Analysis stability of rock slope at left bank of South portal of North tunnel – Da Nang – Quang Ngai expressway

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Abstract

Da Nang – Quang Ngai highway is one part of the North South Expressway with 139.52 km long, 24.5m wide. Tunnel is section of package 4 with station Km 22+500 – Km 23+000. Region tunnel located at Duy Son and Duy Chung commune, DuyXuyen district, Quang Nam province. Tunnel was designed to go through the small hill at altitude of about 120m above sea level. Bedrock is a sedimentary rock (alternation of sandstone and conglomerate).

Authors have detected incorrect at geotechnical investigation report and in situ analysis of intact rock. In situ intact rock have 2 fault system with grade V, location of faults in region South portal of including tunnel North and South. Intact sandstone location in left side of South portal of tunnel north has 3 faults system and bedding system. The bedding system has direction angle 150- 200, fault system perpendicular with bedding system have direction angle 75-80o; fault system overlap with face of rock slope have direction angle perpendicular with axis tunnel.

Application discontinuity model and failure criterion for anisotropic rock, analysis stability rock slope at left bank of south portal of North tunnel – Da Nang – Quang Ngai expressway.

Key words: Discontinuity model, failure criterion of anisotropic rock, Hoek-Brown, Barton-Bandis…

1. Introduction

Da Nang – Quang Ngai highway is one part of the North South Expressway with 139.52 km long, 24.5m wide. Tunnel is section of package 4 with station Km 22+500 – Km 23+000. Region tunnel located at Duy Son and Duy Chung commune, DuyXuyen district, Quang Nam province.

1.1 *Geotechnicalinvestigationresults*

Tunnel was designed to go through the small hill at altitude of about 120m above sea level. Bedrock is a sedimentary rock (alternation of sandstone and conglomerate). Line of strike of the terrain is Northeast – southwest with strike angle about 60^0 from the North, bedding dipping 30^o to the Northwest.

At North portal: many blocks of unstable rock located on the surface with different sizes (from 0.5m to 5m in diameter), plants grow poorly.

At South portal: bedrock exposed on the surface at some positions, rock was highly weathered, tree grow well. However, surface failure (mass movement) was found near the tunnel: the new is about 15m width x 30m length on the South bound tunnel, the older is about 30m width x 50m length on the North bound tunnel.

- Geological condition of South portal:A layer of extremely weathered rock is found over the bedrock with different thickness (4m thick at BV-4; but 0.65m thick at BV-3); residual soil: sand with gravel, reddish brown, medium dense. Conglomerate and sandstone usually alternate below, the proportion of conglomerate and sandstone is 4:1. Particles of conglomerate is rounded, granule and pebble size (2 ~ 20mm), fresh to lightly weathered condition.Permeability of the fracture zone is quite small (nearly 0.5mm/min with the pressure 1 kgf/cm^2). Compression strength of lightly weathered rock is high, approximately 50Mpa in average (laboratory test).

1.2 ***Seismicrefractionprospectingresults:***

Results of data processing and analysis have determined velocity of geological layers. At the same time, it has determined positions of low longitudinal wave velocity zone (involved in fracture and fault zone). The elastic parameters are determined according to each profile.

The result of seismic refraction survey in the North bound and South bound profile have many similar properties. The stratigraphic classification of the survey areas is as following:

Layer 1: is the covering layer, rather thin, from 0 to 4.5 meters. Longitudinal wave velocities are between 400 to 1000 m/sec. Modulus of elasticity are from 4 to 25 (1000 Kg/cm^2); modulus of deformation from 0.25 to 2.5 (1000 Kg/cm^2).

Layer 2: average thickness is about 4 meters; some positions in the profile north bound have more thickness of 6.5m. Longitudinal wave velocities are from 900 to 1800 m/sec, almost above the groundwater level. Modulus of elasticity is from 20 to 81 (1000 Kg/cm^2). Modulus of deformation is between from1.8 to 10 (1000 Kg/cm^2).

Layer 3: average thickness is about 4 meters, most thick positions more than 7 meters. Longitudinal wave velocities are between 2100 to 2300 m/sec. modulus of elasticity is from 122 to 133 (1000 Kg/cm^2); modulus of deformation from 10 to 15 (1000 Kg/cm^2).

Layer 4: more thickness, averagely from 7 to 9 meters, some few position thinner about 5 meters. Longitudinal wave velocities are between 2700 to 3500 m/sec. modulus of elasticity is between 184 to 312 (1000 kg/cm^2); modulus of elasticity is between 25 to 60 (1000Kg/cm^2).

Layer 5: longitudinal wave velocities in this layer are between 3700 to 6000 m/s, average value is 4200 m/s. modulus of elasticity is between 349 to 932 (1000 Kg/cm^2); modulus of deformation between 75 to 400 (1000 Kg/cm^2).

Damage zones, faults and geological anomalies: seen at six locations in each survey line. Longitudinal wave velocities is 2000 to 3200m/sec. modulus of elasticity is between 100 to 260 (1000 Kg/cm^2); modulus of deformation between 10 to 40 (1000Kg/cm^2).

1.3 *Resultsinvestigationconstructionsite of teamexperts*

Experts search have incorrect with geotechnical investigation report and in situ analysis of intact rock. In situ intact rock have 2 fault system with grade V, location of faults in region South portal of including tunnel North and South. Intact sandstone location in left side of South portal of tunnel north has 3 faults system and bedding system. The bedding system have direction angle 15^0- 20^0, fault system perpendicular with bedding system have direction angle 75-80^o; fault system overlap with face of rock slope have direction angle perpendicular with axis tunnel.

In addition, from survey, topography, we are have intact rock in studies area is tectonic system with grade II, divide region delta river and hilly.

After, presentation photos about studies area at construction site.

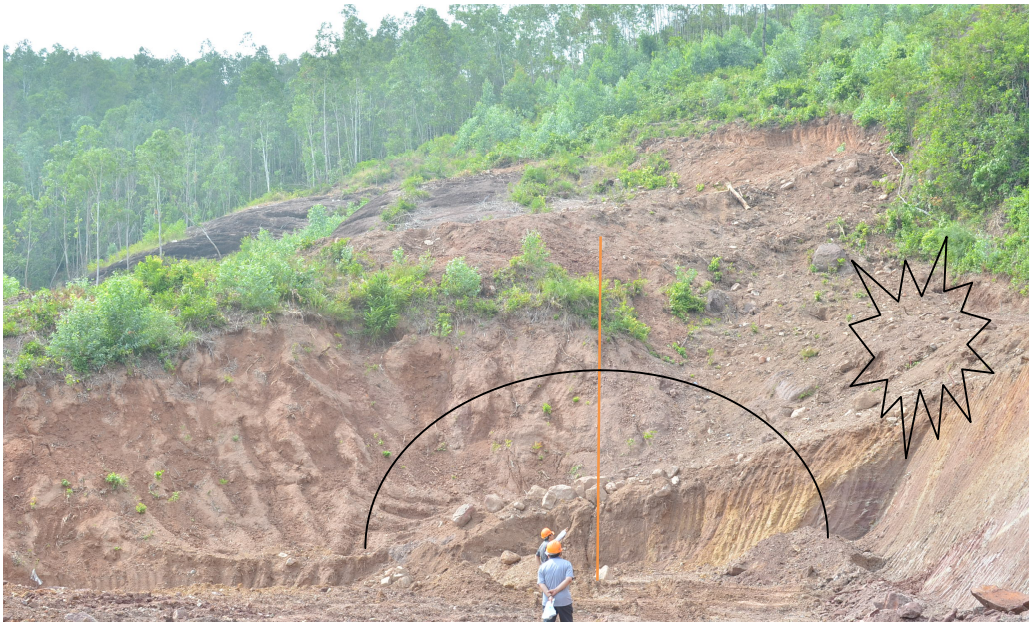


Fig. 1 South portal of North tunnel, fault zone grade V, right side main view from South portal;

1.4 *Establishedprofile and cross-geological sectionforcalculation:*

After research documents of project and combined result investigation construction site and experience experts, team experts established profile and cross geological section for studies area, follows :

Table 1: Statistics sections geological structure

No.	Name of section	Location	remark
1	Profile section of axis North tunnel with studies area South portal		
2	Profile section of axis Expressway, studies area South of tunnels		
3	Profile section of axis South tunnel studies area South portal.		
4	Section MC01	Km23+021	
5	Section MC02	Km23+031	

6	Section MC03	Km23+041	South portal
7	Section MC04	Km23+051	
8	Section MC05	Km23+061	

Results sections geological structure shown in Fig. 2, Fig. 3, Fig. 4, Fig. 5, (with dimension and arrangement, structural update from contractor drawing construction is TEDI contractor).

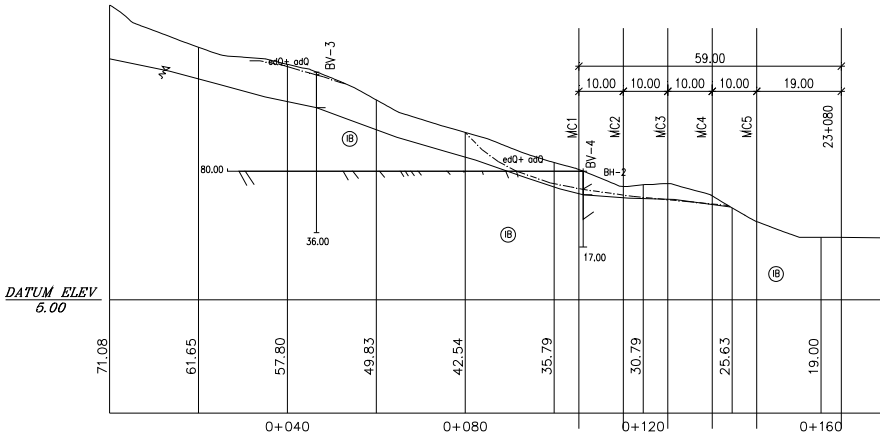


Fig. 2: Section geological structure of axis expressway;

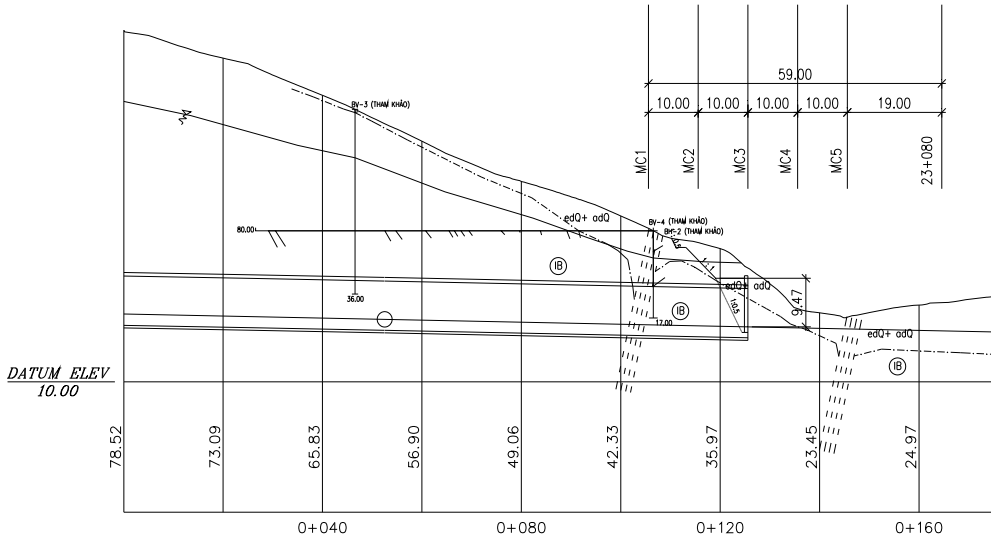


Fig. 3: Profile section geological of axis North tunnel, South portal;

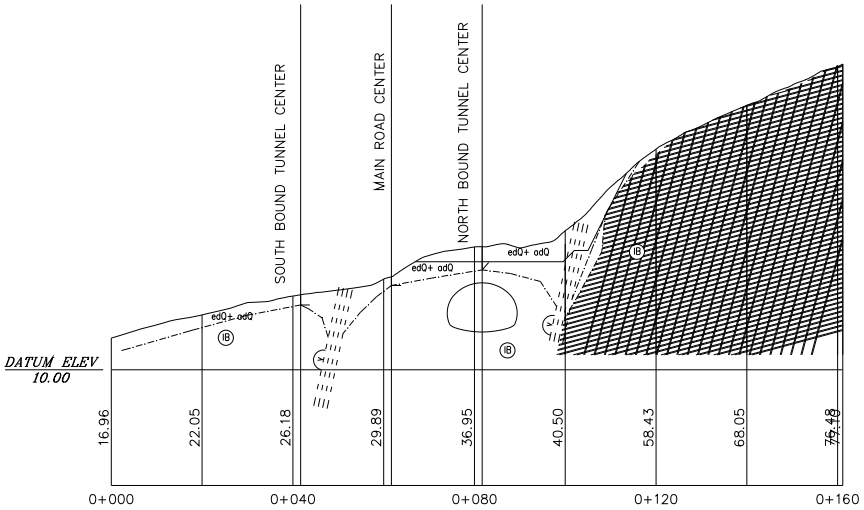


Fig. 4: Cross Section geological – MC02;

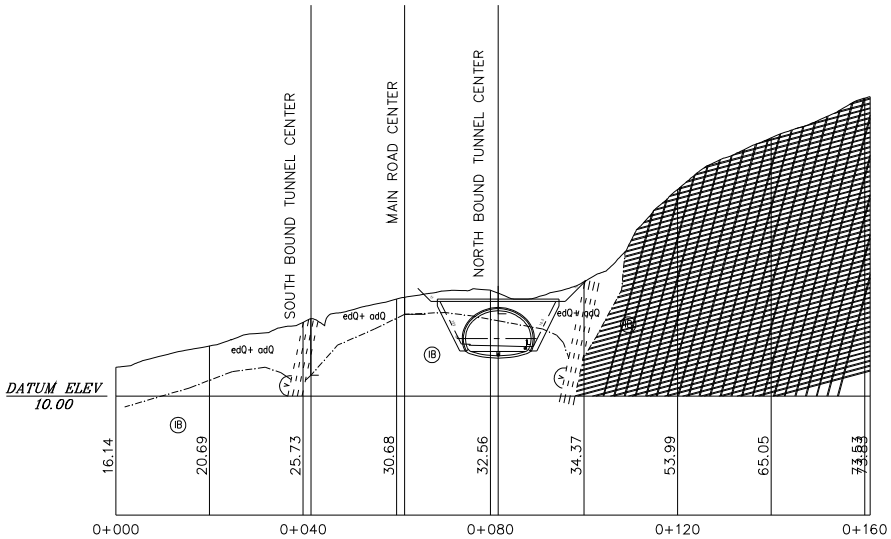


Fig. 5: Cross Section geological – MC03;

2. Propose parameters for intact rock and soil application for analysis:

Weathering crust on rock beds can be summarized as follows:

- Layer weather edQ+IA1: Due in report geotechnical investigation had not been to results of parameters of strength Mohr- Coulomb. So, team experts propose use parameters of layer 9 (sand clay, grey green, grey brown, produce of weathering complete of sandstone with thickness from 0.5 to 1.2m). SPT of layer 9, minimum is 26 to 50; maximum is 26 to 62. The parameters of layer weathering edQ+IA1 showed in table 2.

Table 2: Parameters of layer weathering edQ+IA1;

Case of analysis	Unit weight (kN/m3)	φ Friction angle (deg)	c (kPa)cohesion(kPa)
Natural	17	19	20
Saturated	20	16	14

– Parameters of rock masses sandstone had been determine by Hoek – Brown methods with software RocLab of Rocscience, follows:

Table 3: Parameters input for Roclab software;

Case of analysis	Sigci (MPa)	GSI	mi	D	Type application
Natural	50	65	17	0,8	Slope (15 m)
Saturated	25	65	17	0,8	Slope (15 m)

Table 4: Results output for parameters strength of Mohr- Coulomb by RocLab software;

Case of analysis	φ (deg)	c (kPa)	Unit weight (kN/m^3)
Natural	58,70	457	25,4
Saturated	55,08	276	25,4

Parameters mechanical and physics of bedding layer had been determine such as clay layer (use parameters of layer 11: clay siltstone have SPT minimum: 35 to 45; maximum: 35 to 50), follows:

Table 5: Parameters mechanical and physics of bedding system

Case of analysis	Unit weight (kN/m^3)	φφ' (deg)	c' (kPa)
Natural	17,0	19,00	36,00
Saturated	20,0	16,00	21,00

Fig. 6: Sandstone has dark red-sandwiched grave;

Fig. 7: Experiment determine friction internal angle of intact rock by rock bars

In the Fig. 7, showed the experiments determine friction internal angle of intact rock by rock bars in construction site is experiment simply shear test. Rock bars form intact rock have fault rough, stacked two rock bars on equipment and tilting until rock bar begin sliding as gravity weight itself. Determine angle minimum when begin sliding by geological compass. This angle is friction internal angle of intact rock (Barton and Choubey, 1977).

Parameters of fault system perpendicular with bedding system had been determine friction angle such as rock masses by Hoek- Brown; cohesion had determine by 20% of cohesion determine by Hoek – Brown, showed in table 6:

Table 6: Parameters mechanical and physics of fault system perpendicular with bedding system

Case of analysis	φφ'' (deg)	c''(kPa)	Unit weight (kN/m^3)
Natural	33	91,40	17
Saturated	29	55,20	20

3. Case of calculation

Case 1st:(construction condition in natural best fit): parameters for calculation such as natural condition.

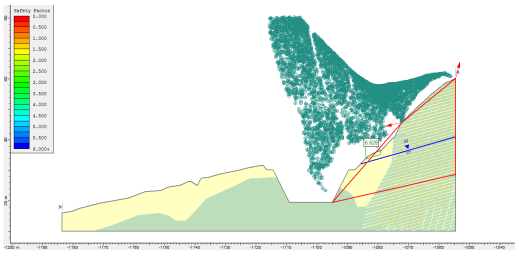
Case 2nd: (construction completed and heavy raining by typhoon or flood); begin seep flow in layer rock and soil.

Case 3rd: propose support solution with parameters such as condition most unfavorable.

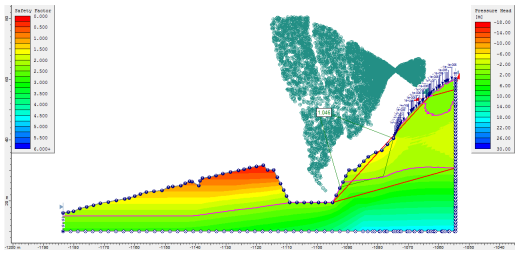
4. Results calculation

4.1 *Resultanalysis non - circular slipping:*

Case 1st:- Janbu simply method



Case 2nd:- Janbu simply method



Case 4th-Janbu simply method

Analysis stability have support by anchors with tensile capacity equal 300kN, spacing 2m; Bond length with 10% anchor length, length anchors equal 6.0m, (type anchors SND32)

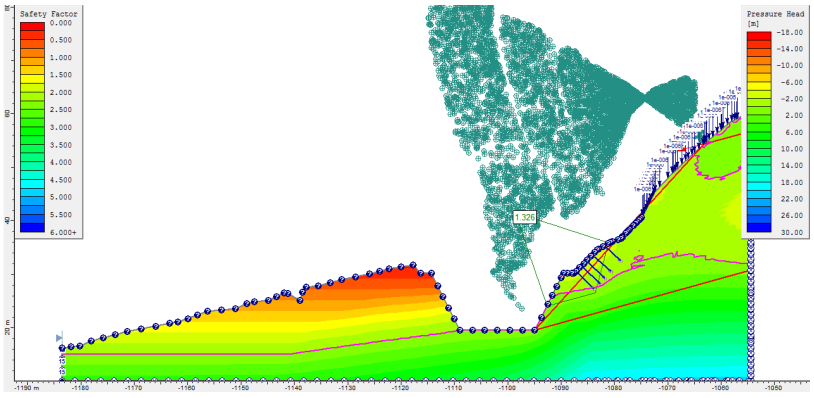


Fig. 8: Result analysis non - circular slipping;

Table 7: Results analysis stability slope cross section MC03

Case of analysis	Non circular slope
	Janbu simply
Case 1	6.628
Case 3	1.046
Case 4	1.326

5. Conclusions

Overview in table results, we have with case studies, results have stability slope is ensuring with the limit equilibrium.

However, with standard design, factor of stability (FS) had been statisified condition FS ≥ [FS].

Value [FS] is proposed difference value depending type of structure, required about value stability and depend consulting group.

In project Noi Bai – Lao Cai expressway, Doosan [3], was used factor stability such as: Standard for construction transport of Korea 2006: With case condition fly, non water ground [FS] >1.5. With case raining: thickness water ground is 50% high fault system, or soil sand that water flooding face then [Fs]>1,2.

Thus, we need to support by anchors. Results analysis stability is satisfy Korea standard for case condition most unfavorable, with have supportby anchors bar have tensile strength 300kN, spacing 2m, bond length equal 10% length anchors with length anchors equal 6m, type SND32; results in case 4^{th} shown slope is stability with FS >[FS]=1,20.

References

Báo cáo khảo sát địa chất công trình. Gói thầu 4 - Đoạn 1 (KM21+500 – KM26+800. Liên danh Tư vấn Nippon Koel Co LTd. Thai Engineering Consultants Co. Ltd. Đà Nẵng, 8/2013.

Geotechnical Investigation Report for Tunnel Section of Pakage 4. Station: KM 22+500 – Km 23+000. The Joint Venture of Nippon Engineering Consultants Co.Ltd. Thai Engineering Consultants Co. Ltd. April 2013.

Slope stability Review. Doc. No DHIC-MS-CMPS-EN-A2. Doosan Hevy Industries and Construction. August 2011.

RocScience Inc. Slide tutorial.

RocScience Inc. Slide software.