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IPL Project (IPL 200) Annual Report 2015

1 January 2016 to 31 December 2017

1. Project Title:

An Assessment of the Rock fall Susceptibility Based on Cut Slopes Adjacent to Highways and Railways.

2. Main Project Fields - Technology Development

Category B. Hazard Mapping, Vulnerability and Risk Assessment

3. **Name of Project Leader** : **Ms. H.M.J.M.K. Herath -** B. Sc.(Special Science degree in Geology),

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Core members of the Project

Eng. (Ms) E M T M Ekanayake – B.Sc (Hons) (Earth Resource Engineering)

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Eng.(Ms) S. S. I. Kodagoda- B.Sc (Hons)Eng, M. Eng., CEng,- Geotechnical Engineer

Eng. A A Virajh Dias – B.Sc (Civil Eng); CEng, PG .Dip; MASCE, MIESL

4. Objectives:

Rock fall from cuts slopes adjacent to roadway and railways are significant during heavy rains in mountainous terrains. The main objective of the project is

- Recognition of the Gravity of rock fall hazard from cut slopes adjacent to highways and railways during heavy rainfalls
- Carrying out appropriate improvements for rock fall hazard assessment by introducing appropriate Rockfall Hazard Rating System (RHRS)

5. **Study Area**:

Two locations along Kandy – Nuwara Elliya highway, Sri Lanka and two locations along Sri Lanka railway Main line (Colombo to Badulla, Sri Lanka)

6. **Project Duration**:

Three years (July, 2015 to July 2019)

7. Report

7.1 Progress in the project: - Introductory Remarks

The evaluation of instability potential of rock slopes are fairly questionable and important and understanding of associated issues related to geological characteristics of overhanging rocks slopes to be evaluated accordingly. Various forms of failures due to non-engineered road construction were studied (Herath, et al., 2014) in hill country of Sri Lanka. The study has been proposed various combination of pair wise comparison approach for the evaluation of geological stability of overhanging rock slopes which will immensely support to improve narrative of significance. Some of the categories are similar to Brawner's and Wyllie's while decision making approach for scoring in geological terms are new due to consideration of mutually dependences. New approach of rock fall hazard rating evaluation is studying based on field observations and recorded road side slope failures. In this situation geological factors or evidences will be considered further as a singular factor. The rating and scoring of evidence still depend on valued judgment but minimize the avoidance of minimum dependences of other factorial significance is given in the Table 1 and comprehensive description of pairwise combined parameters is given in below.

Pair 1: Dipping and Slope Height (DSH)

Instability of a cut slope is directly interrelated with the height of the earth cutting. A consideration of combined parameter of dipping and slope height will demarcate the potential instability more precisely rather than independent evaluation. Therefore, DSH can be considered as the first most combined parameters for the evaluation of RHRS.

Pair 2: Block Size and Rock Character (BRC)

It is noticed that, different rocks form various disintegration of blocks, capacity to explore climatic conditions, weathering, etc. Therefore, formation of blocks is largely depended on rock character or the lithology.

Pair 3: Persistence and Joint Density (PJD)

Random joint and fractures create irregular shaped blocks. Some slope cuts with continuous joints show two or more joint sets with rock blocks and wedge features which also exhibit adverse conditions. Therefore, detachment of blocks from a cutting is reasonable to consider together with the persistence and joint density. All comparisons were to be made in vertical or horizontal axis.

Pair 4: Weathering Discontinuity and Aperture Sizes (DAS)

In general, formation of rock blocks is a function of the discontinuities of the intact rock. Potential for rockfall by movement along discontinuities is controlled by the characteristic of joints or the aperture size. The condition of the joints is described in terms of micro and macro roughness. The aperture size always indicates the possibility of absorbing water and saturation potential. In addition, water ingress through discontinuities always reduces the strength of an interface and increase weathering. Therefore discontinuity nature (fracture, joint, fault) of the mass of rock and observations of aperture size is an important combined parameter for the assessment.

Pair 5: Rock Friction and Weathering State (RFWS)

Angle of internal friction of intact rock is usually high in crystalline formations. However, interface friction of the facture or joint surface will indicate state of stability. The RFWS includes few categories (see Table 1) considering the selected site and the system is adapted to deal with different rocks in crystalline slope cuts. Rock friction is a function along a joint, bedding plane, or other discontinuity which is governed by the macro and micro roughness of the surfaces.

Pair 6: Cutting Plane and Block Movement Direction (CPBMD)

Cutting plane is the exposed face of the cutting which may adversely effects to an orientation of a detachment of blocks. The study on cutting face with the block orientation is used for slopes where differential blocks, over steepening and under steeping conditions which leads to control or aggravate the detachment possibility of overhanging rocks. Thus, in order to evaluate the stability of rock cuts and/or rock slopes, rock block orientation with the plane of cutting is to be evaluated and valued for appropriate scoring according to the Table 1.

Pair 7: Overhang and Fall History (ODH)

The historical rockfall and detachment of adjoining blocks at a rock cut is an indicator of future instability event. Typically, the frequency and magnitude of past events is an excellent indicator of the type of events to expect. In addition, overhang rocks are mainly due to the fall history and therefore information is an important check on the potential for future failure. The second stage of rockfall event when the large overhang becomes unstable and a large volume of rock falls off at one time. Erosion features include over steepened slopes, unsupported rock units (overhangs), or exposed resistant rocks on a slope, which may eventually lead to a rockfall event. Therefore overhang of rocks with fall history is a useful combined parameter for the revised RHRS.

7.2 Planned future activities or Statement of completion of the Project

July 2015 - December, 2016:	Identification of sampling locations and field work – Completed
January 2016 – July 2016:	Laboratory and Field testing, data collection (Phase 1 activity) - completed
August 2017- July 2018:	Back analysis; Numerical evaluation of data – on going
January 2018 – December 2018:	Laboratory and Field testing, data collection (Phase 2 activity) – on going
August 2018 to December, 2018:	Development of advanced method of assessments, conducting in-situ testing, back analysis and modeling of case studies; verification and sensitivity assessment.
	Development of numerical rating of RHRS with known and visible samples
January, 2019- June 2020:	Finalizing the design approaches for evaluation and design of cut slope stabilization in roadway and railways in hill country slopes.

7.3 Beneficiaries of Project for Science, Education and/or Society

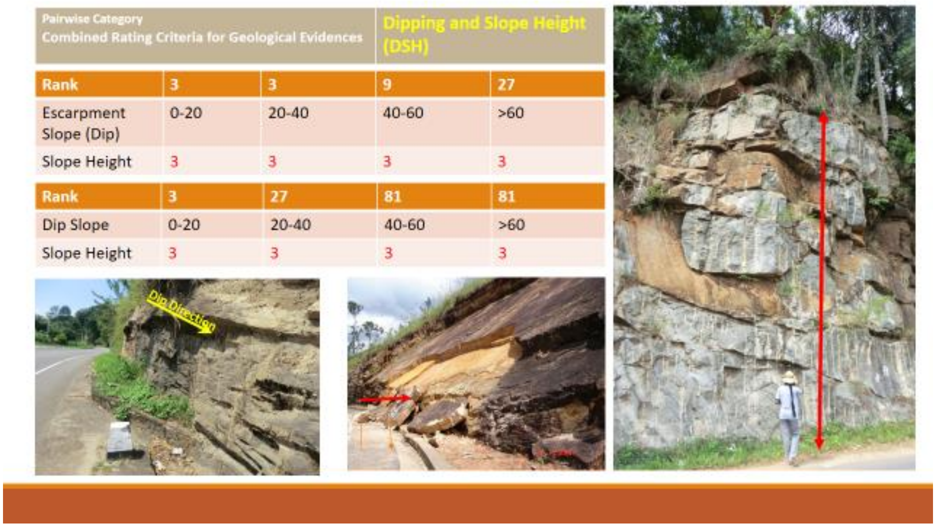
The beneficiaries of this project would be the road trace designers, engineering consultant and other professionals, academics, planners and people residing in landslide prone areas in the hill country of Sri Lanka.

7.4 Results (resent Outputs):

The proposed rating mechanism for geological factors of the RHRS is based on an evaluation of geological stability of overhanging rock slopes in 7 different pairwise categories summarized in the Table 1: .Combined Rating Criteria for Geological Evidences for Rockfall Hazard System below. This system is supported to give the narativeness of decision making in geological factors.

Table 1: .Combined Rating Criteria for Geological Evidences for Rockfall Hazard System

No	Pairwise Category	Rating Criteria and Score			
		Points 3	**Points 9**	**Points 27**	**Points 81**
1	Dipping and Slope Height (DSH)	20-50 ft , and Dip / Escarpment slope	50-75 ft, and Dip slope	75-100 ft, and Dip slope	> 100 ft, and Dip slope
2	Block Size and Rock Character (BSRC)	>5ft,poorly defined Foliation planes/joints and Crystalline gneissic rocks	1-2 ft, Poorly defined Foliation planes and Crystalline gneissic rocks	2-5ft, well defined Foliation planes and Bedded / jointed Quartzite; crystalline gneissic rocks	<1 ft, well defined Foliation planes and Bedded / jointed Quartzite; crystalline gneissic rocks
3	Joint Intensity & Persistence (JIP)	JI : 1-2, and Non/low persistence	JI : 2-3, and Medium persistence	JI : 3-5, and High persistence	JI >5, and Very high persistence
4	Weathering of Discontinuity with Aperture Sizes (WDAS)	Fresh and Tight/Closed	Surface weathering and Open	Granular weathering and Gapped	Highly weathered/ clay filling and Very open
5	Rock Friction and Weathering State (RFWS)	Rough, and Fresh	Undulating, and Slightly weathered	Planner, and Moderately weathered	Smooth/ Slickenside, and Highly weathered
6	Cutting Plane and Block Movement Direction (CPMD)	< 45 deg and towards the mountain	45 to 60 deg And 60 deg. towards both sides	60 to 70 deg and 30 deg. towards both sides	>70 deg and towards the road
7	Overhang Volume and Rockfall History (OVRH)	1 sq ft and Few falls	1 – 10 sq ft and Occasional falls	11- 100 sq ft and Many falls	>100 sq ft and Continuous falls



Pairwise Category Combined Rating Criteria for Geological Evidences			Dipping and Slope Height (DSH)	
Rank	3	3	9	27
Escarpment Slope (Dip)	0-20	20-40	40-60	>60
Slope Height	3	3	3	3
Rank	3	27	81	81
Dip Slope	0-20	20-40	40-60	>60
Slope Height	3	3	3	3

Fig 1: On site evaluation of Dipping and Slope Height issue

Pairwise Category Combined Rating Criteria for Geological Evidences			Block Size and Rock Character (BSRC)	
Rank	3	3	9	27
Block Size	>5ft	1-2 ft	2-5ft	<1 ft
Rock Character (BSRC)	Poorly bedded/jointed crystalline rock	Poorly bedded/jointed crystalline rock	Poorly bedded/jointed crystalline rock	Poorly bedded/jointed crystalline rock
Rank	9	27	81	81
Block Size	>5ft,	1-2 ft	2-5ft,	<1 ft,
Rock Character (BSRC)	Bedded/jointed crystalline rocks/ quartzite	Bedded/jointed crystalline rocks/ quartzite	Bedded/jointed crystalline rocks/ quartzite	Bedded/jointed crystalline rocks/ quartzite

Fig 2: On site evaluation of Block size and Rock Character

8. Publications (Journal Papers and conference Papers)

1. H M Janaki, M K Herath, S S I Kodagoda and A A Virajh Dias; Shallow Modes of Slope Failure in Road Earth Cuttings in Sri Lanka; World Landslide Forum 3; Beijing, China, 2014.
2. “Empirical Relationships of Elastic Modules and Uniaxial Strength of Intact Metamorphic Rocks of Sri Lanka”; Proceeding of the International Conference of Geotechnical Engineering(ICGE) 10th – 11th August 2015 in Colombo, Sri Lanka; PP 515 -518; Authors were E M T M Ekanayake , H M J M K Herath and A A Virajh Dias; ISBN 978-955-1411-01-5.

9. References

1. Pierson, L.A., Davis, S.A. and Van Vickle, R. 1990. Rockfall Hazard Rating System Implementation Manual. Federal Highway Administration (FHWA) Report; FHWA-OR—EG-90-01. FHWA, U.S. Department of Transportation.
2. Russell, C. P., Santi, P., & Humphrey, J. D. (2008). Modification and statistical analysis of the Colorado Rockfall Hazard Rating System: Report No. CDOT-2008-7, 139 pp.