Slope Stability Analysis in Rocks

Part 3 – Rock mass

(Intensely Fractured Rock)

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Slope Stability Analysis in Rocks

This Presentation on Slope stability analysis is divided into three parts. **This presentation we will cover the failure in rockmass (intensly fractured rockmass).**

1. Planar Failure
2. Wedge Failure
3. **Failure in Rock mass**

The slopes are analyzed using the finite element program RS2 (Rocscience).

Input Parameters for Numerical Analysis

Generalized Hoek Brown criteria is used for calculating the shear strength parameters of rock mass (input parameter). Following parameters are considered for the numerical analysis:

- mi = Constant (Figure 1)
- GSI = Geological Strength Index (Figure 2)
- UCS = Intact Uniaxial Compressive Strength
- MR = Modulus Ratio (Figure 3)
- D = Disturbance factor (Figure 4)

With the help of Roclab, software of Rocscience, will provide you the shear strength parameter of rockmass by using the above parameters from the figures mentioned in below slides.

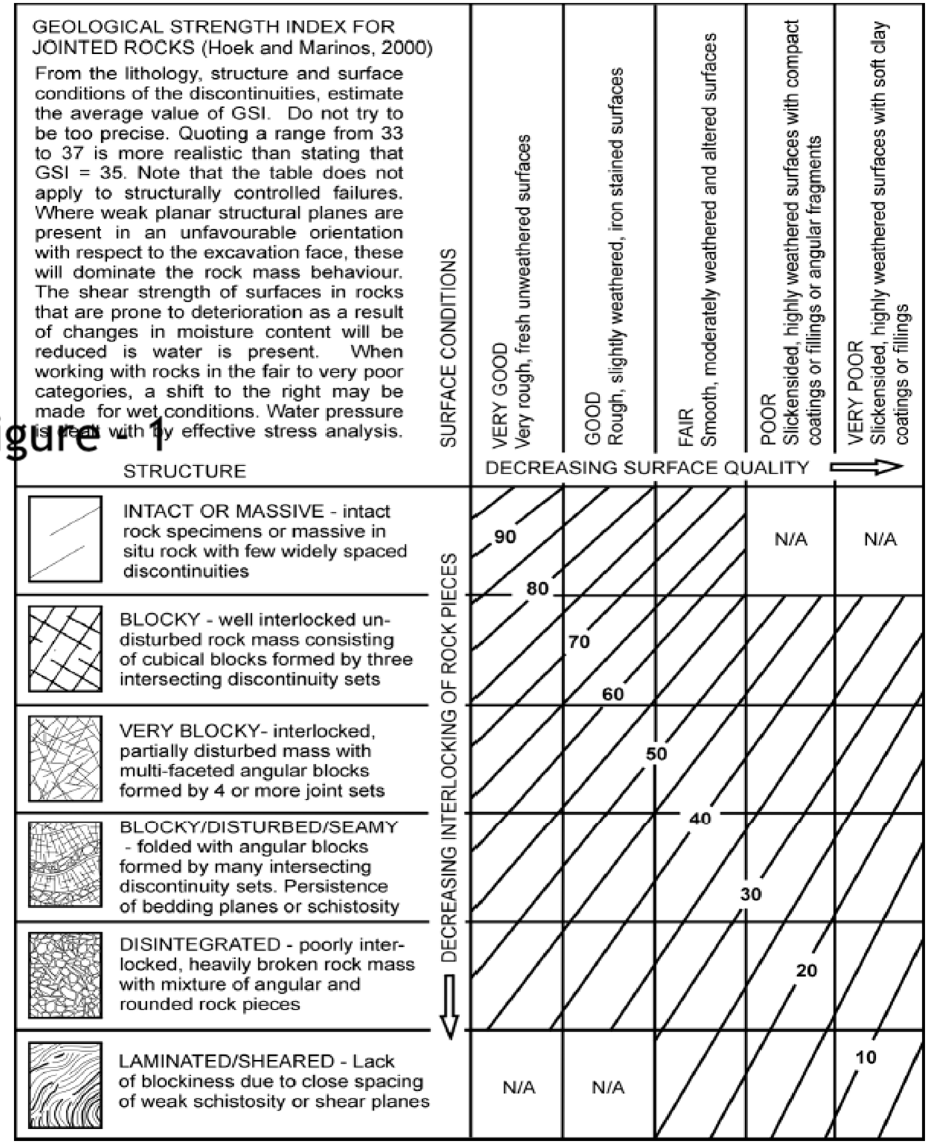
Parameter to Determine Strength Parameters of Rockmass

Figure - 1

Table 3: Values of the constant m_i for intact rock, by rock group. Note that values in parenthesis are estimates.

Rock type	Class	Group	Texture: Coarse	Medium	Fine	Very fine
SEDIMENTARY	Clastic		Conglomerates* (21 ± 3) Breccias (19 ± 5)	Sandstones 17 ± 4	Siltstones 7 ± 2 Greywackes (18 ± 3)	Claystones 4 ± 2 Shales (6 ± 2) Marls (7 ± 2)
	Non-Clastic	Carbonates	Crystalline Limestone (12 ± 3)	Sparitic Limestones (10 ± 2)	Micritic Limestones (9 ± 2)	Dolomites (9 ± 3)
		Evaporites		Gypsum 8 ± 2	Anhydrite 12 ± 2	
		Organic				Chalk 7 ± 2
METAMORPHIC	Non Foliated		Marble 9 ± 3	Hornfels (19 ± 4) Metasandstone (19 ± 3)	Quartzites 20 ± 3	
	Slightly foliated		Migmatite (29 ± 3)	Amphibolites 26 ± 6		
	Foliated**		Gneiss 28 ± 5	Schists 12 ± 3	Phyllites (7 ± 3)	Slates 7 ± 4
IGNEOUS	Plutonic	Light	Granite 32 ± 3 Diorite 25 ± 5 Granodiorite (29 ± 3)			
		Dark	Gabbro 27 ± 3 Norite 20 ± 5	Dolerite (16 ± 5)		
	Hypabyssal		Porphyries (20 ± 5)		Diabase (15 ± 5)	Peridotite (25 ± 5)
	Volcanic	Lava		Rhyolite (25 ± 5) Andesite 25 ± 5	Dacite (25 ± 3) Basalt (25 ± 5)	Obsidian (19 ± 3)
		Pyroclastic	Agglomerate (19 ± 3)	Breccia (19 ± 5)	Tuff (13 ± 5)	

Figure - 2



Parameter to Determine Strength Parameters of Rockmass

Figure - 3

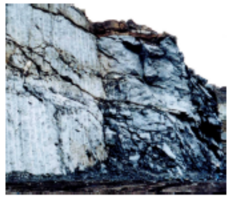
Table 8: Guidelines for the selection of modulus ratio (MR) values in Equation (26) based on Deere (1968) and Palmstrom and Singh (2001)

	Class	Group	Texture: Coarse	Texture: Medium	Texture: Fine	Texture: Very fine
SEDIMENTARY	Clastic		Conglomerates 300-400 Breccias 230-350	Sandstones 200-350	Siltstones 350-400 Greywackes 350	Claystones 200-300 Shales 150-250 * Marls 150-200
SEDIMENTARY	Non-Clastic	Carbonates	Crystalline Limestone 400-600	Sparitic Limestones 600-800	Micritic Limestones 800-1000	Dolomites 350-500
SEDIMENTARY	Non-Clastic	Evaporites		Gypsum (350)**	Anhydrite (350)**	
SEDIMENTARY	Non-Clastic	Organic				Chalk 1000+
METAMORPHIC	Non Foliated		Marble 700-1000	Hornfels 400-700 Metasandstone 200-300	Quartzites 300-450	
METAMORPHIC	Slightly foliated		Migmatite 350-400	Amphibolites 400-500	Gneiss 300-750*	
METAMORPHIC	Foliated*			Schists 250-1100*	Phyllites /Mica Schist 300-800*	Slates 400-600*
IGNEOUS	Plutonic	Light	Granite+ 300-550 Granodiorite+ 400-450	Diorite+ 300-350		
IGNEOUS	Plutonic	Dark	Gabbro 400-500 Norite 350-400	Dolerite 300-400		
IGNEOUS	Hypabyssal		Porphyries (400)**		Diabase 300-350	Peridotite 250-300
IGNEOUS	Volcanic	Lava		Rhyolite 300-500 Andesite 300-500	Dacite 350-450 Basalt 250-450	
IGNEOUS	Volcanic	Pyroclastic	Agglomerate 400-600	Volcanic breccia (500) **	Tuff 200-400	

* Highly anisotropic rocks: the value of MR will be significantly different if normal strain and/or loading occurs parallel (high MR) or perpendicular (low MR) to a weakness plane. Uniaxial test loading direction should be equivalent to field application.
+ Felsic Granitoids: Coarse Grained or Altered (high MR), fined grained (low MR).
** No data available, estimated on the basis of geological logic.

Figure - 4

Table 7: Guidelines for estimating disturbance factor D

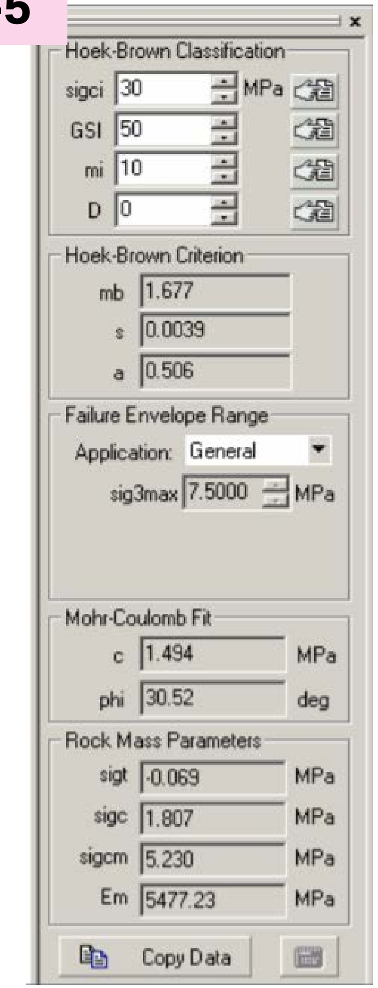
Appearance of rock mass	Description of rock mass	Suggested value of D
	Excellent quality controlled blasting or excavation by Tunnel Boring Machine results in minimal disturbance to the confined rock mass surrounding a tunnel.	D = 0
	Mechanical or hand excavation in poor quality rock masses (no blasting) results in minimal disturbance to the surrounding rock mass. Where squeezing problems result in significant floor heave, disturbance can be severe unless a temporary invert, as shown in the photograph, is placed.	D = 0 D = 0.5 No invert
	Very poor quality blasting in a hard rock tunnel results in severe local damage, extending 2 or 3 m, in the surrounding rock mass.	D = 0.8
	Small scale blasting in civil engineering slopes results in modest rock mass damage, particularly if controlled blasting is used as shown on the left hand side of the photograph. However, stress relief results in some disturbance.	D = 0.7 Good blasting D = 1.0 Poor blasting
	Very large open pit mine slopes suffer significant disturbance due to heavy production blasting and also due to stress relief from overburden removal. In some softer rocks excavation can be carried out by ripping and dozing and the degree of damage to the slopes is less.	D = 1.0 Production blasting D = 0.7 Mechanical excavation

ROCLAB – For Determining Shear strength of Rock mass

The calculations in the RocLab program, are based on the latest version of the Generalized Hoek-Brown failure criterion.

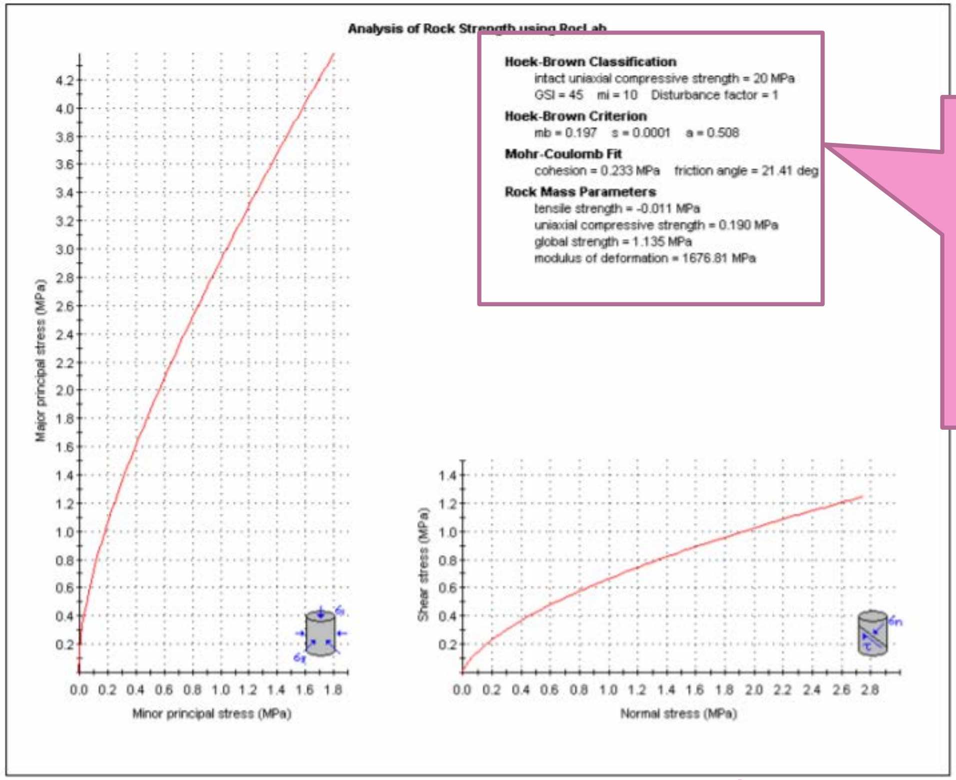
All the above inputs will be provided in the below **Figure -5**

Figure -5



RocLab will plot the rock mass failure envelopes in:

- Principal stress space (sigma1 vs. sigma3)
- Shear – Normal stress space (sigma normal vs. Tau)



This is the result or output of rockmass parameters which we put in numerical analysis to get the Factor of safety of Slopes

Numerical Analysis

Here excavated slope of about 45m has been analysed.
The input parameters for RS2 software has been adopted from Roclab software as describe in above slides. The input parameters are as follows:

Quartzite

Name: Quartzite Fill: Hatch:

Initial Conditions | Stiffness | Strength | Hydraulic Properties | Datum Dependency

Type: Isotropic

Type	Data
Use Unloading Condition	No
Loading	
Poisson's Ratio	0.25
Young's Modulus (MPa)	2000
Use Residual Young's Modulus	No

Quartzite

Name: Quartzite Fill: Hatch:

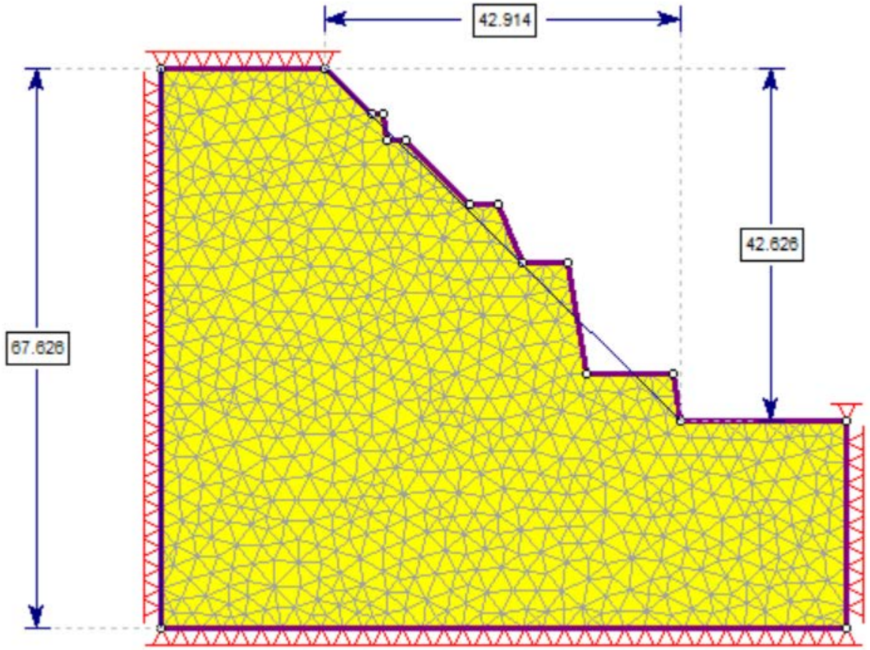
Initial Conditions | Stiffness | Strength | Hydraulic Properties | Datum Dependency

Failure Criterion: Mohr-Coulomb

Type	Data
Material Type	Plastic
Peak Strength	
Peak Tensile Strength (MPa)	0
Peak Friction Angle (degrees)	36
Peak Cohesion (MPa)	0.1
Residual Strength	
Residual Tensile Strength (MPa)	0
Residual Friction Angle (degrees)	25
Residual Cohesion (MPa)	0.05
Dilation Angle (degrees)	0
Apply SSR (Shear Strength Reduction)	Yes
Unsaturated Strength Properties	
Use Unsaturated Parameters	No

Numerical Analysis

In this analysis we will see the factor of safety of slope with and without support measures. The model which we have prepared without and with support system are as follows



Unsupported Slope

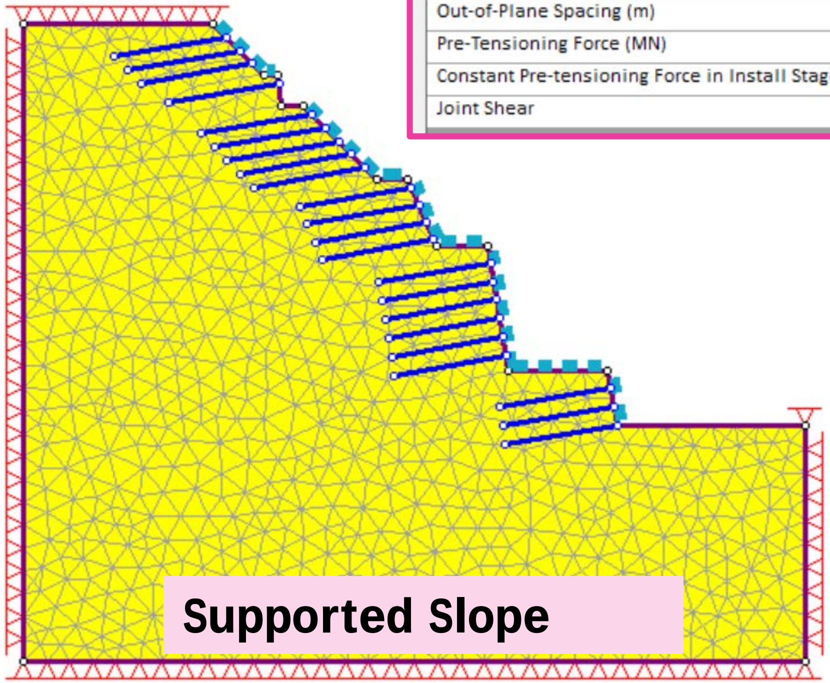
Rock Anchor Details

Bolt 1

Name: Bolt 1   Bolt Color:

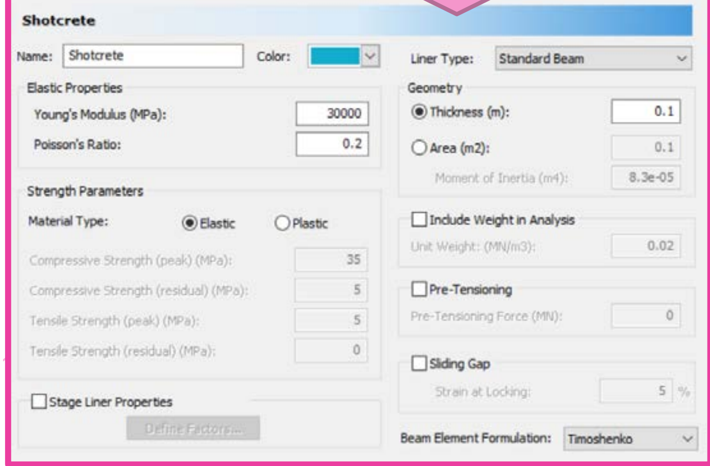
Bolt Type: Fully Bonded

Type	Data
Bolt Diameter (mm)	32
Bolt Modulus,E (MPa)	200000
Tensile Capacity (MN)	0.36
Residual Tensile Capacity (MN)	0.1
Out-of-Plane Spacing (m)	2
Pre-Tensioning Force (MN)	0
Constant Pre-tensioning Force in Install Stage	☑ Yes
Joint Shear	☑ Yes



Supported Slope

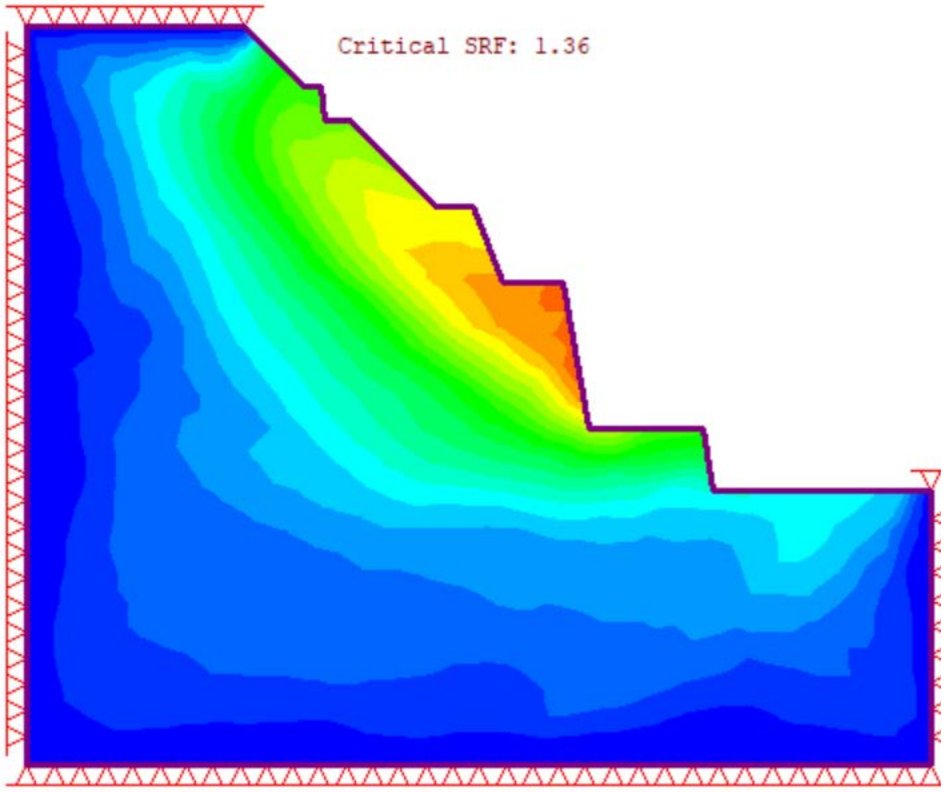
Shotcrete Details

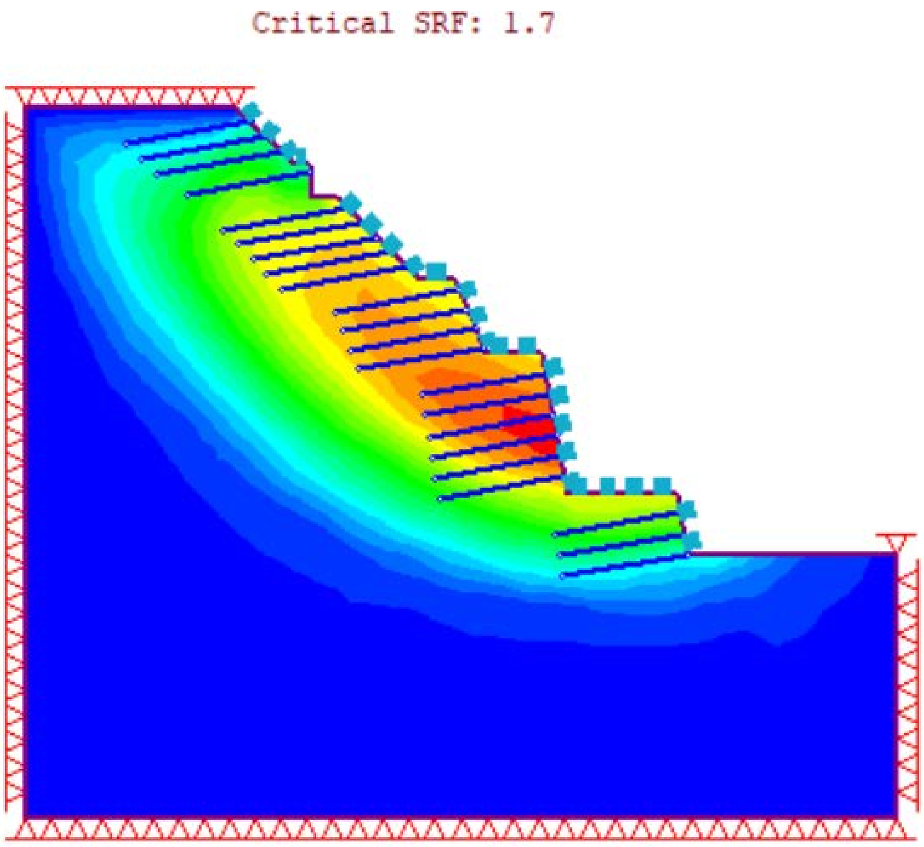


Numerical Analysis – Factor of Safety

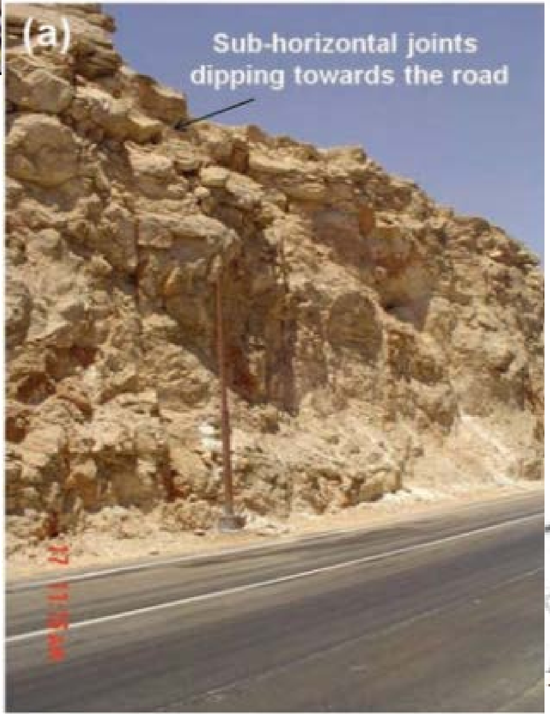
In this analysis we will the factor of safety of slope with and without support measures. The model which we have prepared without and with support system are as follows:

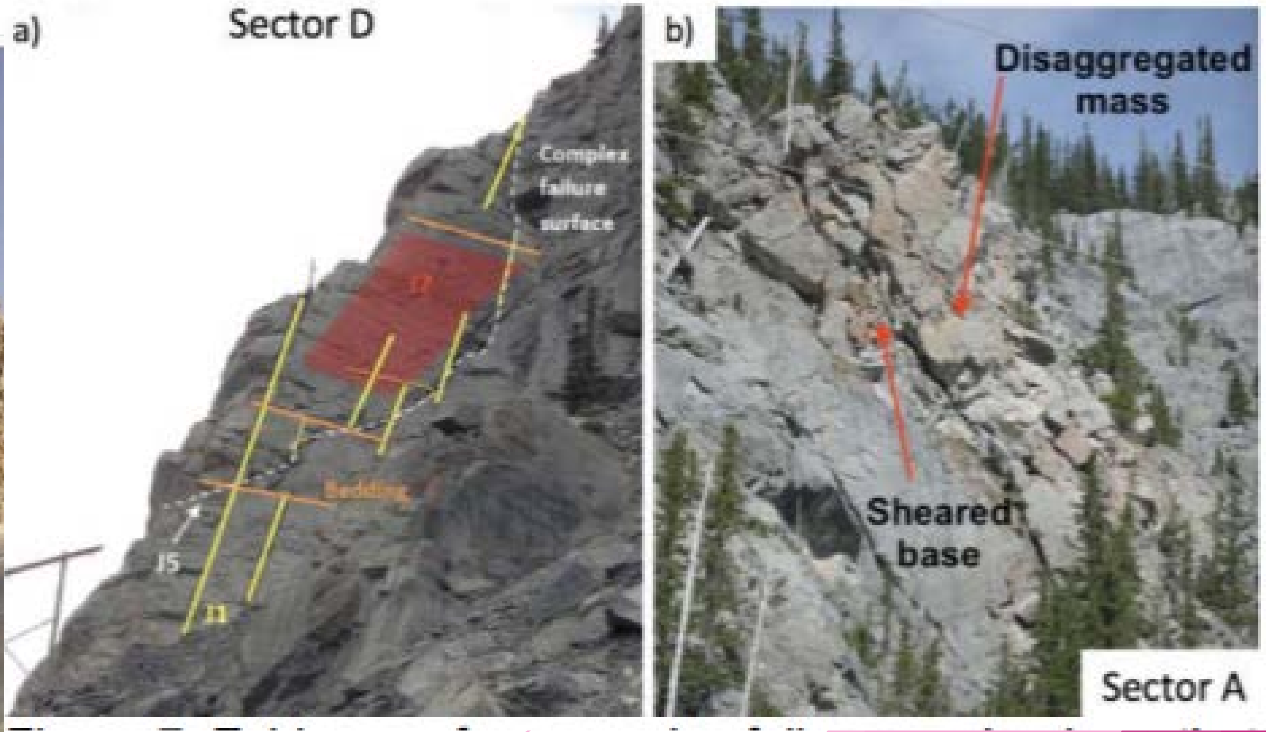
FOS with Support System = 1.36 < 1.5 (FOS for static condition, so supports needed)
FOS with Support System = 1.7 > 1.5 (FOS for static condition)



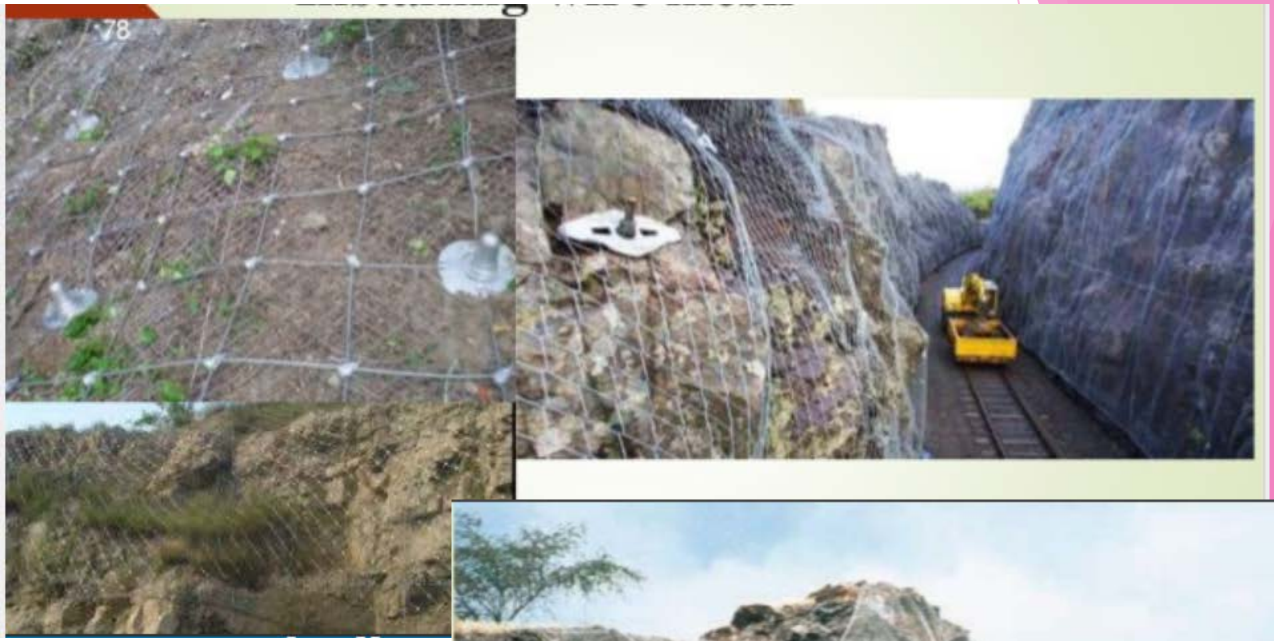


Examples of Rock Mass Failure





Example of Stabilised Slopes



Thanks for watching presentation

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