GEOTECHNICS STUDY FOR DESIGN OF OPEN PIT SLOPES AT COAL MINING SITE PLAN, SAROLANGUN, JAMBI

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ABSTRACT

Site plan of coal mining at Sorolangun, Jambi, is required geotechnical study for cut slope design. Mining plan. In open pit plan, to take stable slope, is required slope mass rating (SMR). SMR method is requiring rock mass rating value. According to soil and weak-rock mass properties of Muaraenim Formation, stable cut slopes of the open pit determined by these rocks vary from 27^{o} to 33^{o}.
Keywords: open pin, cut slope, SMR, RMR.

ABSTRAK

Perencanaan tapak penambangan batubara di Sorolangun, Jambi, diperlukan kajian geoteknik untuk rancangbangun lereng stabil. Dalam perencanaan tambang terbuka, untuk mendapatkan lereng dengan sudut yang stabil, diperlukan metode pembobotan massa lereng. Metode pembobotan massa lereng memerlukan nilai pembobotan massa batuan. Berdasarkan sifat massa batuan-lemah dan tanah dari Formasi Muaraenim, sudut lereng kupasan stabil dari tambang terbuka ditentukan oleh variasi batuan ini adalah antara 27 sampai 33 derajat.
Kata kunci: *tambang terbuka, lereng kupasan, SMR, RMR*

INTRODUCTION

Surface geotechnical mapping, geotechnical, and hydrogeological studies for the design of open pit slopes and overburden dump at coal mining site plan, Sarolangun, Jambi, had been conducted in about two months beginning from December 2008 till February 2009. Six geotechnics bore holes were drilled to penetrate Muaraenim Formation which consists of claystone and sandstone layers alternation with several coal seams intercalation.

Geometry of stable slopes of the pit involving single and overall slopes should be determined as the result of slope stability analyses through simulation and iteration being based on material properties (rock and soil mentioned earlier) taken from the bore holes at the proposed mine site plan. The slopes have to remain stable in the rainy season (saturated) under earthquake load at the peak local horizontal acceleration. Seismic loading could be an important trigger mechanism when combined with high precipitation events. The design criteria should be achieved to ensure that the slopes remain stable in that worst condition.

To satisfy the design criteria, which should use data of ground water condition, hydrogeological study had been conducted to observe ground water level at many places, especially at several locations of man made water springs, by pumping tests to obtain permeability and transmisivity of the rock formation. Besides, infiltration tests at 20 scattered locations over the proposed mine area were also carried out. As the result of these field works underground water contour map and flow pattern can be obtained and mapped, of which the data is used for the slope stability analysis.

Again, to study the feasibility of proposed dumping area three geotechnical drilling had also been carried out. The bore holes data obtained as the result of laboratory tests will be used for the analyses of slope stability of the soil and rock waste dump.

This report has been prepared in accordance with Bussiness Term of Engagement (BTE), December 2008, between PT. Britmindo and Geotechnics and Hydrogeology Study Center, Geotechnics Laboratory, Padjadjaran University as External Associate Consultant, which is based on generally accepted geotechnical practice and engineering judgment and experience has been used in the development of recommendations.

The project site is located in Subdistrict of Pauh, the Regency of Sarolangun, The Province of Jambi, Sumatera, which can be reached from Jambi by car in about 4 hours. The road condition in many places are damaged because of heavy vehicles that frequently passed through it.

SITE INVESTIGATION

General

Pevious drillings had been conducted to explore and to characterize the sedimentary rocks of Muaraenim Formation, which consists of strongly to moderately weathered claystone and sandstone layers alternation. It is clear that from the descriptions of rock cores and the results of soil and rocks mechanics laboratory the rock strata exhibit weak to moderate strength of materials, which shall construct the cut slopes of the pit, while the mine runs to excavate waste rocks from the open pit.

Drilling and Mapping Program

To provide geotechnical data of the rock strata needed for the slope stability analysis for determining the stable pit slopes five geotechnical bore holes of more than 400 meters total depth had been drilled, from which both the undisturbed soil samples representing surficial parts of the strata and the rock cores underneath had been tested in the soil and rock mechanics laboratory. Two hundreds samples were sent to laboratory for basic physical properties, uniaxial and triaxial compressive strengths, and permeability determinations and classification testing.

These data with the hydrogeological data, and seismic loading at the peak local acceleration will determine the geometry of the pit slopes at the stable condition. So, hydrogeological and seismic data should be provided for the support of the slope stability analysis.

To select and/or to geotechnically design a dump at the proposed site three bore holes had also been drilled. Undisturbed soil samples from the upper part of rock strata near the surface and rock samples underneath had been sent to laboratory for their strength properties tests. All the data obtained will be used for determining stable slope of the dump of considerable dumping capacity at saturation state and peak local seismic acceleration. Besides, in situ Standard Penetration Tests in the bore hole were carried out to measure the penetration resistances of the rocks using split-spoon sampler and the undisturbed soil samples obtained by the sampler were also tested in the laboratory to determine the soil types.

SITE CONDITIONS

Surficial Geology

Both from descriptions of bore holes and surface geotechnical mapping it is clear that the sites for the mine and the dump consist of residual soils being originated from weathered sedimentary rocks of coal bearing formation, namely, Muaraenim Formation. This low strength of rock strata need to be properly examined for determining the geometry of the stable cut slopes of the pit. Ground water levels are very shallow at many bore hole locations, for example, the depth is 0.60 meter at GT. 01.

Reconstruction of the plotted data of strike and dip of the bedding planes of this formation exhibit a conclusion that a gently folded rock strata occur in this study area as a structural geological configuration.

Subsurface Condition

Underneath the soil mass the alternation of claystone and sandstone layers with intercalation of several coal seams occur. These rocks are partly to moderately weathered, and at several depth intervals in the bore holes joints and crushes are found. These data are important for the characterization purpose of the rock mass using Rock Mass Rating (RMR) for the geomechanics classifications, which explain the relative strength and behavior of every class of the rock mass. According to Bieniawsky (1989) and many other authors there is a strong correlation or relationship between RMR rating of a rock mass and ultimate angle of slope constructed by the rock mass.

Table 1 is presented below listing the results of drilling from bore holes GT.01 up to GT.06 with their soil and rock characteristic. Classification of cohesive soil and rock based on uniaxial compressive strength or UCS (Hoek & Bray, 1977) is used for classifying the soil and rockmass penetrated by drilling at all bore holes as follows.

1. < 0.4 kg/cm^2 – VERY SOFT SOIL – easily moulded with fingers
2. 0.4-0.8 kg/cm^2 – SOFT SOIL – moulds with strong pressure from fingers
3. 0.8-1.5 kg/cm^2 – FIRM SOIL – very difficult to mould with fingers
4. 1.5-6.0 kg/cm^2 – STIFF SOIL – cannot be moulded by fingers, requires hand picking for excavation
5. 6.0-10.0 kg/cm^2 – VERY STIFF SOIL – very tough, difficult to move with hand pick, requires pneumatic spade for excavation
6. 10.0-250.0 – VERY WEAK ROCK – crumbles under sharp blows with geological pick point, can be cut with pocket knife

Based on the result of field description and laboratory test the soil and rock mass of the Muara Enim Formation exhibit the low strength sedimentary rocks. These rocks are mainly characterized by low values of unconfined compressive strength (UCS) of lower than 10 kg/cm^2, which are categoried as soil. Some of them are very weak rocks with their USC values are slightly larger than 10 kg/cm^2.

The results of laboratory tests of rock samples taken from GT.01 confirm that the rocks are of low strength properties. According to Shower & Shower (1978) about characteristics of rocks, as well as Bieniawski (1989) about geo-mechanical rock mass classification in rock engineering, rocks of Muaraenim Formation can be classified as "soil", which behave like soil mass. This kind of weak rocks can only construct the stable overall angle of cut slope of less than 30 ^{o} for pit of depth varying from 60 to 70 meters, of which the slope angle for every single stable bench can be 4H : 5V.

The result of RMR using Bieniawski geomechanical classification of rocks in GT.01 shows that the values range from about 39 to 72, which are categoried as poor to fair rock (Rock Mass Class IV and III), with some of them are good rock. But, these classes do not really exhibit good rocks because their UCS values are low as listed in the table below.

Slope Design of Open Pit

Geometry of cut slope of the open pit plan consists of finite and infinite slopes. The finite slope constructed of one bench, of which the width, the height, and the angle of its slope determine its stability. The stability is analyzed to obtain the stable slope.

Besides, the overall slope, also known as infinite slope, consists of many benches from the summit to the toe of the slope it self. Both the overall slope with all benches and every single bench should be designed stable at worse condition (at earthquake loading of peak local acceleration and in rainy season).

Stability Evaluation

Analysis methodology

Limit equilibrium analyses were conducted to determine the safety factor against slope failure during mining and operation of heavy mine vehicles. The analyses were conducted using available two-dimentional approach, limit equilibrium software, SLOPE/W. The method of slope stability analyses used was soil slope stability because the material properties presented by their UCS values, such as listed in Table 1, are for soil mass. The principles underlying the method of limit equilibrium analysis of slope stability are presented below.

1. A slip mechanism of slope failure is postulated;
2. The shear resistance required to equilibrate the assumed slip mechanism is calculated by means of statics (in a state of balance, motionless);
3. The calculated shear resistance required for the equilibrium is compared with the available shear stress in terms of factor of safety Fs;
4. The slip mechanism with the lowest factor of safety is determined through iteration;
5. The lowest value of Fs of slope design should be larger than a critical value according to design criteria to keep the slope in a stable condition; and
6. Design criteria for the stability condition involve rainy season (saturated soil/rock of slope) and seismic or earthquake loading at peak local acceleration.

Factor of safety is used to account for the uncertainty and variability in the strength and pore water pressure parameters, and to limit deformation. Earthquake loading including vibration from the use of heavy vehicles during mining is modeled using pseudostatic peak horizontal ground acceleration (horizontal earthquake coefficient).

Slope stability analyses were conducted for the deepest cross sections of the open pit. The soils and rocks constructing the open-pit cut slopes were inferred, being based on the results of drilling represented by bore hole logs, to be clays and silts of high plasticity, grading into alternation of soft claystones and thin bedded sandstones with coal seams intercalation as bed rocks of Muaraenim Formation.

Design Criteria

Design criteria of a stable cut slope should be achieved through simulation and iteration in the process of slope stability analyses. This design criteria used as a guideline in open pit mining is listed below.

Earthquake loading for the slope stability analyses were conducted at peak local horizontal acceleration in Jambi area α_{hor} = 0,10g (USGS, 2003). This acceleration value is larger close to the Semangko Fault Zone of no less than 0,15g.

Material Properties

Soils properties of the open pit plan penetrated by drilling are presented in the geotechnical drilling logs. The soil properties used for the cut slope stability analyses represented by every sample from GT.01, GT.03, GT.04, and GT.06 are listed below (Table 3). Soil and rock properties from the study area assumed as have been represented by these bore hole logs, which were then used for the analyses to determine the economic-stable cut slopes of the open pit.

For the slope stability analyses of the dumping area at which the dump berm is proposed to be constructed the material used for the slope analyses is the rock waste from the open pit and soils data from bore holes DD.01, DD.02, and DD.03.

RESULT OF STABILITY ANALYSES

Cut slope stability analyses had been conducted by means of statics and pseudostatics at earthquake loading of peak horizontal acceleration of α_{hor} = 0,10g as mentioned earlier.
Every slope profile listed below was drawn through bore hole location to exhibit the subsurface geotechnical condition of the cut open pit slope. By using the soil- and rock mass properties penetrated by the bore hole the simulation to analyze the cut slope stability was carried out. This simulation was conducted using different slope angle of bench and overall cut slope from the existing ground surface till the deepest open pit plan as the deepest available coal seam shall be mined. The preferable overall cut slope together with the bench's slope as a result of simulation is that with its factor of safety which achieves the design criteria (Table 2).
Below are the results of simulation and the preferable overall slopes (Table 5).

Economic slopes are chosen according to design criteria in Table 2 as the result of stability analyses of cut slope geometries through simulation. The results of slope stability analyses for slope geometry being based on laboratory test data of soils and rocks obtained from the drill holes were selected for slopes with the safety factor Fs = 1.3 or larger at statics, and slightly larger than 1 at pseudostatics.

The economic overall slopes and their bench slope geometries are determined by the rock and soil mass properties when wet or saturated at earthquake loading condition at peak local ground acceleration.

Based on the result of rock mass rating (RMR) approach using Geomechanical Classification by Bieniawski (1989) the rock mass classes at every bore hole location are listed below (Table 6). Every class of rock mass obtained using this classification exhibit its relative strength which is characterized by its number of score. RMR value of rock mass can be used as an indicator to estimate the slope mass rating in terms of stable slope of bench being constructed by the rock mass using formulae by the authors as follows.

According to these authors, Laubscher (1975), Romano (1980), Hall (1985), and Orr (1992) in Hirnawan (2000) the following formulae are used for calculating the slope mass rating of the rock mass based on its RMR.

Laubscher (1975)

RMR	SMR (^{o})
80 – 100	75
60 –80	65
40 – 60	55
20 – 40	45
00 - 20	35

Romana (1980)

SMR = RMR – (F1 x F2 x F3) + F4
F4 = 0

Hall (1985)

SMR = 0.65 RMR + 25

Orr (1992)

SMR = 35 ln RMR - 71

Angles of benches presented in Table 5 are lower than those presented in Table 6 as slope mass rating. This is because UCS values for every core sampes taken from bore holes GT.01 up to GT.06 are low representing soils or very weak rocks (Table 1). The large values of RMR of the samples, in general, are because the other parameters determining rock mass rating, such as RQD representing unjointed rocks, and the related parameters, are large. In this case, RMR is not really able to be used for estimating stable slope. RMR is only suitable for estimating angle of stable slope constructed by moderately strong to strong rock mass (rock slope stability cases).

From Table 5 it is clear that over all angles of selected slope profiles drawn through bore holes GT.01, GT.03, and GT.06 are 36.8^o, 30 ^{o} to 33 ^{o}, and 33.12 ^{o} respectively. These angles are larger than that of profile through GT. 04, which is only 15.9 ^{o}(see Appendix). This is because the data of material properties used for the slope stability analyses of this profile are too low, which are obtained from direct shear test. The data used are residual cohesion and residual internal friction angle of the samples. So, actually, based on the assumption of the relatively same rock mass properties from the job site, the overall angle of slope of this profile should be no less than 30 ^{o}.

CONCLUSION AND RECOMMENDATION

Soil and rock mass properties of Muaraenim Formation exhibit soil and very weak rock. Stable cut slopes of the open pit determined by these rocks vary from 27 ^{o} to 33^o. Factor of safety at static condition is about 1.3, and is slightly larger than 1.0 at pseudostatic condition. These stable cut slopes of open pit were represented by soil and rock properties data from GT. 01 and GT.03. On the other hand, the use of data from GT.04 presenting low strength soil and rock mass generates slope angle of about 16 ^{o} with factor of safety Fs = 1.478 (deep seated stability) and 1.019 (seismic stability).

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Table 1. Soil- and rock mass characteristics or classes from every bore holes in area of open pit plan, Pauh, Sarolangun, Jambi

No.	**No. Bor Hole**	**Soil and Rock Description and Class**	**UCS (kg/cm^2)**	**Class of soil and rock (Hoek & Bray, 1977)**
	GT.01	Residual soil as weathered bed rock, CH, soft, cohesive, and claystone and sandstone alternation with coal seams intercalation	1.3-9.6 and 11.00-24	firm soil to very stiff soil very weak rock
2	GT.02	Ditto	1.79-5.47 6.54-9.88 15.7-17.06	stiff soil very stiff soil, and very weak rock
3	GT.03	Ditto	2.21-5.47 6.54-9.84 15.11-19.97	stiff soil very stiff soil, and very weak rock
4	GT.04	Ditto	2.81-5.87 6.06-9.67 10.67-15.42	stiff soil very stiff soil, and very weak rock
5	GT.05	Ditto	1.01-1.43 1.81-5.91 6.30-9.05 10.22-17.09	firm soil stiff soil very stiff soil, and very weak rock
6	GT.06	Ditto	1.36 1.68-5.68 6.06-6.55	firm soil stiff soil very stiff soil, and

Table 2. Design Factor of Safety

Stability Condition	**Minimum Design Factor of Safety**
Long Term Deep Seated Stability	1.3
Seismic (Pseudo-static) Stability	1.0

Table 3. Soil Properties used for the slope stability analyses of open pit

Bore Hole Nos.	Soil/Rock Description	Saturated Volume Unit Weight (KN/m^3)	Cohesion (KN/m^2)	Angle of Internal Friction (φ;^{0})
GT -01	Soil 1 : clay	16.247	5.88	6.3
	Soil 2 : carbonaceous claystone.	14.15	56.875	25.72
	Soil 3 : coal dark brown.	17	10	28
	Soil 4 : carbonaceous claystone	14.15	56.875	25.72
	Soil 5 : carbonaceous claystone alternation with coal dark brown	13.826	114.73	9.11
	Soil 6 : carbonaceous claystone	14.011	78.448	26.71
	Soil 7 : claystone alternation with sandstone	19.022	38.22	20.46
	Soil 8 : claystone,	14.011	78.448	26.71
	Soil 9 : carbonaceous claystone intercalated with coal	17.217	78.448	26.71
GT-03	Soil 1 : clay	11.79	49.03	7.35
	Soil 2 : Claystone intercalated with coal,	19.12	93.353	14.87
	Soil 3 : coal	17.649	26.084	13.92
	Soil 4 : claystone	18.531	77.075	18.633
	Soil 5 : coal dark brown	19.708	44.519	10.8
	Soil 6 : carbonaceous claystone	18.678	40.498	20.628
GT-04	Soil 1 : clay	16.744	40.205	8.5767
	Soil 2 : claystone, alternation with sandstone	18.067	26.084	9.0075
	Soil 3 : coal	18.63	35.512	14.06
	Soil 4 : claystone	18.854	35.512	10.343
	Soil 5 : coal	17.355	16.072	13.73
	Soil 6 :claystone intercalated with sandstone.	19.522	113.36	22.169
GT-06	Soil 1 : clay.	16.744	40.205	8.5767
	Soil 2 : claystone,	18.531	700.54	36.705
	Soil 3 : siltstone	16.669	216.62	25.125
	Soil 4 : sandstone intercalated with claystone	18.041	190.24	25.658
	Soil 5 : claystone	18.63	223.77	25.753
	Soil 6 : coal	17.355	16.072	13.73
	Soil 7 : claystone.	19.522	113.36	22.169

Table 5. Results of simulation to achieve design criteria of economic slope

No.	Overall Slope and bench slope	Minimum Fs		slope
		statics	Pseudo-statics $\alpha_{hor} = 0,10g$	
1	1.1. Slope profile through GT.01. Bench slope geometry 4H : 4.5V or 8m : 9m (48°); angle of overall slope = 28.26°	1.533	1.201	no
	1.2. Ditto, bench slope 3.5H : 4.5V or 7m : 9m (52.12°); angle of overall slope = 36.8° (FS slope is 2.635)	1.300	1.062	yes
2	2.1. Slope profile through GT.03. Bench slope geometry 1H : 1V or 6 m : 6m (45°); angle of overall slope = 27°	1.456	1.156	no
	2.2. Ditto, bench slope 4H : 4.5 V or 8 m : 9m (48.36°); angle of overall slope = 30° (Factor of safety of bench slope is 3.587)	1.355	1.069	yes
	2.3. Ditto, bench slope 2H : 2.5 V or 4 m : 5m (51.34°); angle of overall slope = 33° (Fig. 7.2)	1.277*)	1.005	Yes
3	3.1. Slope profile through GT.04. Bench slope geometry 3H : 2V or 12m : 8m (33.6°); angle of overall slope = 21.32°	1.226	0.896	no
	3.2. Ditto, bench slope 13H : 7V 0r 13 m : 7m (28.3°); angle of overall slope = 15.9° (Factor of safety of bench slope is 2.694; Fig. 7.3)	1.478	1.019	yes
4	4.1. Slope profile through GT.06. Bench slope geometry 4H : 4.5V or 8m : 9m (48.38°); angle of overall slope = 33.12°	2.943	2.329	no
	4.2. Ditto, bench slope 7H : 9V or 7m : 9m (52.12°); angle of overall slope = 35.35° (Factor of safety of bench slope is 4.999; Fig. 7.4)	2.486*)	2.023	yes
	*) not yet been completed, still be simulated, while lab tests is under way			

Table 6a. Rock Mass Rating and stable bench slope at every bore hole location

No	**Bore Hole Nos**	**Depth (m)**	**RMR**	**Class *)**	**Slope Mass Rating (SMR)**			
					Laubscher, 1975	Romano, 1980	Hall, 1985	Orr, 1992
1	GT.01	0.00 - 13.00	72	II	65	81	72	79
		13.00 - 20.50	39 - 40	IV	45	48- 49	50-51	57-58
		20.50 - 32.50	43 - 59	III	55	52- 68	53-63	61-72
		32.50 - 37.00	62	II	65	71	65	73
		37.00 - 50.50	50 - 59	III	55	59- 68	57-63	66-72
		50.50 - 52.00	67	II	65	76	69	76
		52.00 - 56.50	50	III	55	59	57	66
		56.50 - 70.00	67	II	65	76	69	76
		70.00 - 82.00	50 - 59	III	55	59-68	57-63	66-72
		82.00 - 95.50	62 - 67	II	65	71-76	65-69	73-76
		95.50 - 100.0	55	III	55	64	61	69
		100.0 - 151.0	72	II	65	81	72	79
2	GT.02	0.00 - 21.00	76 - 77	II	65	85-86	74-75	81
		21.00 -22.50	43	III	55	52	53	61
		22.50 - 57.00	76.77	II	65	85-86	74-75	81
		57.00 - 58.50	54	III	55	64	61	69
		58.50 - 61.50	76 - 77	II	65	85-86	74-75	81
		61.50 - 63.00	69	III	65	78	70	77
3	GT.03	0.00 - 3.50	62	II	65	71	65	73
		3.50 - 5.00	50	III	55	59	57	66
		5.00 - 6.50	38	IV	45	47	50	56
		6.50 - 8.00	52	III	55	61	59	67
		8.00 - 9.50	38	IV	45	47	50	56
		9.50 - 11.00	72	II	65	81	72	79
		11.00 - 26.00	43 - 47	III	55	52-56	53-56	61-64
		26.00 - 38.00	71 - 72	II	65	80-81	71-72	78-79

Table 6b. Rock Mass Rating and stable bench slope at every bore hole location

No	**Bore Hole Nos**	**Depth (m)**	**RMR**	**Class *)**	**Slope Mass Rating (SMR)**			
					Laubscher, 1975	Romano, 1980	Hall, 1985	Orr, 1992
4	GT.04	0.00 - 9.50	72	II	65	81	72	79
		9.50 - 14.00	50 - 55	III	55	59-64	57-61	66-69
		14.00 - 21.50	25	IV	45	34	41	42
		21.50 - 26.00	54	III	55	63	60	69
		26.00 - 39.50	72	II	65	81	72	79
5	GT.05	0.00 - 31.00	64 - 72	II	65	73-81	67-72	75-79
		31.00 - 43.00	57 - 59	III	55	66-68	62-63	71-72
		43.00 - 47.50	72	II	65	81	72	79
		47.50 - 50.50	49 - 51	III	55	58-59	57-58	65-66
		50.50 - 115.00	63 - 77	II	65	72-76	66-69	74-76
		115.00 - 124.00	59	III	55	68	63	72
		124.00 - 145.50	63 - 74	II	65	72-73	66-67	74-75
		145.50 - 147.00	55	III	55	64	61	69
		147.00 - 150.00	72	II	65	81	72	79
		150.00 - 153.00	59	III	55	68	63	72
		153.00 - 158.50	72	II	65	81	72	79
6	GT.06	0.00 – 10.00	72	II	65	81	72	79
		10.00 – 14.50	59	III	55	68	63	72
		14.50 – 61.00	63 - 77	II	65	72-76	66-69	74-76

*) Notes :

I : Very Good Rock Mass ; II : Good ; III : Fair; IV : Poor; V : Very Poor

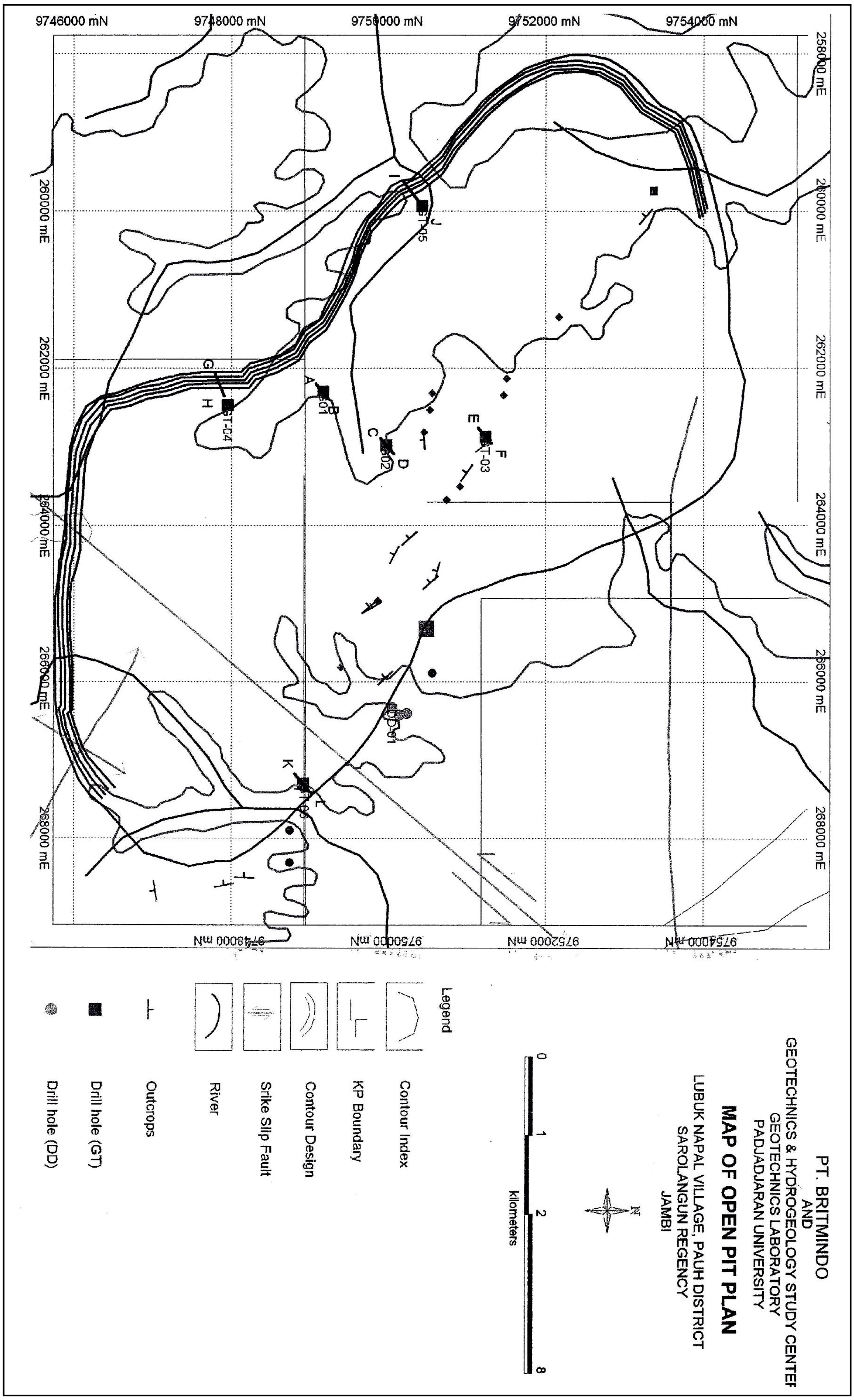

Figure 1. Map of open pti plan

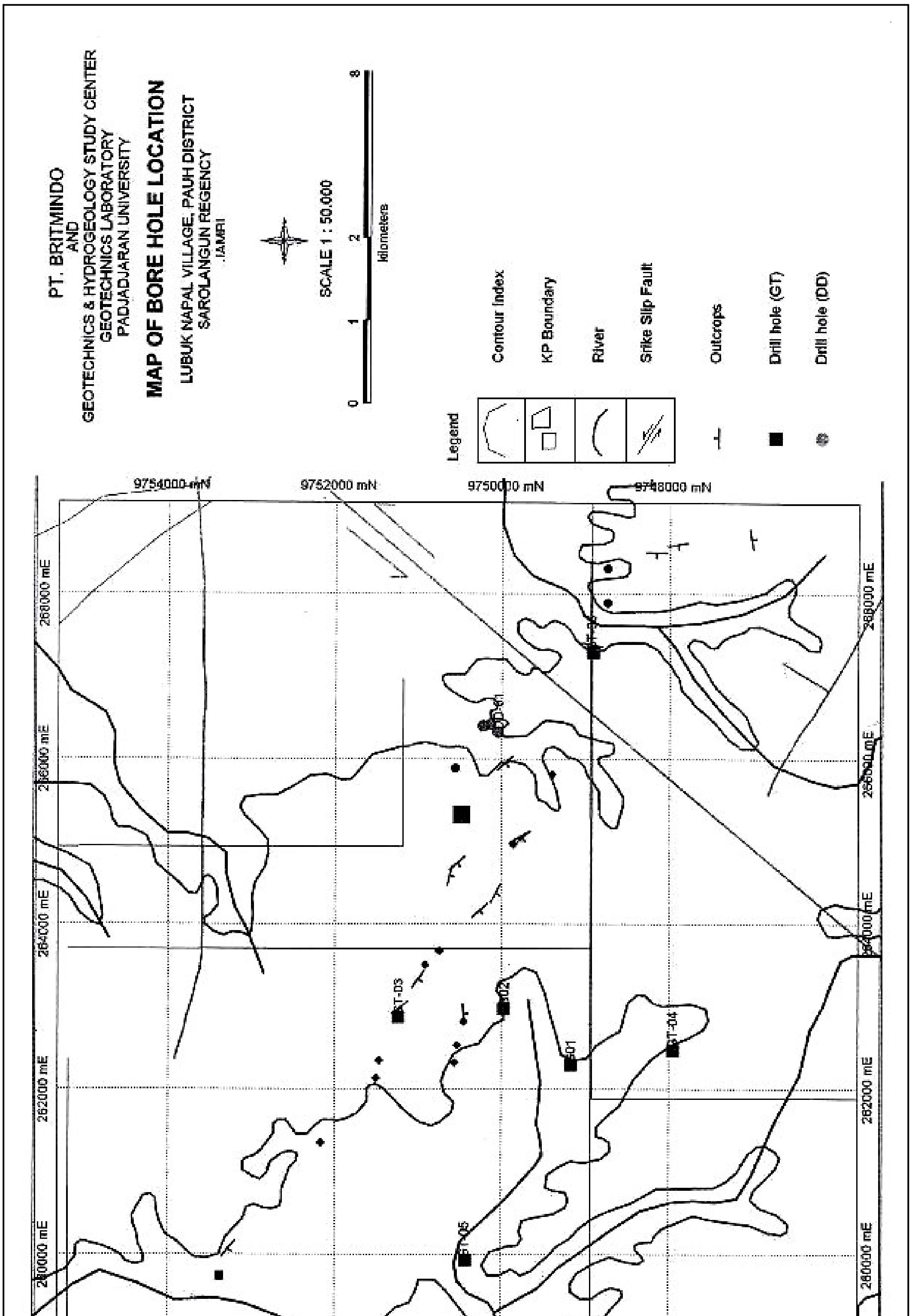

Figure 2. Map of Borehole location

PT.BRITMINDO

GEOTECHNICS & HYDROGEOLOGY STUDY CENTER PADJADJARAN UNIVERSITY

GEOTECHNICAL DRILLING LOG

PROJECT	: PT. Artha Nusantara Resources	SHEET No.	: 1 of 1
LOCATION	: Jambi Project Site	BORING MACHINE	: MAXI
HOLE No.	: GT - 03	CORE BARREL TYPE	: HQ
COORDINATE	: (x) 262858,421 (y) 9751228,547	LOGGED BY	: Yuyus Brahman & R. M. Mahbub
GROUND ELEVATION	: 67,816 m	CHECKED BY	: Geni Dipatunggoro, Ir., MT
DECLINATION (°)	: Vertical		: Prof. Febri Hirnawan
		APPROVED BY	: Achmad Hawadi, Ir.

ROCK MASS CLASSIFICATION

DEPTH (m)	WATER LEVEL (m)	ROCK TYPE OR FORMATION	COLUMN SECTION	LITHOLOGIC ENGINEERING DESCRIPTION	CORE RECOV. (%)	SAMPLING FOR LAB TEST	WEATHERING STAGE	SLACKING POTENTIAL	SPT (0 30 60)	STRENGTH: E (GPa)	STRENGTH: UCS (Mpa)	RQD (%)	JOINT SPACE (cm/joint)	JOINT CONDITION (-Type/ shape/ dip/ surface/ infill/ opening. -Soft gouge 5 mm, continues -Slicken side, gouge 5 mm, 1-5 mm opening -Rough surface, 1 mm opening, weathering stage)	GROUND WATER CONDITION	EXCAVATION METHOD	RMR - SMR
		Soil		clay, yellowish brown, high plasticity, impermeable.		US	CW										
		claystone		claystone, at 1,80 to 6,93 m depth, brownish grey to pale grey, well cemented, dense, soft, masif. intercalated with coal, soft. moderately hard			SW	Med			0.416	100	75	Joint/planar/5°/smooth/ opening			61
											0.249	33	75	Joint/planar/10°/smooth/ opening			49
5					100						0.472	60	38	Joint/curve planar/85°/ rough/slickenside			39
								Low			0.451	80	50	Joint/planar/5°/smooth / opening			53
											0.398	53	38	Joint/curve planar/50°/ slickensided/opening			39
10								Med			0.718	100					71
											0.325	89	15	Joint/curve planar/45°/ slickensided/opening			41
								Low			1.573	33	17	Joint/curve planar/80°/ slickensided/opening			34
											0.968	100					71
15					97						0.298	65	13	Joint/planar/10°/smooth/ opening			47
					100						0.216	53	17	Crushed/planar/10°/smooth/ opening			47
												35	11	Joint/planar/10°/smooth/ opening			43
20		coal		coal, dull, hard,some resin	73			Med				100					
					100							100			Wet		
					83		MW					100					
		claystone		claystone, dark brown,moderately hard, well cemented				Low				100					
25											0.641	100					71
											1.538	100					72
											0.536	100					71
30					100						0.744	100					71
											1.481	100					72
		coal		coal, dark brown, dull							1.533	100					72
35		claystone		claystone, blackish grey to grey, carbonaceous claystone.							1.663	100					72
											0.3528	100					71
												100					

Notes :

CW = Completely Weathered
SW = Strongly Weathered
MW = Moderately Weathered
US = Undisturbed Sample

Geotechnical Drilling Logs GT-03

Figure 3. Geotechnical drilling log

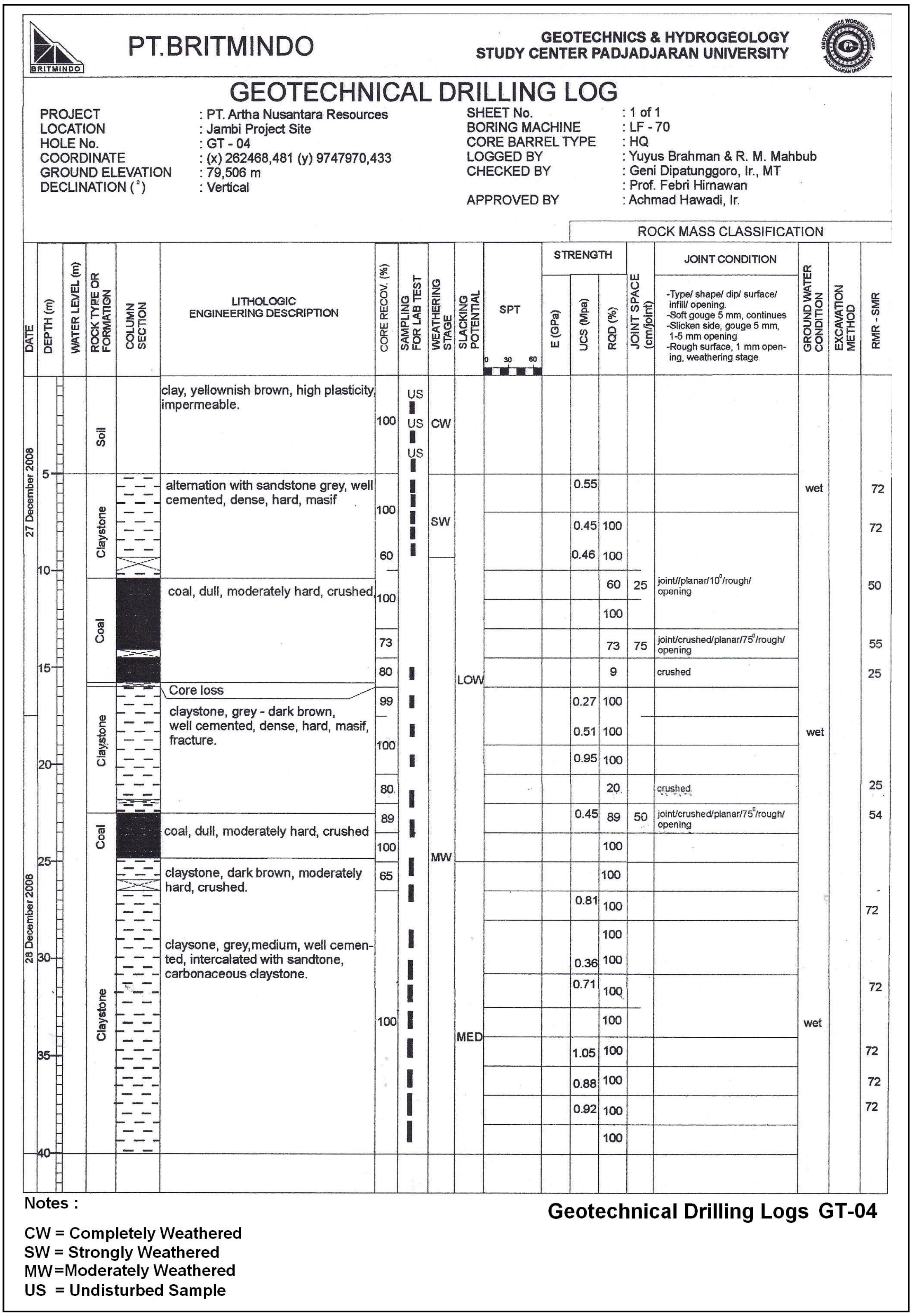

Figure 4. Geotechnical drilling log

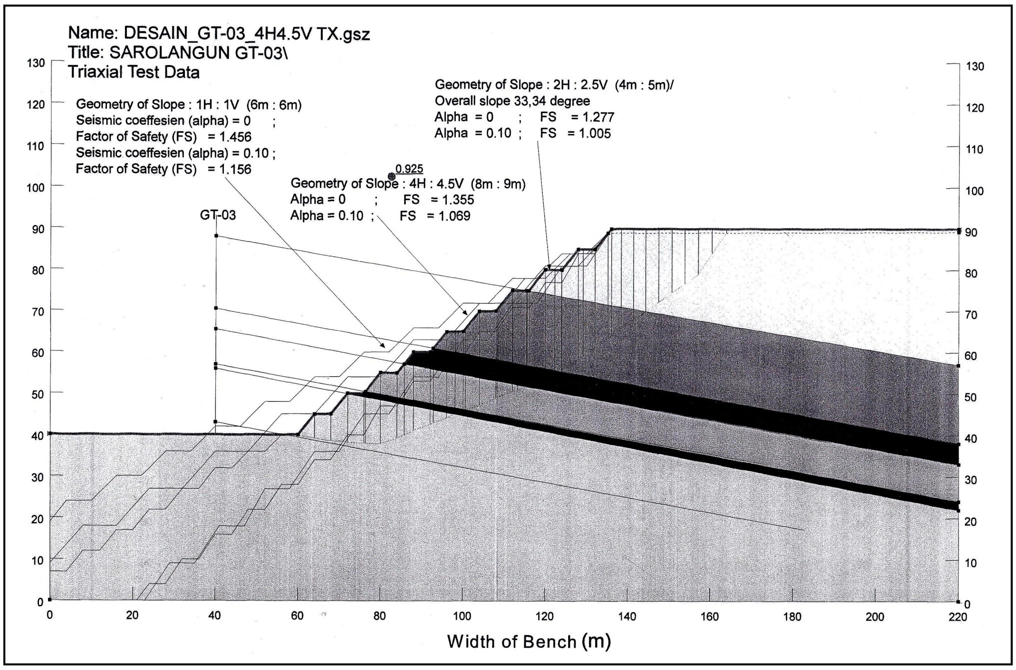

Figure 5. Result of slope stability analysis of slope profiles through GT.03

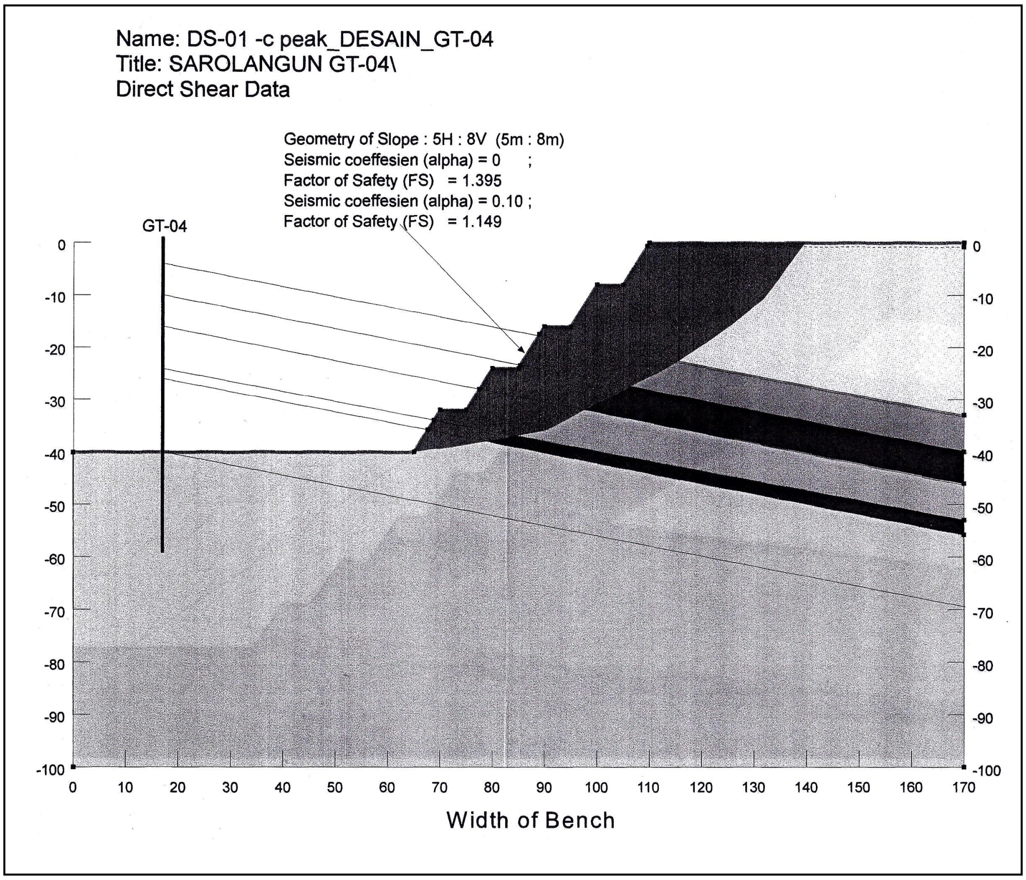

Figure 6. Result of slope stability analysis of slope profiles through GT.4