ZIBELINE INTERNATIONAL PUBLISHING

ISSN: 2521-0890 (Print)
ISSN: 2521-0491 (Online)

CODEN : GBEEB6

Geological Behavior (GBR)

DOI : http://doi.org/10.26480/gbr.02.2018.01.09

ENGINEERING GEOLOGICAL STUDY ON THE SLOPE FAILURE ALONG THE KIMANIS TO KENINGAU HIGHWAY, SABAH, MALAYSIA

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ARTICLE DETAILS

Article History:

Received 26 June 2018
Accepted 2 July 2018
Available online 1 August 2018

ABSTRACT

The geology along the Kimanis to Keningau Highway provides a favourable setting for engineering geological instability. The area is underlain by the Crocker Formation (Late Eocene to Early Miocene age) to vary recent Quaternary alluvial materials which are still being deposited. Crocker Formation consists mostly of interbedded grey sandstones and grey mudstones or shales. The sandstones are texturally immature where angular to subrounded quarts grains are cemented by clay minerals and occasionally by calcite. The Crocker Formation has also undergone intense deformation. The tectonic complexities influenced the physical and mechanical properties of the rocks, resulting in a high degree of weathering and instability. The weathered materials are unstable and may experience sliding due to by high pore pressure and intensively geomorphological processes. In this study, a total of 28 selected critical slope failures were studied and classified into two main groups: rock slope and soil slope. Failures in soil slopes (including embankments) are 18 (64 %) whereas 10 of all failures (36 %) of rock slope. Soil slope failures normally involved large volumes of failed material as compared much rock slopes, where the failures are mostly small. Of the 18 failures in soil slopes, 6 (33 %) are embankment failures making them 21 % of all types of failures. Kinematics rock slope analyses indicates that the variable potential of circular, planar, wedges and toppling failures modes as well as the combination of more than one mode of aforementioned failure. Rock and soil slopes stability analysis indicates that the factor of safety value as unsafe (0.50 to 0.96). The main factors causing slope failure occurrences in the study area are natural (geology, meteorology, topography and drainage system) and human factors (lack of proper planning, human activities and community's attitude). Development planning has to consider the hazard and environmental management program. This engineering geological study should be prioritized and take into consideration in the initial step in all infrastructures program and it may play a vital role in landslide hazard and risk assessment to ensure the public safety.

KEYWORDS

Geological instability, Quaternary, grey sandstones, grey mudstones or shales, Soil slope.

1. INTRODUCTION

Landslide is among the major geohazard occurrences in Sabah, Malaysia. As with flooding, tsunami, siltation and coastal erosion, landslides repeatedly occurred in the region with disastrous effect. Landslide is a general term for a variety of earth processes by which large masses of rock and earth materials spontaneously move downward, either slowly or quickly by gravitation [1]. Such earth processes become natural hazard when their direct interaction with the material environment is capable of causing significant negative impact on a property and human's well being. With the growth of human population and the expansion of the scope of human's activities in Sabah, we find ourselves increasingly in conflict along steeply area [2]. A landslide zoning provides information on the susceptibility of the terrain to slope failures and can be used for the estimation of the loss of fertile soil due to slope failures (in agriculture areas), the selection of new construction sites and road alignments (in urban or rural areas) and the preparation of landslide prevention, evacuation and mitigation plans. Natural hazard mapping concerns not only delineation of past occurrences of natural hazards such as landslide, but it also includes predicting such occurrences.

Among the earlier research on landslide hazard occurrences which taking into account the geological inputs was prepared by some researchers [2,3]. Apart from that, a few researchers also found have discussed the similar matter might be referred worldwide for examples the geotechnical properties, slope instability, engineering seismology and geological risk [4-15].

This paper deals with the engineering geological study on 28 selected critical slopes with the aims of analysis the physical and mechanical properties of soil and rock, calculate the factor of safety for slopes and to evaluate the main factors contributing to slope failures. The study area lies centrally on the weastern coast of Sabah pass through the Crocker Range roughly about longitude line E 116° 00’ to E 116° 06’ and latitude line N 05° 25’ to N 05°32’ (Figure 1). The mainland part of the Kimanis to Keningau area is the most accessible. Good networks of sealed and unsealed roads connecting most of the prime villages around it. Part of the roads is constructed across the steep, hummocky and rugged slopes, creating problems of slope and road stability especially during periods of intense rainfall. Since it's developed, the problem of slope stability has adversely affected the use of the road. The Public Work Department of Malaysia (JKR) authority has started a program of repairing and rehabilitation of slope failures since 2005 to improve the communication system. This work is still going on today.

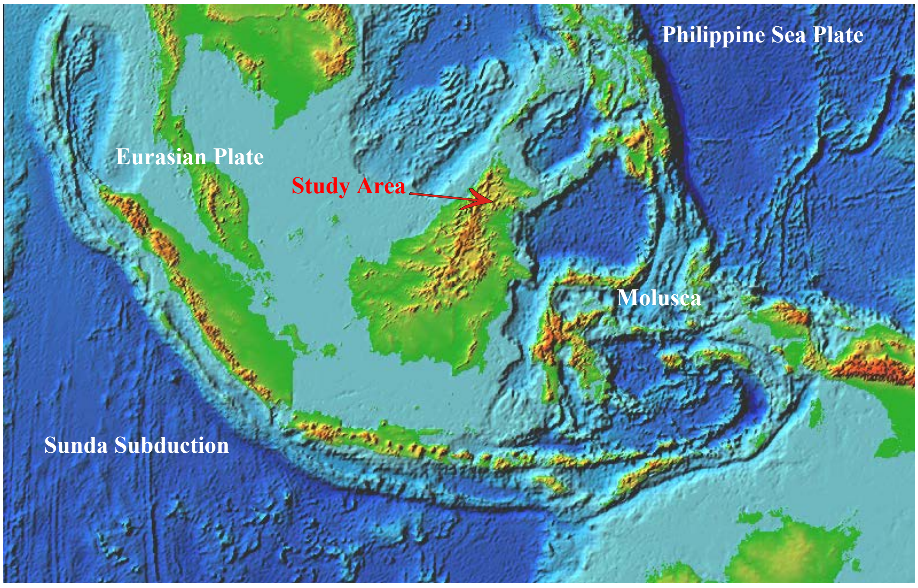

Figure 1: Location of the study area

2. METHODOLOGY

Several classifications can be used to describe slope failures. For this study in the topics, the types of slope failures were classified according to the proposals of a researchers [16]. In this system, slope failures are classified into two main groups: soil slope failures and rock slope failures. Soil slope failures were divided into slides (T1), slumps (T2), flows (T3), creep (T4) and complex failures (T5) whereas rock slope failures were divided into circular (B1), planar (B2) and wedge failures (B3) together with toppling (B4). In this study, only failures with volume exceeding 10 m^3 were considered, since failures involving smaller volume did not generally affect the road users. On the basis, the slope failure was divided into three groups: small (10 – 50 m^3), Medium (50 – 500 m^3) and Large (> 500 m^3). For each slope failures that were studied (Figure 2), type of failures, the geometry of the slope, geological background characteristics, weathering characteristics, ground water condition, discontinuity characteristics, physical and mechanical of the sliding materials and an interpretation of the factors causing the failure based on field observations were recorded. Soil and rock samples from the study area were collected during field mapping for detailed laboratory analysis.

The laboratory works such as classification tests (grain size, atterberg limit, shrinkage limit, specific gravity and water content), permeability test, consolidated isotropically undrained (CIU) test, rock uniaxial compressive strength and point load test were carried out in compliance and accordance to British Standard Code of Practice BS 5930-1981 *(Site Investigation),* British Standard Code of Practice BS 1377-1990 *(Method of Test for Soils for Civil Engineering Purposes)* and ISRM [17-21].
For the soil slopes stability analysis, using the *"SLOPE/W"* software was done successfully to determine susceptibility of the slopes to shallow non-circular slides based on the determination of factor of safety values, which are common in the study area [22]. The advantage of these methods is that in its limit equilibrium calculations, forces and moments on each slice is considered.

Discontinuity orientation data has been collected from ten (10) selected of rock slope failure by random method. For each rock slope failures that were studied, the geometry of the slope, dip direction and dip value, persistence, roughness, unevenness, aperture, infilling material, water condition, weathering, geological background characteristics, engineering properties of the sliding materials and an interpretation of the factors causing the failure were recorded. Determination of discontinuities sets, critical discontinuities plane, potential mode and rock slope stability analysis has been performed by RockPack III program [23].

3. LOCAL GEOLOGY AND ENGINEERING GEOLOGY CHARACTERISTICS

The geology of the study area is made up of sedimentary rock of the arenaceous Crocker Formation (Late Eocene age) and Quaternary Alluvium Deposits (Figure 2). Table 1 shows the composite stratigraphic column of rock units with their water bearing and engineering properties. The layered nature of the sandstone and shale of the Crocker Formation are generally oriented between N325E to N010E and show steep dips (40- 85 degrees) eastward. Large scale folds (> 100 meter wavelength), faults (several meters wide) and more than four (4) set joints orientation are common in the study area.

The sandstone-shale contact is easily accessible by water and such contact seepage may weaken the shale surface and cause slides and falls within the formation. Interbedded sandstone and shale may also present problems of settlement and rebound. The magnitude, however, depends on the character and extent of shearing in the shale. The strength of the sandstone will also depend on the amount and type of cement-matrix material occupying the voids. The sandstones are compacted and in grain to grain contact with each other. Instead of chemical cement (vein) or matrix, the pores are filled by finer-grained sands to silt-sized materials or squeezed rock fragments. The absence of chemical cement reduces the strength of the sandstone especially when it is weathered or structurally disturbed.

The shale units have an adequate strength under dry conditions but lose this strength when wet [8]. During the rainy season, the shale becomes highly saturated with water which increases the water pressure and reduces resistances to sliding and falling especially within the sandstones-shale contact. This condition, in addition to varying amounts of bitumen and levels of degradation, makes shale unpredictable and unsuitable for road construction sites. Its unstable nature can be remedied by proper management of soaking and draining of water from the rock or along the sandstone-shale contact.

The alluvium is mainly represent unconsolidated alluvial sediment on river terraces and weathered product materials composed of unsorted to well-sorted, sand, silt and clay of varying proportions which were derived from the bed rocks. They occur in irregular lenses varying in the form and thickness. The alluvium may also consist of very thin layer of organic matter and characterized as soft, compressible and may be prone to settlement.

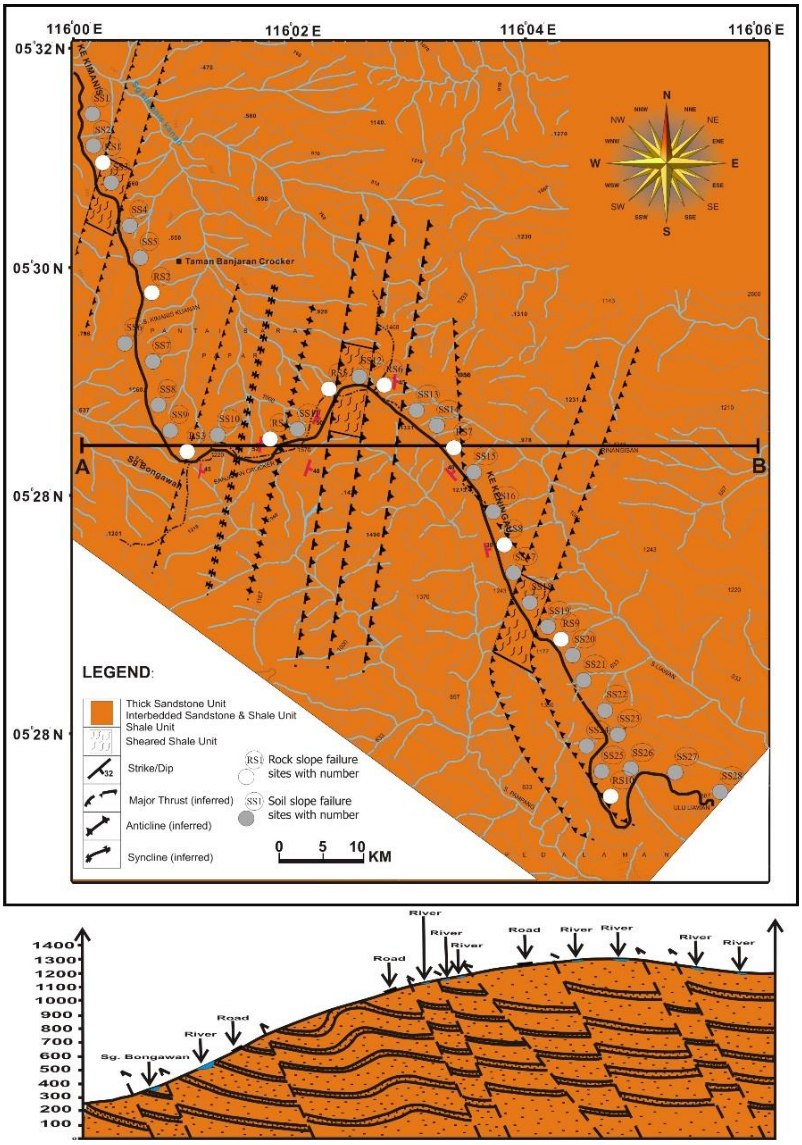

Figure 2: Geological map with their location of slope failures [24]

Table 1: Local Stratigraphic Column and their lithological characteristics

Rock Formation	Lithologic Units	Average Thickness (cm)	General Character	Water-Bearing Properties	Engineering Properties	Petrology	Sedimentary Structures	Fossil	Depositional Mechanism	Depositional Environment
Alluvium and Colluvium	Alluvial terraces and flood plains	-	Unconsolidated gravel, sand and silt with minor amounts of clay deposited along the rivers or streams and their tributaries. Includes natural levee and flood plain deposit.	Gravelly and sandy, portions are highly permeable and yield large quantities of water. Important to groundwater development.	Generally poorly consolidated. Hence not suitable for heavy structures and subsidence under heavy load.	Angular to sub rounded sandstone blocks in a silty matrix	-	-	Alluvial terraces and flood plains	-

Crocker Formation	Massive Sandstone (Facies B)	100 – 1,000	Light grey to cream colour, medium to course -grained and some time pebbly. It is highly folded, faulted, jointed, fractured occasionally cavernous, surfically oxidized and exhibits spheriodal weathering.	Importance to groundwater.	Good site for heavy structures with careful investigation. Stable from mass movement and provide some modification like closing of continuous structure.	Quarzarenite and Sublitharenite (Immature)	**Inorganic Structures** **Pre – depositional** 1. Climbing Ripple 2. Ripple Marks 3. Tool Marks 4. Scour Marks **Syn – depositional** 1. Bedding 2. Lamination 3. Graded bedding 4. Cross bedding 5. Convolute lamination **Post – depositional** 1. Slump structures 2. Soft sediment fault 3. Lutite clasts 4. Load structures 5. Ball and pillow structures 6. Water escapes structures **Organic**	1. Bathysiphon spp 2. Glomospira sp 3. Cyclammina cancellata (Brady) 4. Haplophragm oideswalteri (Grzybowski) 5. Trochammin oides sp.	Grain flow deposits	Upper fan to Middle fan
	Thick bedded Sandstone (Facies C)	10 – 50 (Sandstone) 1 – 15 (Shale)	It is a sequence of interlayering of permeable sandstone with impermeable shale. The permeability of this unit is quite variable.	Groundwater in this unit tends to be under semi-confined to confined system. Little importance to groundwater provides some water but not enough for groundwater development.	Dangerous site for heavy structures and high potential for mass movement.	Moderately well sorted to moderately sorted (Mature and Immature)			High density, high velocity turbidity currents (Proximal turbidites)	Outer fan localized in channels and in the prograding depositional lobes.
	Thin bedded Sandstone (Facies D/E)	3 – 5 (Sandstone) 5 – 10 (Shale)							Waning or low velocity turbidity currents (Distal turbidites)	Middle to outer fan and particularly basin plain
	Slumped (Facies F)	-	This unit is composed of two types of shale red and grey. It is a sequence of alteration of shale with siltstone of very fine.	It has no significant to groundwater development due to its impermeable characteristic.	Very dangerous site for heavy structures and the main causes of mass movement.	-			Turbidite and debris flow sedimentation	Shelf to lower slope and partly in the channels of inner fan, middle fan and basin plain
	Red / Grey Shale (Facies G)	1 – 2 (Siltstone) 10 – 50 (Mudstone)				-	**Structures** **Plant remains** **Trace fossil** **Pre – depositional traces** 1. *Paleodictyon minimum* Cosmorhaphe sinuosa **Post – depositional traces** 1. Post – depositional burrow type 1 2. Post – depositional burrow type 2 3. Post – depositional burrow type 3 4. Post – depositional burrow type 4 5. Post – depositional burrow type 5		Debris flow	Plain basin, middle fan and slope region

4. SLOPE STABILITY ASSESSMENT

In this study, a total of 28 selected critical slope failures were studied and classified into two main groups: rock slope and soil slope (Figure 2). Failures in soil slopes (including embankments) are 18 (64 %) (Figure 3) whereas 10 of all failures (36 %) of rock slope (Figure 4). Soil slope failures normally involved large volumes of failed material as compared much rock slopes, where the failures are mostly small. Of the 18 failures in soil slopes, 6 (33 %) are embankment failures making them 21 % of all types of failure.

Results of a detailed analysis of soil slope stability are presented in Table 2. Considering cut slopes, all the major lithologies are involved showing that this type of failure is mostly controlled by lithology. The failure volume scale involved generally small to large in size possibly endangering road users. In term of weathering grades, the materials that underwent failure were in the ranges from grade IV to VI (Figures 5 to 8). Intense water runoff and emitted water seepage is the main factor causing failure with the depth of weathering influencing the volume of material that fails. It appears that grade IV to grade V materials actually failed with the overlying grade VI material sliding or slumping down together with this material during failure. Physical and mechanical properties of 72 soil samples indicated that the failure materials mainly consist of poorly graded to well graded materials of sandy clay and clayey silt soils, which characterized by low to intermediate plasticity content (9 % to 28 %), containing of inactive to normal clay (0.34 to 1.45), very high to medium degree of swelling (5.63 to 13.85), variable low to high water content (4 % to 25 %), specific gravity ranges from 2.57 to 2.80, low permeability (9.66 X 10^{-3} to 3.32 X 10^{-3} cm/s), friction angle (ϕ) ranges from 7.70˚ to 29.50˚ and cohesion (C) ranges from 3.20 KPa to 17.27 KPa. Soil slopes stability analysis indicates that the factor of safety value as unsafe (0.76 to 0.94). The presence of ground water, slope angle, removal of vegetation cover, lack of proper drainage system, artificial changing, climatological setting, geological characteristics and material characteristics are additional factors contributing to the failures.

Table 3 shows the results of a detailed analysis of rock slope failures. Although rock slope failures contributed only 36 % (10 failures) of the total failures, they involved large volume of weathered and brecciated rocks (Figures 9 & 10). The main factor contributing to rock slope failures was the orientation and intensity of discontinuity planes. That is why rock slope failures occur most frequently along the highway on slate, phyllites, meta-sediment and sedimentary rocks, which were highly brecciated and fractured. Generally the failed material underwent only moderately to completely weathering (grade III to V). The rock properties characterization for 10 rock samples indicated that point load strength index ranges from 0.35 MPa to 0.52 MPa (moderately week). Kinematics slope analyses indicates that the variable potential of circular, planar, wedges and toppling failures modes as well as the combination of more than one mode of aforementioned failure. Rock slopes stability analysis indicates that the factor of safety value as unsafe (0.52 to 0.96). Other factors contributing to rock slope failure are the presence of groundwater, climatological setting, joints filling material, high degree of rock fracturing due to shearing, steep of slope angle, high intensive of faulting and folding activities and locating at the fault zones area.

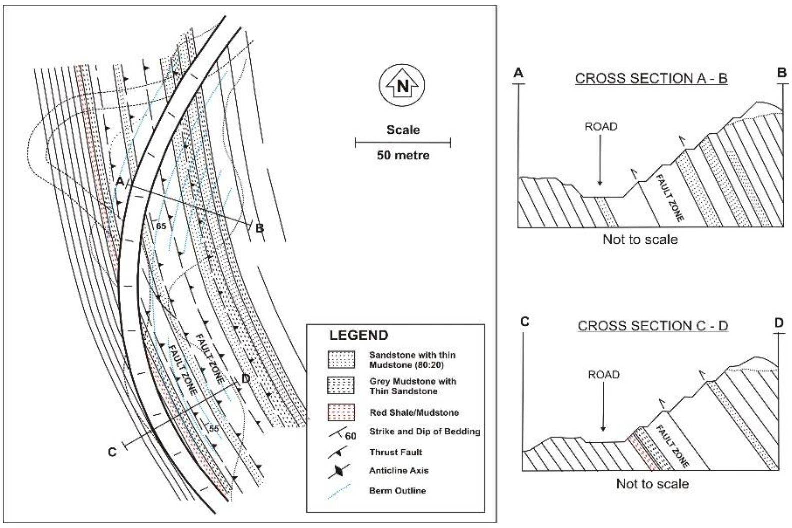

Figure 3: Sketch of slope failure showing the failure movement are starting from the hill side to the road and/or village sides through the development of water runoff (Location: KM 134 (S8)) [24]

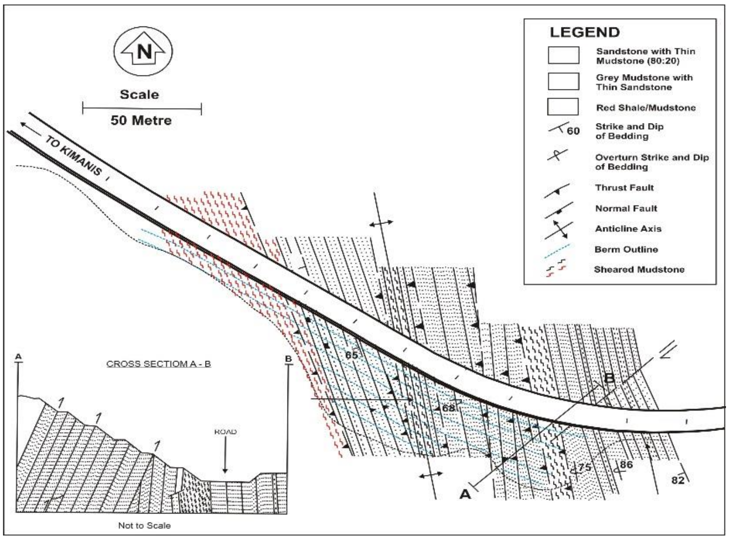

Figure 4: Sketch of slope failure showing the movement pattern is to collapse at the head, fall rapidly within narrow tracks, finally dispersing across the accumulation talus deposits (Location: KM 156 (R8)) [24]

Table 2: Analysis results of soil slope failures

Type of failure	Shallow slide (T1 –a)					Deep slide (T1 – b)			
Location (km)	KM 110	KM 113	KM 117	KM 120	KM 122	KM 129	KM 130	KM 134	KM 138
Slope	S1	S2	S3	S4	S5	S6	S7	S8	S9
	Crocker Formation	Trusmadi Formation	Trusmadi Formation	Trusmadi Formation	Trusmadi Formation	Trusmadi Formation	Trusmadi Formation	Crocker Formation	Trusmadi Formation
Lithology	Interbedded Sandstone & Shale	Sub-Phyllite	Slate	Sub-Phyllite	Slate	Sub-Phyllite	Sub-Phyllite	Interbedded Sandstone & Shale	Slate
Weathering grade	IV to VI	IV to VI	IV to VI	IV to VI	IV to VI	IV to VI	IV to VI	IV to VI	IV to VI
Volume (1)	Large	Medium	Large	Large	Small	Large	Medium	Large	Medium
Sand (%)	63 – 65	20 – 23	48 – 51	45 – 48	21 – 24	46 – 50	44 – 45	59 – 61	22 – 24
Silt (%)	5 – 12	52 – 55	18 – 22	13 – 16	54 – 58	18 – 20	16 – 19	6 – 10	13 – 14
Clay (%)	32 – 36	20 – 22	26 – 30	38 – 40	20 – 22	30 – 33	32 – 35	30 – 33	76 – 78
Liquid limit (%)	28 – 31	28 – 32	31 – 33	31 – 33	31 – 34	35 – 37	39 – 41	26 – 30	37 – 39
Plastic limit (%)	15 – 18	13 – 15	14 – 16	16 – 19	12 – 14	22 – 25	16 – 19	10 – 14	21 – 23
Plasticity index (%)	12 – 16	15 – 19	17 – 19	15 – 17	19 – 22	13 – 15	20 – 23	12 – 18	15 – 18
Liquidity index (%)	- 0.68 to – 0.60	- 0.35 to - 0.30	0.18 to 0.20	- 0.11 to - 0.09	0.14 to 0.18	- 1.08 to - 1.05	- 0.33 to - 0.25	- 0.02 to - 0.01	- 0.88 to - 0.85
Clay activity	0.47 – 0.50	0.98 – 0.99	0.38 – 0.47	0.41 – 0.45	0.53 – 0.55	0.35 – 0.40	1.00 – 1.11	0.87 – 0.91	0.38 – 0.39
Shrinkage limit (%)	7.51 – 7.95	8.68 – 8.89	8.22 – 10.54	7.28 – 7.55	8.84 – 9.98	6.10 – 7.33	9.16 – 9.86	8.53 – 9.12	5.63 – 6.66
Moisture content (%)	4 – 8	5 – 8	14 – 17	11 – 14	22 – 25	8 – 10	6 – 10	13 – 15	4 – 8
Specific gravity	2.57 – 2.58	2.60 – 2.62	2.65 – 2.68	2.60 – 2.62	2.60 – 2.62	2.64 – 2.65	2.61 – 2.64	2.61 – 2.63	2.66 – 2.68
Permeability (cm/s) (X 10^{-3})	7.83	3.32	8.47	6.39	5.66	7.61	5.60	5.41	8.78
Cohesion, C (kN/m^2)	9.82	5.13	8.53	9.50	7.76	10.36	17.27	11.43	10.40
Friction angle (^{o})	29.50	7.70	20.45	25.50	27.70	18.50	23.70	11.29	24.50
Factor of Safety	0.78	0.65	0.92	0.78	0.88	0.95	0.56	0.85	0.98
Main factors causing failures	SA, W, V, GWL, M, C, G, OBV, DS, EC and AC								

Table 2: (*Cont'd)* Analysis results of soil slope failures

Type of failure	**Multiple Slump (T2-b)**			**Complex failure (Slide Flow) (T5 – a)**			**Complex failure (Slump flow) (T5 – b)**		
Location (km)	KM 140	KM 142	KM 145	KM 147	KM 152	KM 155	KM 158	KM 162	KM 165
Slope	S10	S11	S12	S13	S14	S15	S16	S17	S18
	Trusmadi Formation	Trusmadi Formation	Trusmadi Formation	Trusmadi Formation	Crocker Formation	Trusmadi Formation	Crocker Formation	Trusmadi Formation	Trusmadi Formation
Lithology	Sub-Phyllite	Slate	Slate	Sub-Phyllite	Interbedded Sandstone & Shale	Slate	Shale	Sub-Phyllite	Slate
Weathering grade	IV to VI	IV to VI	IV to VI	IV to VI	IV to VI	IV to VI	IV to VI	IV to VI	IV to VI
Volume (1)	Small	Large	Medium	Large	Large	Medium	Large	Medium	Large
Sand (%)	36 – 39	46 – 47	31 – 33	48 – 51	54 – 58	39 – 42	68 – 70	30 – 33	22 – 26
Silt (%)	22 – 26	10 – 13	9 – 13	7 – 11	21 – 23	18 – 20	12 – 16	6 – 10	10 – 13
Clay (%)	38 – 40	36 – 38	55 – 58	38 – 42	20 – 22	40 – 43	18 – 22	59 – 61	62 – 63
Liquid limit (%)	41 – 44	46 – 49	25 – 29	29 – 32	31 – 33	41 – 43	28 – 30	26 – 30	33 – 38
Plastic limit (%)	22 – 24	19 – 21	15 – 18	13 – 17	13 – 16	23 – 25	16 – 20	10 – 14	16 – 19
Plasticity index (%)	17 – 19	27 – 28	14 – 16	18 – 21	18 – 20	18 – 20	9 – 12	12 – 18	17 – 20
Liquidity index (%)	- 0.85 to - 0.83	- 0.41 to - 0.38	0.09 to 0.15	- 0.26 to - 0.22	- 0.88 to - 0.85	- 0.84 to - 0.78	- 0.62 to - 0.58	- 0.05 to - 0.03	- 0.18 to - 0.14
Clay activity	1.43 – 1.45	0.69 – 0.77	0.42 – 0.47	0.62 – 0.68	0.38 – 0.39	0.43 – 0.49	0.48 – 0.50	0.98 – 1.00	0.46 – 0.52
Shrinkage limit (%)	8.45 – 9.26	12.68 – 13.85	7.98 – 8.33	7.98 – 8.12	5.63 – 6.66	7.98 – 8.65	5.63 – 6.53	8.45 – 8.50	6.34 – 677
Moisture content (%)	7 – 11	6 – 10	10 – 14	9 – 12	4 – 8	9 – 12	7 – 12	20 – 22	12 – 14
Specific gravity	2.62 – 2.69	2.58 – 2.60	2.74 – 2.80	2.60 – 2.62	2.66 – 2.68	2.64 – 2.68	2.72 – 2.77	2.65 – 2.68	2.68 – 2.72
Permeability (cm/s) ($X 10^{-3}$)	5.58	4.62	7.40	7.81	8.78	4.33	9.66	8.54	7.98
Cohesion, C (kN/m^2)	15.47	11.43	3.20	10.40	10.40	12.80	9.62	7.20	12.54
Friction angle (^{o})	22.30	11.29	21.00	24.50	24.50	21.50	21.20	26.30	9.30
Factor of Safety	0.63	0.79	0.91	0.87	0.98	0.58	0.89	0.87	0.89
Main factors causing failures	SA, W, V, GWL, M, C, G, OBV, DS, EC and AC								

Note: (1) Volume: small (10 – 50 m^3), Medium (50 – 500 m^3) and Large (> 500 m^3) and (2) Discontinuity (D), Slope angle (SA), Weathering (W), Vegetation (V), Groundwater level (GWL), Material characteristics (M), Climatological setting (C), Geological characteristics (G), Over burden or vibration (OBV), Drainage system (DS), Embankment construction (EC) and Artificial changing (AC)

Apart from that, fieldwork observation indicates that too many cut and filled slopes was designed does not take into account input or geological interest. For example most of the slopes were designed too steep, lack of monitoring on proper drainage system or slope physical state and also we can found most of the slope cutting surface activities is parallel following to the strike direction of the sandstone bedding orientation. The trend of strike and dip of the sandstone bedding orientation along the highway can be observed in different patterns such low angle dip (030-100/10-20); medium angle dip (220-280/30-50) and high angle dip (320-345/60-70). The slope surface orientation was observed is ranging from 210-330 (dip-direction) and 35-80 (dip) values. Hence, the main factors of slope failures occurrences along the highway are sourced from the relationship between the factors of dip-direction slope cutting surfaces with the strike direction of the sandstone bedding orientation. That is why there were some slopes in the study area were found in the variable potential of falls, slides and topples mode types as well as the combination of more than one mode of aforementioned in the form of the slope failures complex due to this design negligence described to the above aided by the discontinuities nature complex very often encountered at study area.

The way groundwater flows; its pressure and gradient at any point within a slope depend on the local geology. Water plays a very important role in landslide study. Water can influence the strength of slope forming material by chemical and solution, increase in pore water pressures and subsequent decrease in shear strength, reduction of apparent cohesion due to capillary forces (soil suction) upon saturation and softening of stiff fissured clays, shale and sandstone [4,6,7,14,15]. All slope forming materials are subject to initial stresses as a result of gravitational loading, tectonic setting activity, weathering, erosion and other processes [25,26]. Stresses produced by these processes are embodied in the materials themselves, remaining there after the stimulus that generated them has been removed (residual stresses). Stress relief many structural features and stress release activity is an important feature in many rock formations [27-30]. High lateral stresses have played a crucial role in initiating in over consolidated of the slope materials.

5. CONCLUSIONS

In light of available information, the following conclusions may be drawn from the present study:

a. A total of 28 selected critical slope failures were studied and classified into two main groups: rock slope and soil slope. Failures in soil slopes (including embankments) are 18 (64 %) whereas 10 of all failures (36 %) of rock slope.
b. Physical and mechanical properties of 72 soil samples indicated that the failure materials mainly consist of poorly graded to well graded materials of sandy clay and clayey silt soils, which characterized by low to intermediate plasticity content, containing of inactive to normal clay, very high to medium degree of swelling, variable low to high water content, specific gravity ranges from 2.57 to 2.80, low permeability, friction angle (ϕ) ranges from 7.70° to 29.50° and cohesion (C) ranges from 3.20 KPa to 17.27 KPa.
c. The rock properties of 10 rock samples indicated that the point load strength index and the uniaxial compressive strength range classified as moderately week. Kinematics slope analyses indicates that the variable potential of circular, planar, wedges and toppling failures modes as well as the combination of more than one mode of aforementioned failure.
d. Rock and soil slopes stability analysis indicates that the factor of safety value as unsafe (0.52 to 0.98).
e. The main factors causing slope failure occurrences in the study area are natural (geology, meteorology, topography and drainage system) and human factors (lack of proper planning, human activities and community's attitude).

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