of sediment disasters) for debris flows in Japan, providing us interesting insights, particularly in our current attempts in mapping debris flow paths.
Aranayake incident as a startling eye-opener and with the experience of Koslanda and Nichola Oya incidents, NBRO now feels the need to follow suit and consider debris flows as a separate phenomenon. Therefore, the new knowledge gathered through the interactions with JICA through the project are expected be of tremendous assistance to widen the scopes of NBRO.

Landslide Mitigations at Pilot Sites

Ryuichi HARA
Japan International Cooperation Agency

This project aims to improve NBRO's capacity relating to structural and non-structural measures for landslide, slope failure and rock fall including survey, design, construction supervision, warning, evacuation and land use regulation.



Pilot Sites

Investigations in the pilot areas

Field surveys for countermeasure design were done by JICA Team in collaboration with NBRO, since October 2014.
The project team clarified overall situations of the pilot sites using preliminary surveys. Subsequently, base maps of the sites were prepared by UAV and plane/cross-section survey. Monitoring instruments were installed in the sites, and basic data for countermeasure design was collected. The project members transferred their knowledge and techniques to NBRO staffs in monitoring and core-sample-boring.

Countermeasure design and bidding

- Stability analysis based on observed data
- Countermeasure design and cost estimation
- Bid document preparation and bidding

Counter measure design, cost estimation and bidding were conducted by the project team in collaboration with NBRO staff. During the process, it appeared that geological condition at the Kandy site is rather weak, and the expected countermeasure is inadequate. Therefore, JICA decided to cancel the planned pilot work at the Kandy site in this project. The pilot work will be conducted by another JICA scheme.

Pilot works and supervision

The bidding for the pilot sites in Badulla and Nuwara Eliya (landslide) and Matale (rock fall) was conducted in January 2016, and constructers were selected. The practical construction works and supervision by the project team and NBRO started in May 2016.

Udamadura

The beneficiary of the mitigation work at this pilot site is the Udamadura village that belongs to the Walapane DS division of Nuwara Eliya district. The first incident of the landslide was reported in 1957 and it was observed to be creeping over the years until another landslide occurred in the area in 2007. Signs of reactivation were identified in year 2011.

The pilot survey at the site was carried out by the JICA study team along with NBRO staff on 11th November 2014. Later, a UAV survey was carried out to obtain 3D terrain data on the target slope along with geological and geophysical surveys. Monitoring instruments were installed at the site following a monitoring plan devised by NBRO and project team.

According to the results of the detailed investigations, the outline of Udamadura landslide mechanism is as follows.

- The landslide is approximately 900 m in length, 600m in width, and 23 m in depth.
- The damage of the road indicates that a lower landslide block is moving. The site has not experienced heavy rains after the monitoring equipment have been installed, and certain landslide activity is not monitored so far. The groundwater level at the lower area of landslide slope stays near the ground surface.
- Countermeasures of groundwater control methods such as surface drainage ditches or horizontal drainage would be effective against the Udamadura landslide.

Stability analysis were conducted to determine the scale and quantity of landslide countermeasure works required to maintain the stability of the landslide slope and to ensure the target safety factor. The groundwater and surface water control works are highly effective for a site like Udamadura where groundwater and rainfall is abundant and ground surface movement tends to accelerate during intense rains. Surface drainage ditches should be designed at the natural channels in the landslide area in order to prevent infiltration of rainwater and spring flows. In addition, check dams should be designed also in order to prevent from further erosion.

Horizontal drainage, which removes groundwater by gravity drainage pipes, were decided to be suitable against the lower landslide block. The length of the drainage pipes is 50 m in order to create a 5 to 10 m overbreak penetrating through the potential slip surface, and their tip intervals are 5 to 10 m. The design groundwater level has been set at -3.0 m from the assumed highest groundwater level, which is used as reference value in Japan.

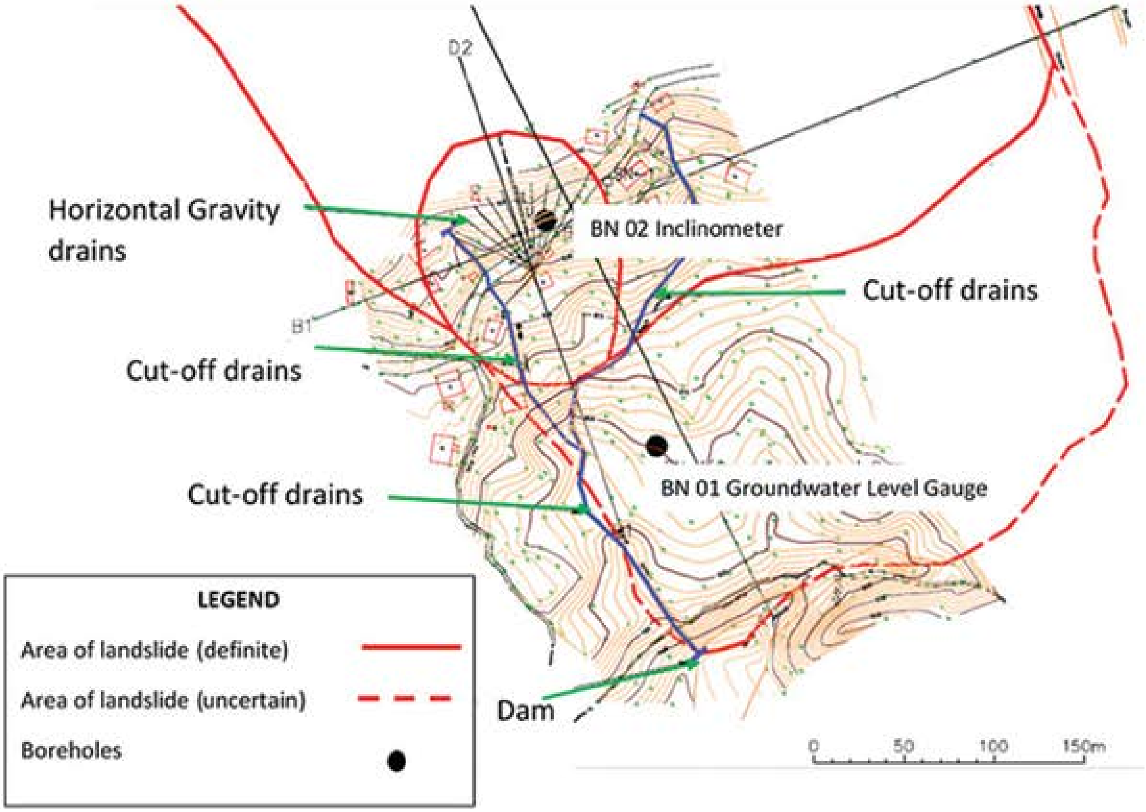
Therefore, horizontal borings (gravity drains), surface drainage ditches, and check dams were selected as the countermeasures for the pilot site. The countermeasures sequence are ordered according to their priority. Lower landslide countermeasure works are recognized as of high priority. The larger remaining portion of the landslide is to be treated with a lower priority. The contract was awarded to Geo Engineering Consultants (PVT) Ltd for a contract price of 12.9 M. The progress of the countermeasure works at Udamadura pilot site as at the end of October is 66.7% of the total work.

PVC pipe insertion

Picture near check dam

Horizontal drilling

Horizontal drains



Countermeasure Design

BADULUSIRIGAMA

Badulusirigama pilot site belongs to the Badulla DS division. Uva Wellassa University and the village of Badulusirigama will benefit from the project. This site was subjected to a landslide, first in 1986 and later in 2011 when around 20 households were damaged as a result. Though the community was resettled by the government, they have returned to their original dwellings, necessitating structural mitigation.

Preliminary survey at the site was carried out on 13.11.2014 by a team of JICA and NBRO personnel. Based on its results, a detailed investigation plan consisted of geomorphological investigations, geological investigations, geophysical investigations and monitoring was implemented at the site. According to the information obtained from these investigations, the mechanism of the Badulusirigama landslide was understood as outlined below:

- The landslide has dimensions with approximate length of 600m, width of 120m and depths of 10m to 13m
- The landslide is moving actively during heavy rain periods
- The main trigger of the landslide is heavy or prolonged precipitation which causes rising of groundwater level, and countermeasures of groundwater control methods such as surface drainage ditch or horizontal drainage could be affective against the landslide.

Further, stability analysis was carried out to determine the scale and quantity of landslide countermeasure works required to maintain the stability of the landslide slope to ensure the target safety factor. The following design concepts were outlined:

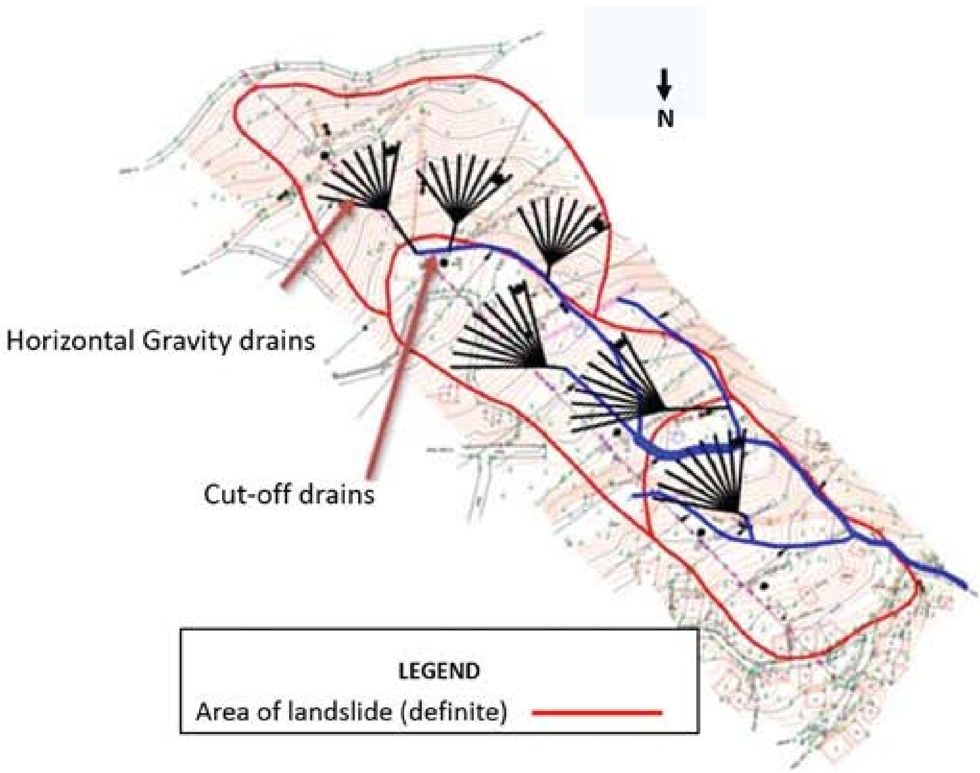
- Groundwater and surface water control methods should be designed for the site
- Surface drainage ditches should be designed at the natural channels in order to prevent infiltration of rainwater and spring flows
- Horizontal drainage, which removes groundwater by gravity drainage pipes, should be designed throughout each landslide block.
- The design groundwater level has been set at 3.0 m from the highest groundwater level measured in monitoring survey, which is used as the reference value in Japan.

Therefore, horizontal borings (gravity drains) and surface drainage ditches were selected as countermeasures to mitigate the landslide. The contract was awarded to ELS Construction (PVT) Ltd for a contract price of 38.9 M. The progress of the drain constructions at Badulusirigama site as at the end of October is 37.7% of the total work.

Progress of drainage constructions

PVC pipe insertion

Horizontal drains



Countermeasure Design

Alagumale

Alagumale pilot site belongs to Harasgama GN division of the Matale district. The site experienced a rock fall incident in 2004 and 2012, which resulted in relocation of number of houses. Most of the tenants have returned exposing them to the threat of more rock fall occurrences. Alagumale was selected as a pilot site for countermeasure designs thereby achieving the Output 4 of the project: "Capacity of design, construction supervision, and monitoring for rock fall mitigation measures". The source of rock fall is a steep slope of the Alagumale Mountain. Large sized boulders (over 3m diameter) and cracked rocks are scattered on the upper slope above the residential area posing a constant threat to the community.

Initial condition of the rock fall site

A UAV survey was carried out at the target slope on 13.11.2014 through the project. Since a considerably wider area including the source area of rock fall needed to be surveyed, ALOS World3D with 5m resolution provided by Japan Aerospace Exploration Agency (JAXA) was adopted for the survey. The foot and top of the rock face in question were inspected by the project team and NBRO personnel on 19.02.2015.

Topo mapping and cross section surveys were carried out followed by geological surveys. Two boreholes (15m drilling depth) were drilled at the site. Further, a fallen rock survey was carried where rocks of more than 2.0m in size were surveyed.

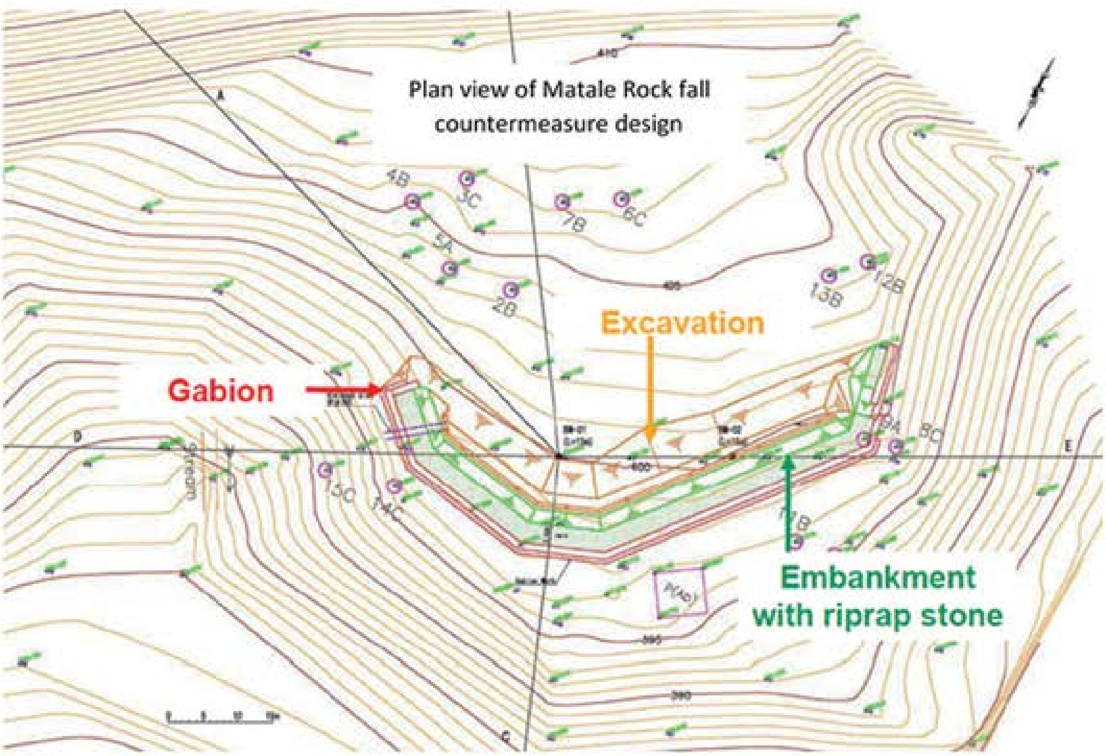
A rock fall simulation was done based on the information collected through the surveys and the energy of rock fall against which countermeasures should be designed were estimated. Due to the effectiveness, economic efficiency and ease of maintenance, earthwork including canal excavation, rock excavation, embankment and gabion work were selected as countermeasures against the landslide.

The contract was awarded to Sanguine Engineering (PVT) Ltd for a contract sum of 30.7 M.

Item	Total Quantity	Work done up to 31st October	Remaining	Total Progress of the work	Remaining Progress of the work
Gabion Work	201 m^3	206 m^3	COMPLETED		
Excavation	450 m^3	1030 m^3	580 m^3	43.70 %	56.30 %
Rock Excavation	412 m^3	210 m^3	202 m^3	51 %	49 %
Rubble Pitching	679 m^2	679 m^2	COMPLETED		
Access Road	100 m	100 m	COMPLETED		

Gabion Wall

Gabion Wall Construction



Countermeasure Design

Japan's Landslide Mitigation Experiences to Sri Lanka

Eshi Eranga Wijegunarathna
Scientist, Human Settlements Planning & Training Division
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Aranayake disaster occurred in last May inferred that a debris flow is also a disaster in Sri Lanka that can be devastating. NBRO assessed the extent of the debris flow by an aerial survey. It has been observed that there are not many studies or survey results in Sri Lanka on the subject of debris flow, and debris flow is not recognized as a separate phenomenon in Sri Lanka so far.

Two experts from Japan, Mr. Koichi ISHIO, Deputy Director of Sabo Division in Ministry of Land, Infrastructure, Transport & Tourism and Dr. Taro UCHIDA, Senior Researcher, Sabo Department, National Institute for Land and Infrastructure Management, who are professionals in early warning, disseminating risk information and land use regulation, visited Sri Lanka, recently. They carried out a three-day field survey together with NBRO officials to study the debris flow at Meeriyabedda, Aranayake, Kothmale and landslide in Rilpola from 27th to 29th August 2016. Further, they conducted two workshops at NBRO to share the information gathered at field. Moreover, they discussed the mechanism of a debris flow, its occurrence, and physical characteristics.

Subsequently, NBRO in collaboration with JICA conducted a seminar on 'Landuse Regulation and Early Warning for Landslide' on Wednesday, 31st August 2016. In this seminar, the two experts presented on debris flows, debris flow initiation processes and physical characteristics. They further elaborated on the present condition at Aranayake landslide, numerical simulation of debris flow and how the yellow zone is set based on Sediment-Related Disaster Prevention Act in Japan. This seminar focused on very important aspects of disaster management in Sri Lanka.

At the end, JICA team agreed with NBRO to extend the programme up to 2017 to analyze debris flows and yellow zones further to incorporate these aspects into risk assessment.

Presentation on Debris flow by Dr. Taro UCHIDA from National Institute for Land and Infrastructure Management

Field Survey on Debris Flow in Rilpola

Post Landslide Aerial Surveys

Kenichi Handa
Chief Advisor, Technical Cooperation for Landslide Mitigation Project
Japan International Cooperation Agency

Koslanda

In response to the Koslanda (Meeriyabedda) landslide, a large-scale disaster occurred in Badulla District on 29th October, a JICA survey team conducted various investigations and gave a demonstration and on-the-job training to NBRO regarding the types of surveys conducted by them when a disaster occurs in Japan.

Firstly, an aerial survey was conducted by a team of JICA, TCLMP and NBRO staff members using a helicopter on 5th November, 2014 to confirm if the risk of a second occurrence of the disaster still existed. Further, a two-day field survey was held on 19th to 20th November to confirm the detailed situation of locals. Later on, an After Action Review survey was conducted to observe the kind of correspondence/ action the related Organisations and inhabitants took at the time of disaster. A team consisted of members of JICA, NBRO and DMC took part in the survey. This was an opportunity to provide an on-the-job training to the officers on After Action Review surveys.

The results of these 3 kinds of survey were presented in a report in all 3 languages (English, Sinhalese and Tamil) and approximately 500 copies were published. [http://www.jica.go.jp/srilanka/english/office/topics/150624.html].

Aerial survey member from JICASL, NBRO and DMC

Aerial view of landslide disaster from chopper

Aranayake

An aerial survey was held at Aranayake by a chopper on 22nd May, fifth day after the disaster with the help of the air force. A whole view of the disaster could be grasped from chopper, including the inundation damage of the Kelani riverside. Thereafter, several field surveys were carried out twice on 8th to 9th June and 21st to 22nd June. In addition, currently, JICA is carrying out an After Action Review in the area.

Investigators of aerial survey

Aerial view of Aranayake landslide disaster

This newsletter is published under the technical cooperation between Japan International Cooperation Agency (JICA) and National Building Research Organisation (NBRO), Sri Lanka on Landslide Mitigation Projects in Sri Lanka.

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