SLOPE STABILITY ANALYSIS IN ROCKS

Part 2 - Wedge failure

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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 Wedge Failure only.**

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

The direction and size of these failures depend upon the following paramete

1. **Joint sets**
2. **Joints dip and dip direction**
3. **Joints frictional properties (c and ϕ)**
4. **Dip and dip direction of slopes face**

KINEMATIC ANALYSIS

Kinematic Analysis is very important method for determining the mode of failures.

This method also **determines which joint sets will have planar failure or wedge failure or toppling failure** with a particular slope face dip direction.

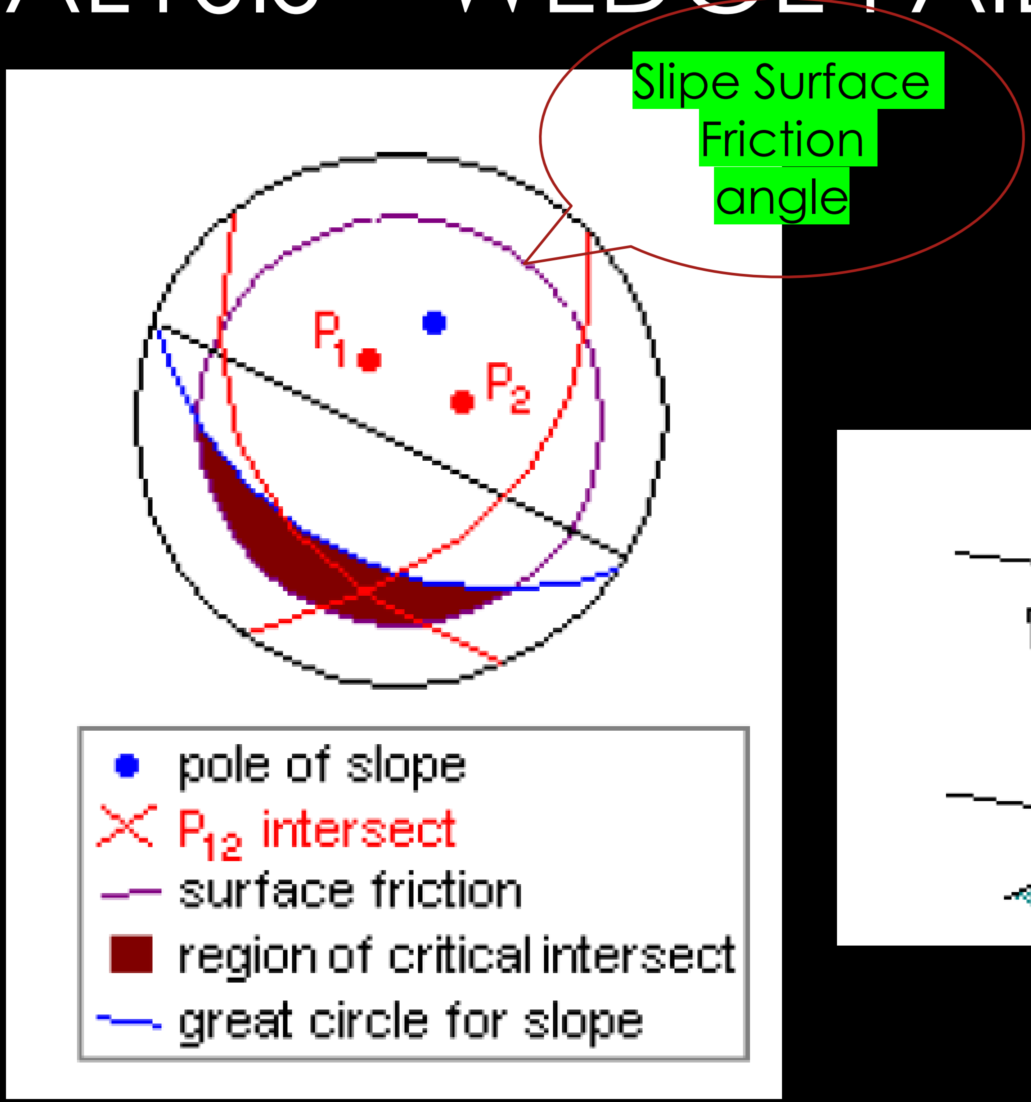
We use Dips software (Rocscience) for determining the mode of failures.

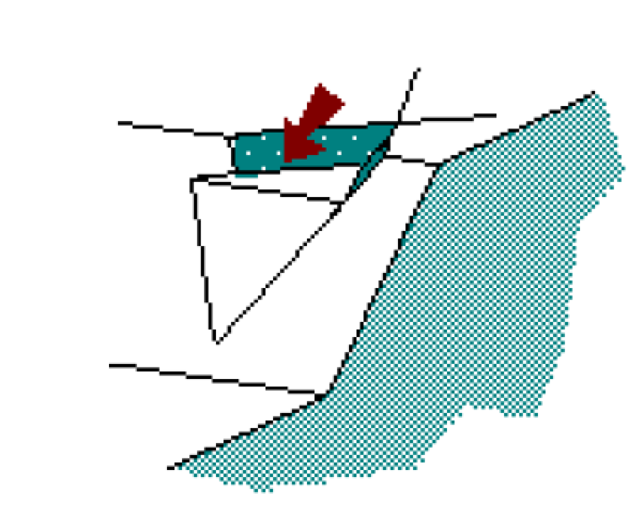
Input dip and dip direction of all the joints, separate poles will develop for each joint sets.

KINEMATIC ANALYSIS – WEDGE FAILURE

Wedge failure, occurs when:

a) **Two intersecting sets of joints** strike oblique to the slope.
b) The line of intersection of the two planes plunges in the direction of slope.
c) The angle of plunge is lower than the angle of slope.
d) The line of intersection needs to crop out twice; once to the slope and again on the surface above the slope.
e) The angle of plunge must be steep enough to produce sliding (>friction angle of the rock material)
f) **i.e plunge <angle of slope and plunge >friction angle of slope** surface





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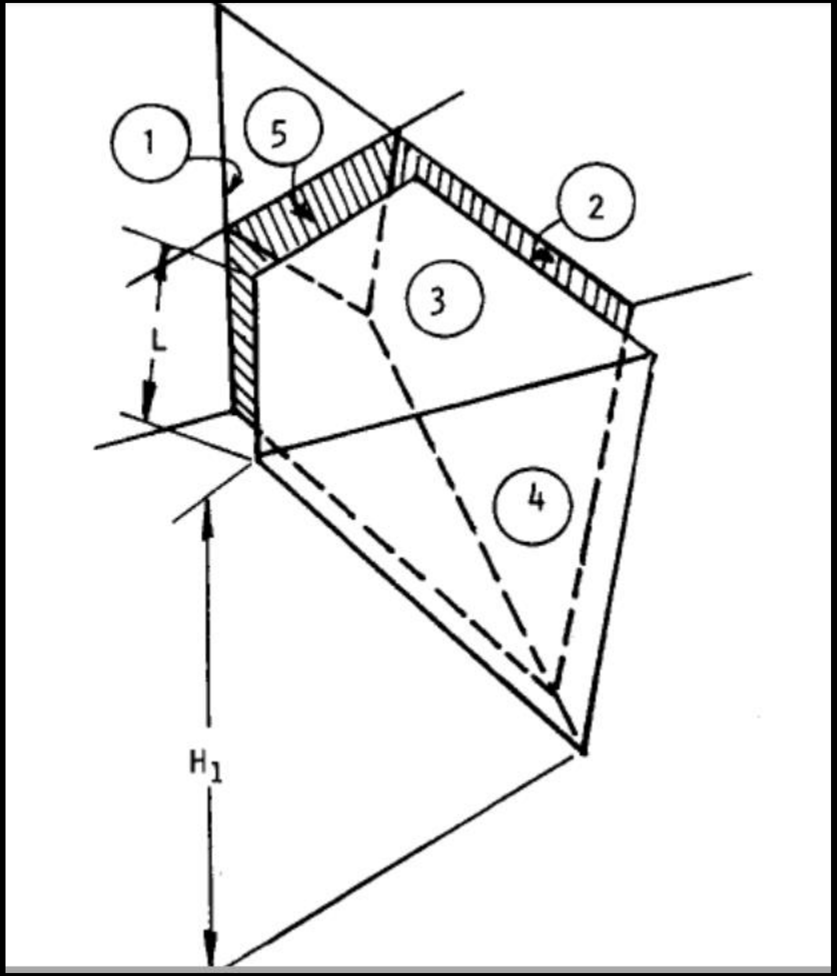
WEDGE FAILURE

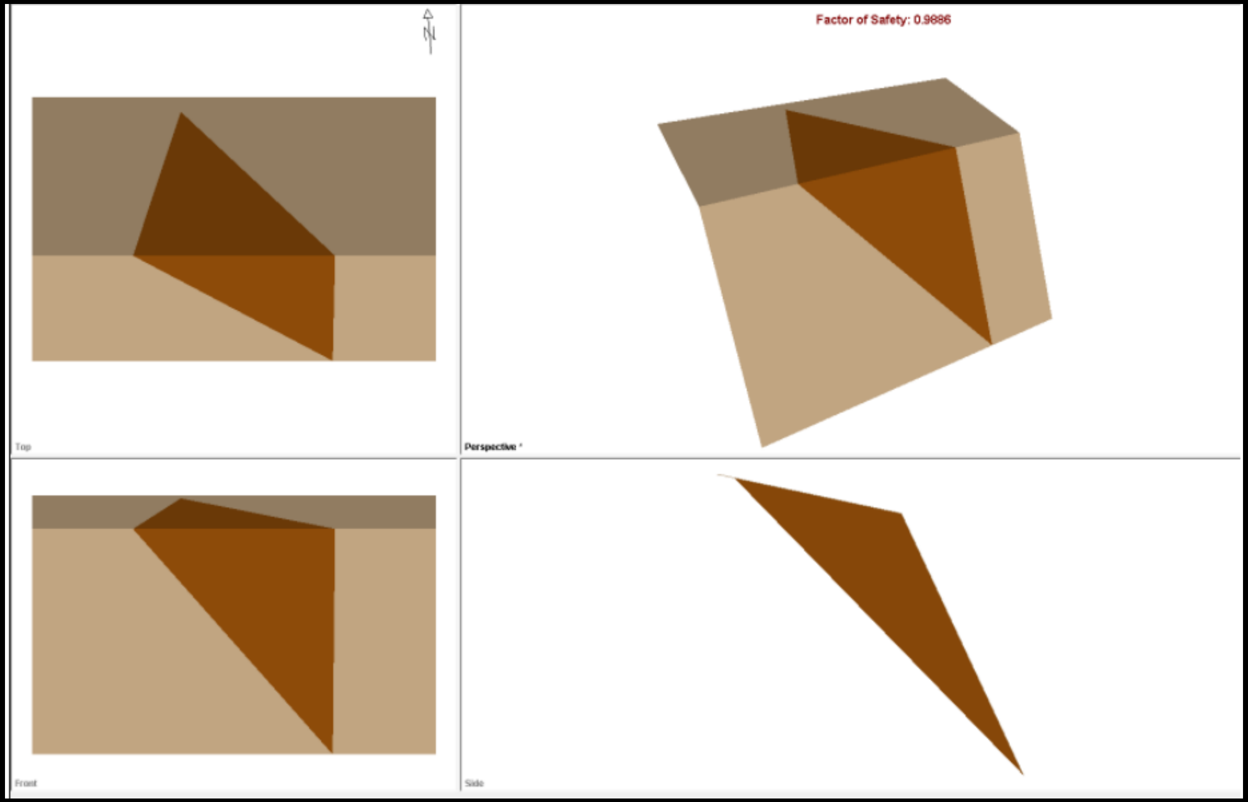
A wedge can be defined by:

1,2 = Failure planes (2 intersecting joint sets)
3 = Upper ground surface
4 = Slope Face
5 = Tension crack
H1 = Slope Height (vertical distance) refer plane 1
L = Distance of tension crack from crest, measured along the trace of plane 1

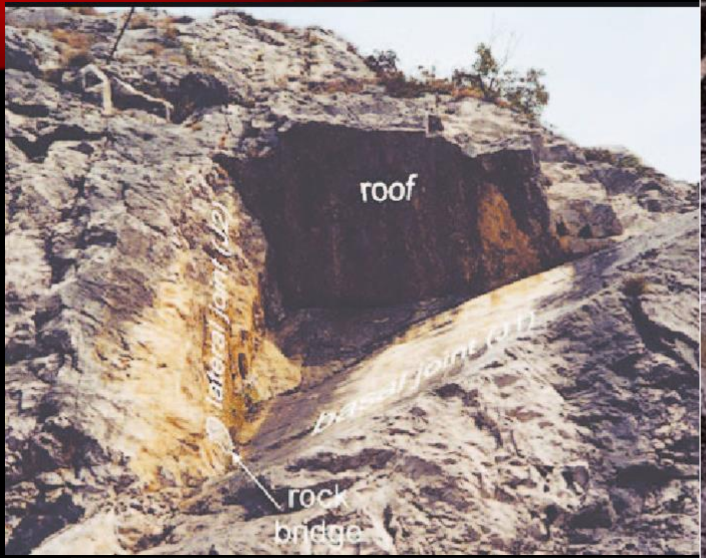


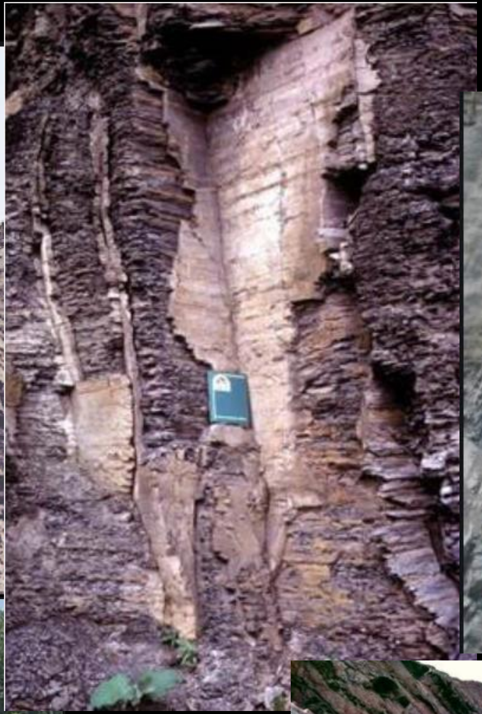
SOFTWARE - SWEDGE

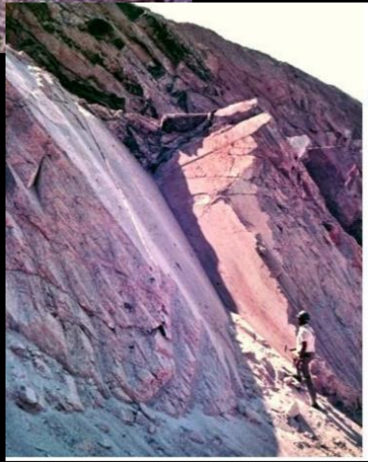
SWedge is a quick, interactive, and simple-to-use analysis tool for evaluating the geometry and stability of surface wedges in rock slopes. Wedges are defined by two intersecting discontinuity planes, the slope surface, and an optional tension crack.

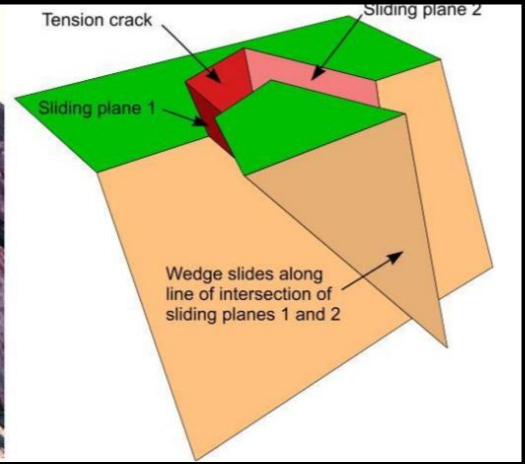


WEDGE FAILURE PICTURES



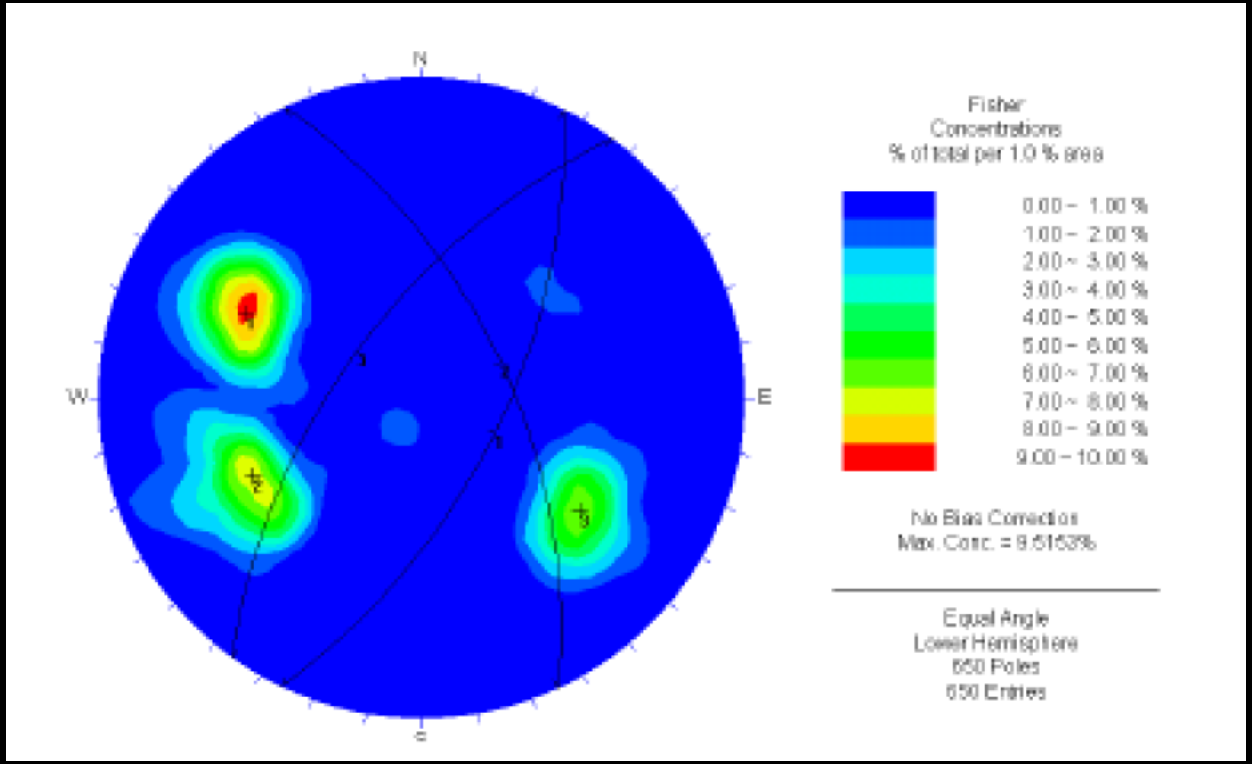






SOFTWARE - SWEDGE

Stereonet View - The Stereonet View in SWedge displays a stereographic projection of plane orientations in your model's Input Data (Slope, Upper Face, Tension Crack, Joint 1, and Joint 2).



DECIDING FACTORS FOR SLOPE STABILITY

The factor which determines the Failure of Wedge are as follows:

1. **Water Pressure in joints.**
2. **Shear Parameters of Slip plane.**
3. **Seismicity**

DECIDING FACTORS FOR SLOPE STABILITY

Shear Strength - Wedge slope stability analysis involves the shear strength of the sliding surfaces.

There is relationship between the **shear strength** of a sliding surfaces and the **effective normal stress** acting on the joint planes.

Sliding Surfaces can be more than two.

Mohr – Coulomb

$$\tau_i = c_i + \sigma_{ni} \tan\phi$$

τ_i= Shear strength of the i^{th} joint

σ_{ni} = Normal Stress of the i^{th} joint

c_i = cohesion of the i^{th} joint

ϕ_i= friction angle of i^{th} joint

There are more strength criteria for analyzing slope stability. But here we are explaining the **Mohr-Coulomb Criteria** only for understanding.

SWEDGE– EXAMPLE 1

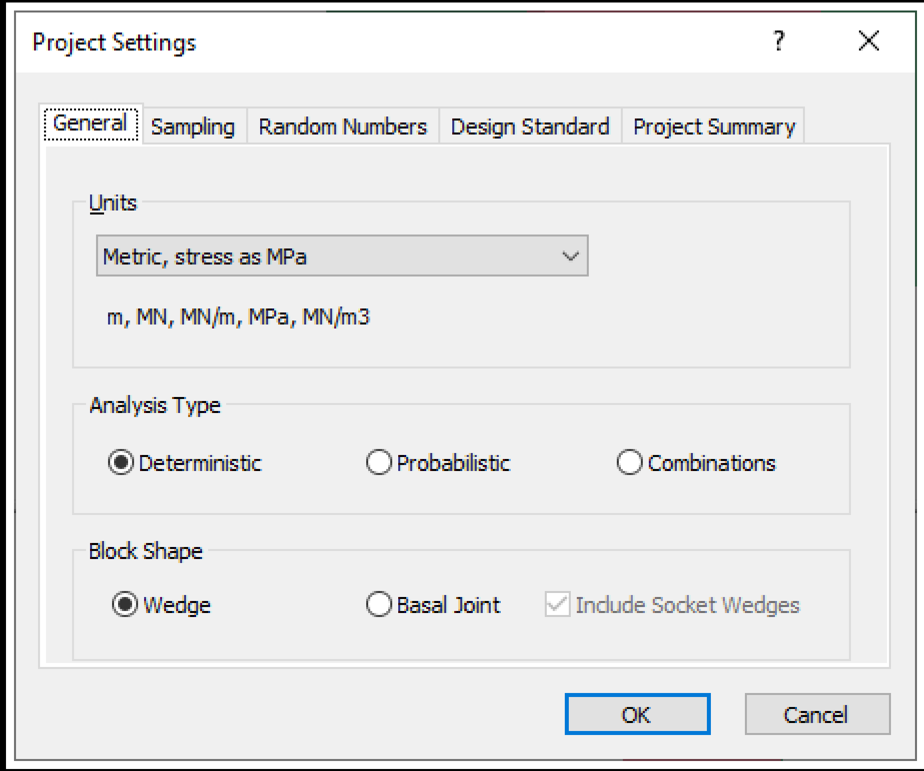
This example will show the basic modelling and data interpretation.

This software will provide the slope stability analysis and design for wedge stability in open pit mines and rock slopes.

Input Data – Input the know parameters in the project settings:

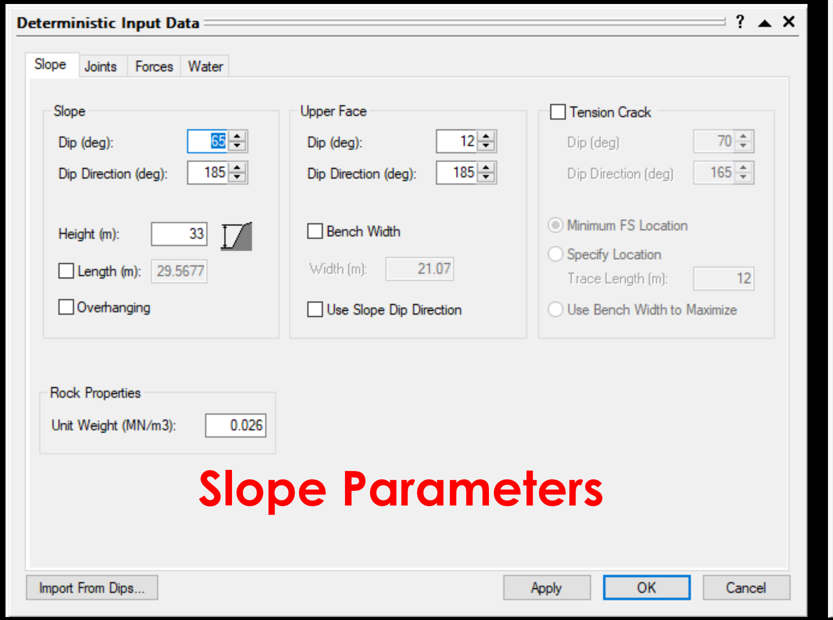
Input the Units in which you want to analyze the slopes.

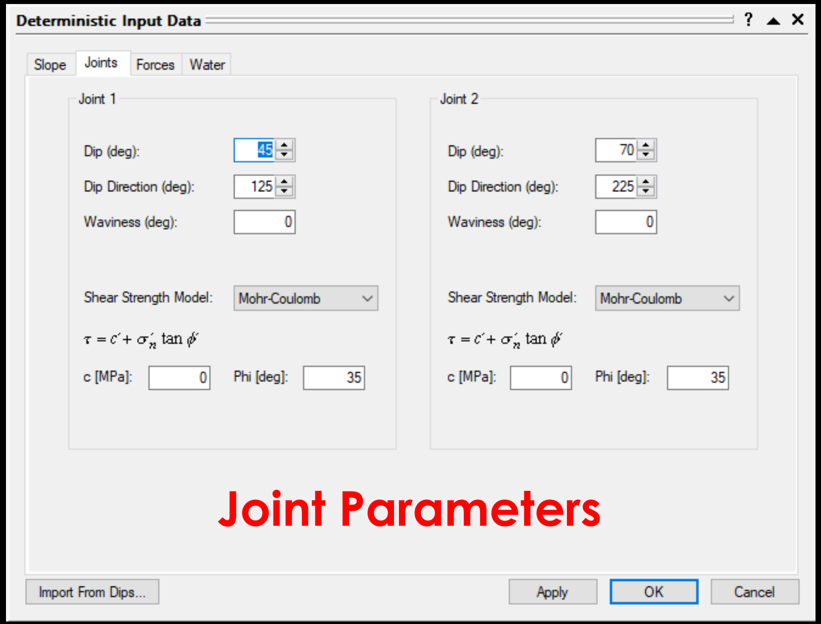
Analysis Type is **Deterministic** where input parameters are known for e.g. c and ϕ of failure plane and dip of joints.

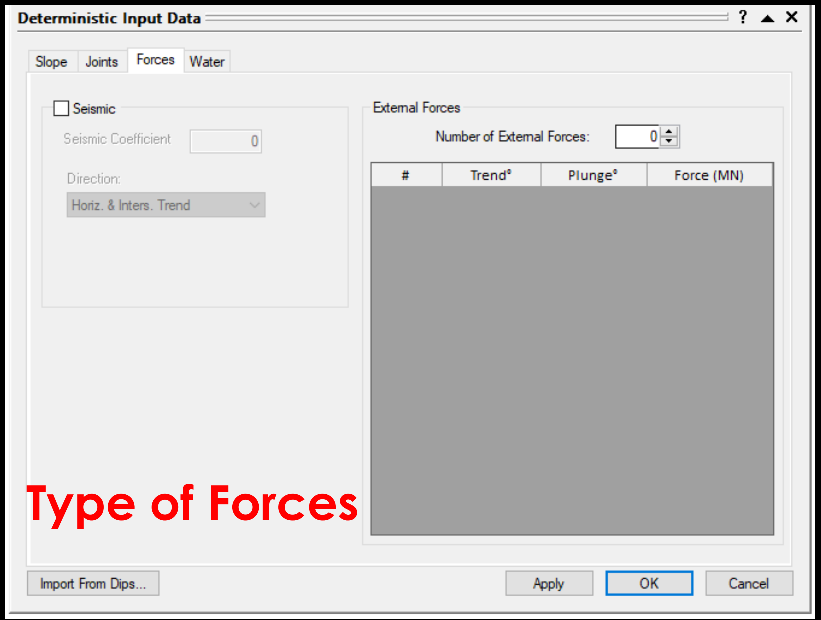


SWEDGE – INPUTS

The Input Data dialog for a Deterministic analysis is organized under three tabs: **Slope, Joints, and Forces**.







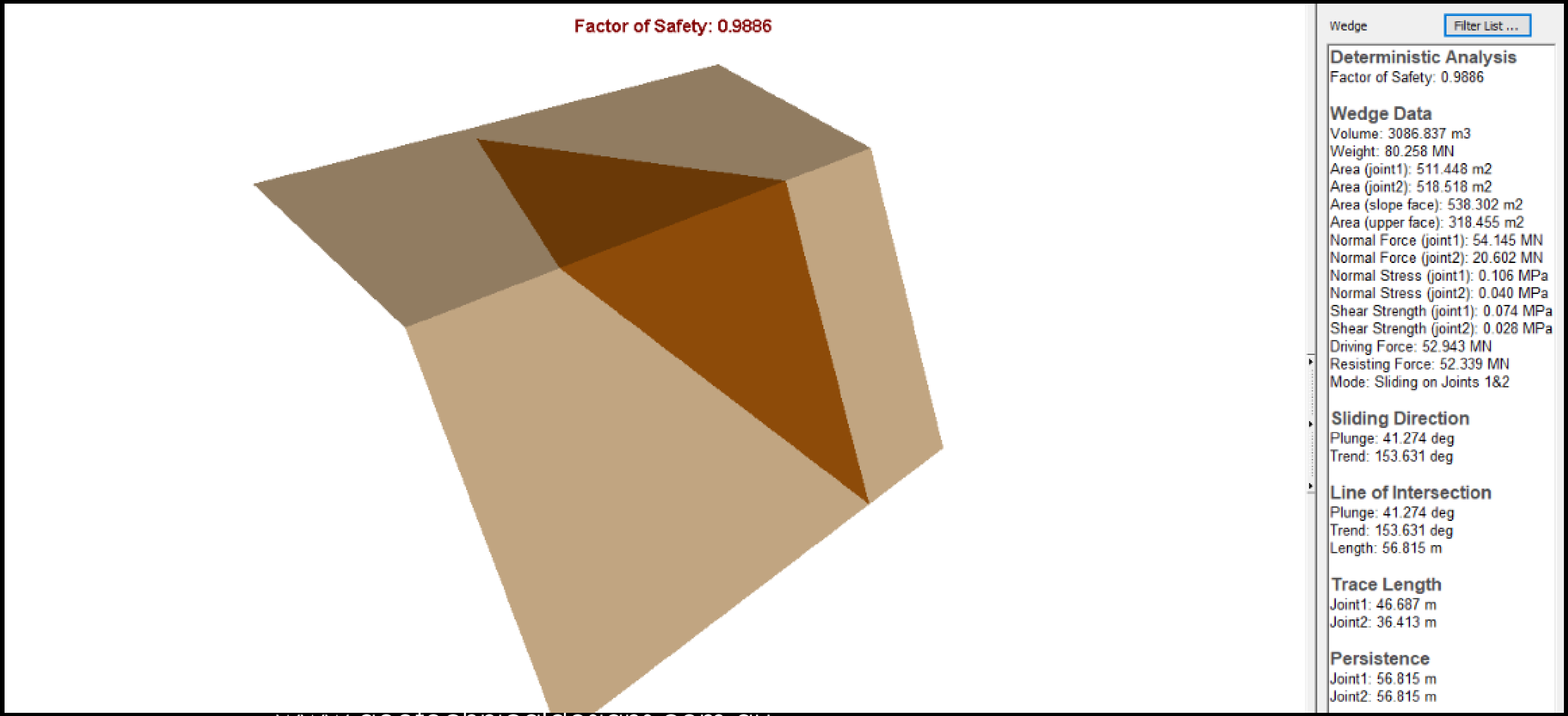
Type of Forces

1. **Water Pressure**
2. **Seismic**
3. **External Forces**

3D PERSPECTIVE VIEW – INTERPRETATION

- Factor of safety = 0.989

  Just in equilibrium.
- In static case **FOS shall be 1.5 or more** and to achieve it, either we will change
- **Friction Parameter of Joint Planes**
- **Slope Inputs or**
- **Provide Supports**

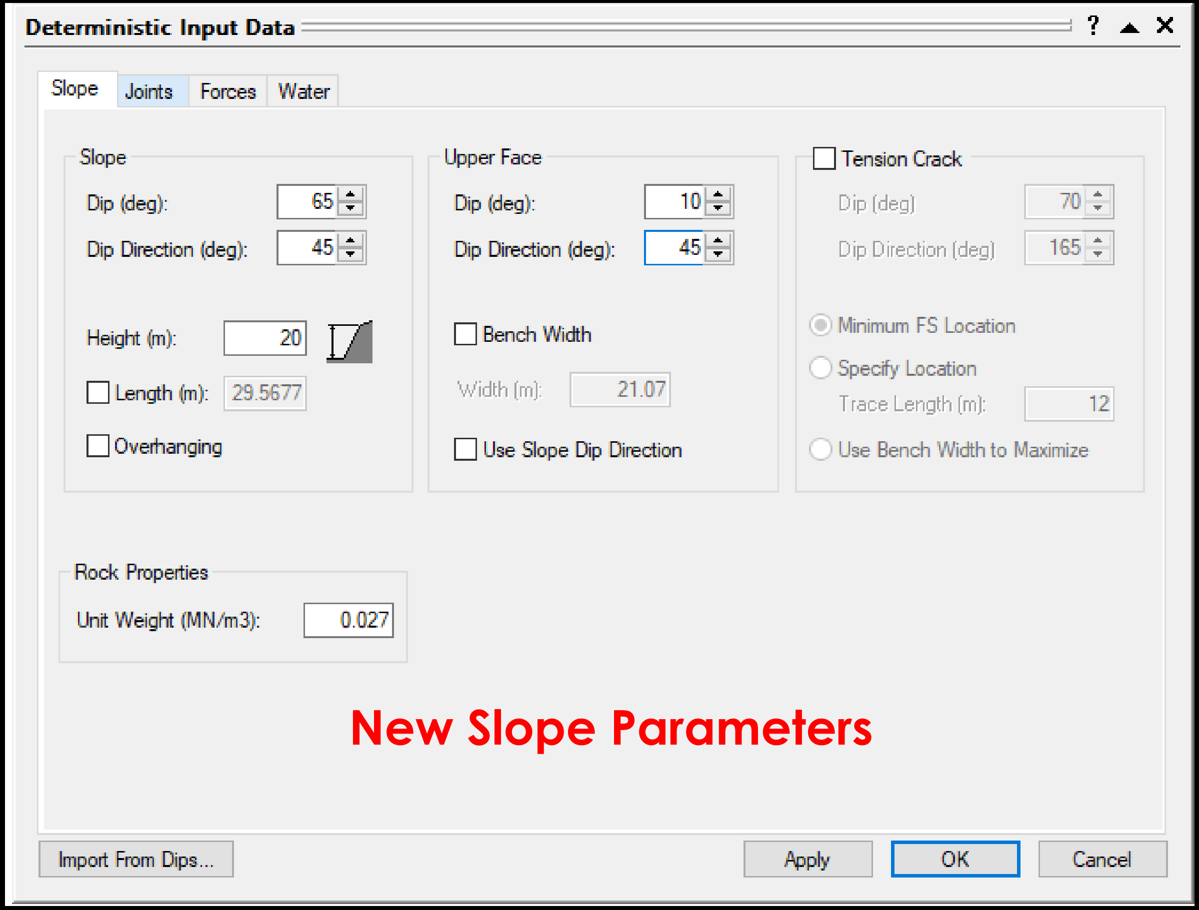


CHANGE SLOPE PARAMETERS TO INCREASE FOS OF SLOPE STABILITY

- If you look at the Slide 11 the Geometry of the slope has been given.
- The initial height of slope was 33m. Now change it to 20m.
- Unit weight to 0.027 MN/m^3

1. Select the **Slope** tab and enter the following data:

Slope Height (m)	20
Slope Dip (°)	65
Slope Dip Direction (°)	45
Upper Face Dip (°)	10
Upper Face Dip Direction (°)	45
Unit Weight (MN/m3)	0.27

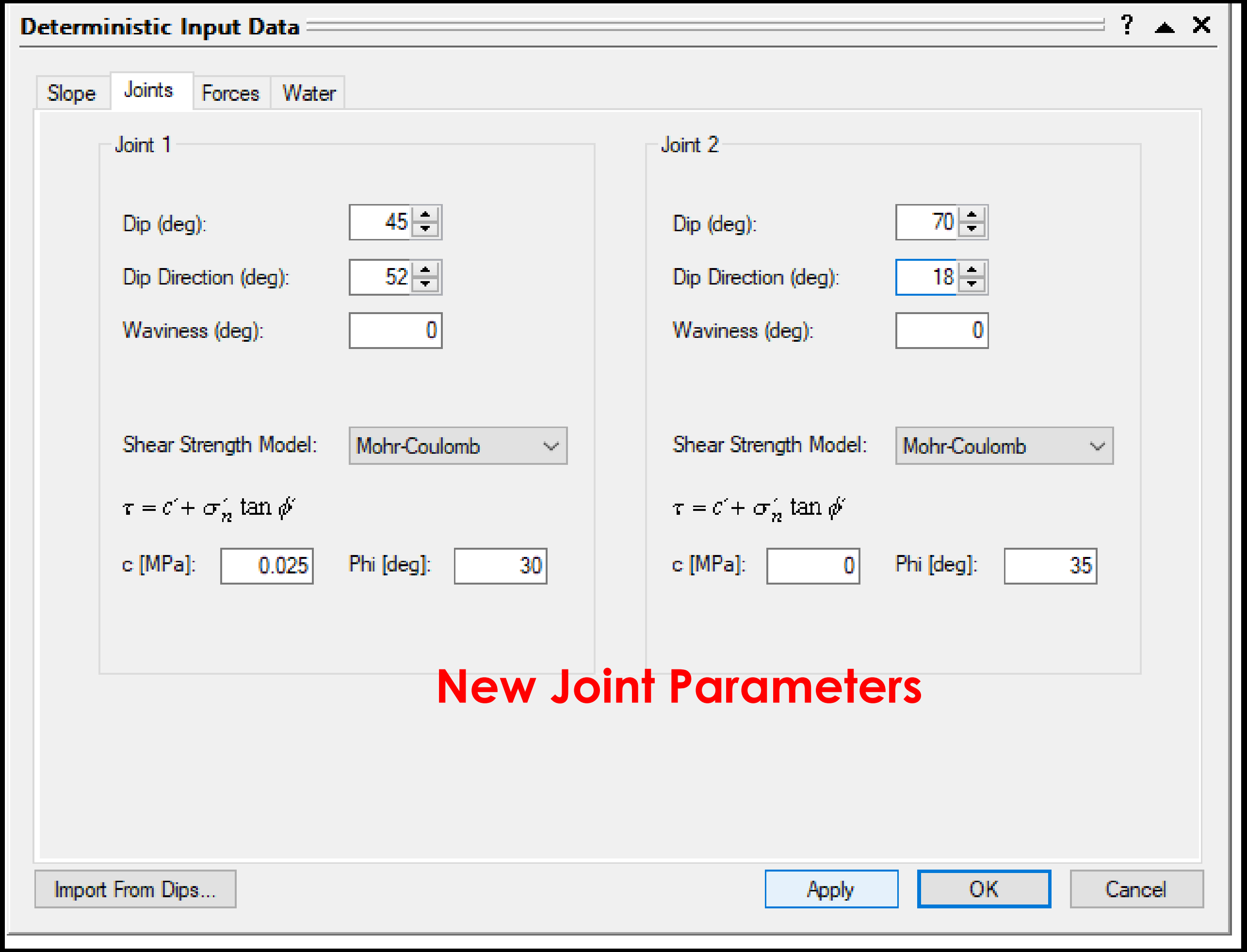


INCREASE JOINTS PARAMETERS TO INCREASE FOS OF SLOPE STABILITY

- If you look at the Slide 11, the **joints friction parameters** of the slope has been given.
- Increase the friction parameters of the joints, so that the FOS of this slope increases.

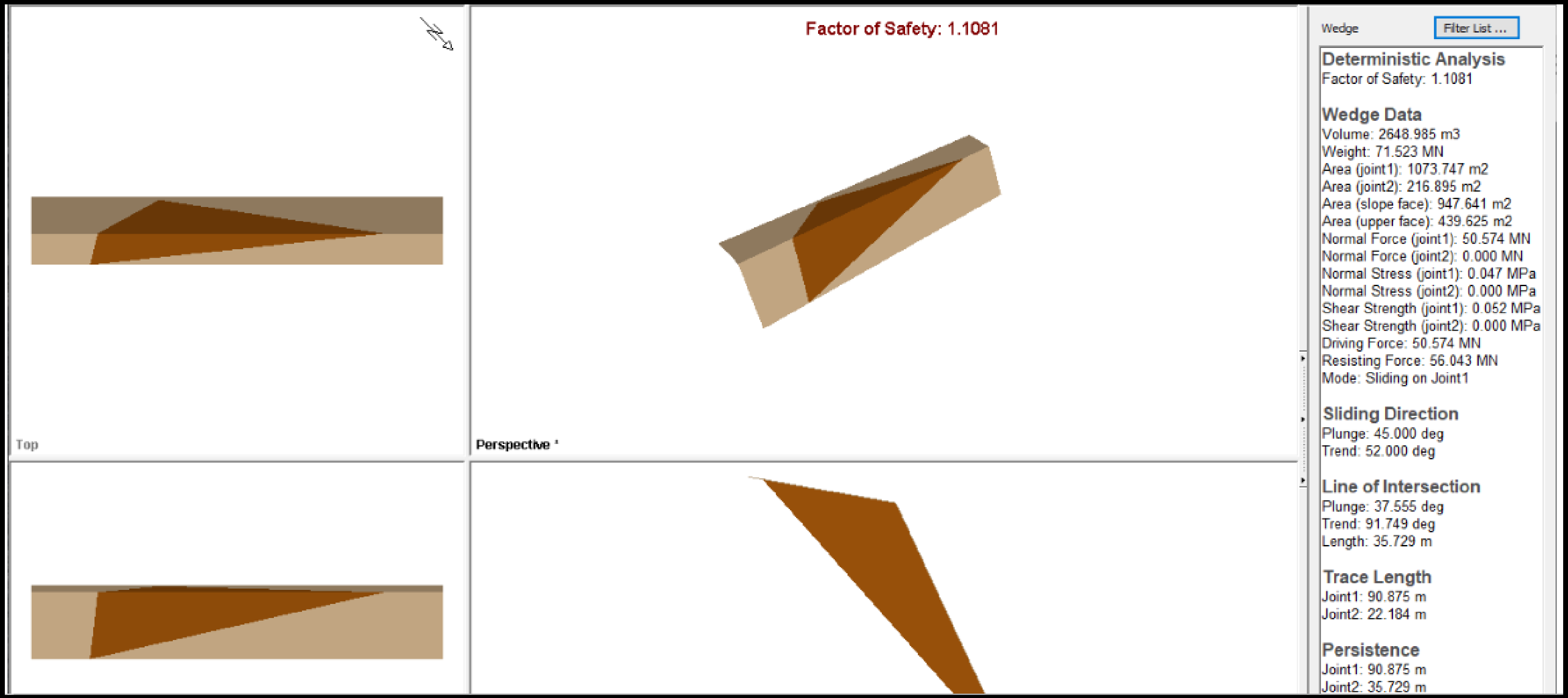
2. Select the **Joints** tab and enter the following data:

Joint 1 Dip (°)	45
Joint 1 Dip Direction (°)	52
Joint 1 Cohesion (MPa)	0.025
Joint 1 Friction Angle (°)	30
Joint 2 Dip (°)	70
Joint 2 Dip Direction (°)	18
Joint 2 Cohesion (MPa)	0
Joint 2 Friction Angle (°)	35



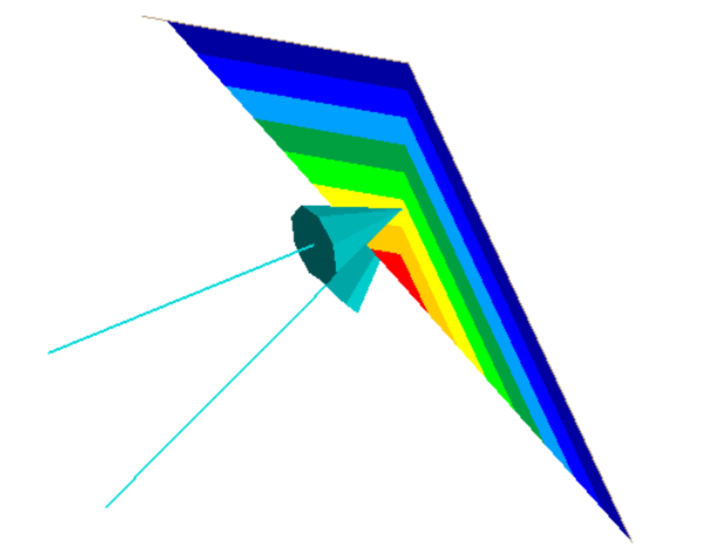
FACTOR OF SAFETY AFTER CHANGES

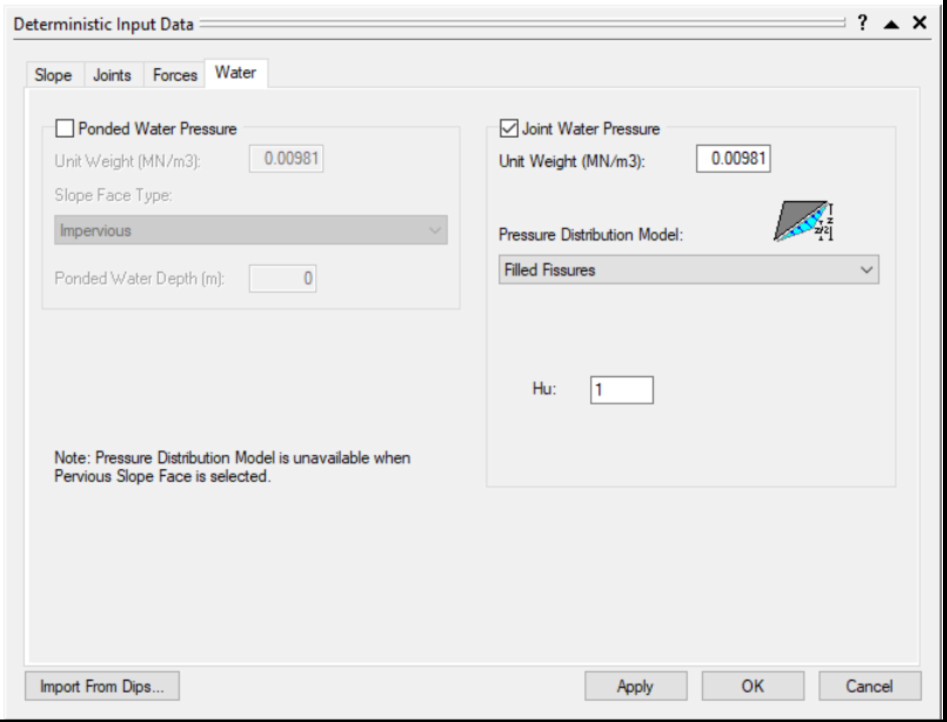
- Increase in FOS after reducing the slope height and Increasing Joint friction parameters
- **Initial FOS = 0.989**
- **After Changes = 1.108**
- But FOS is still less than the required 1.5.



WATER PRESSURE

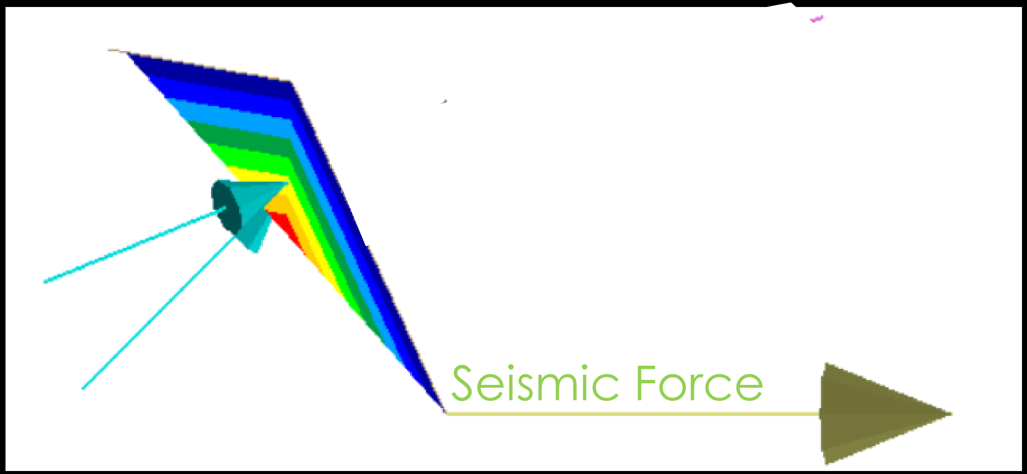
- The Filled Fissures option assumes extreme conditions of heavy rainfall such that **maximum (average) values of water pressure** are applied on the failure planes.
- Now on applying full water pressure **FOS has reduced to 0.57**.

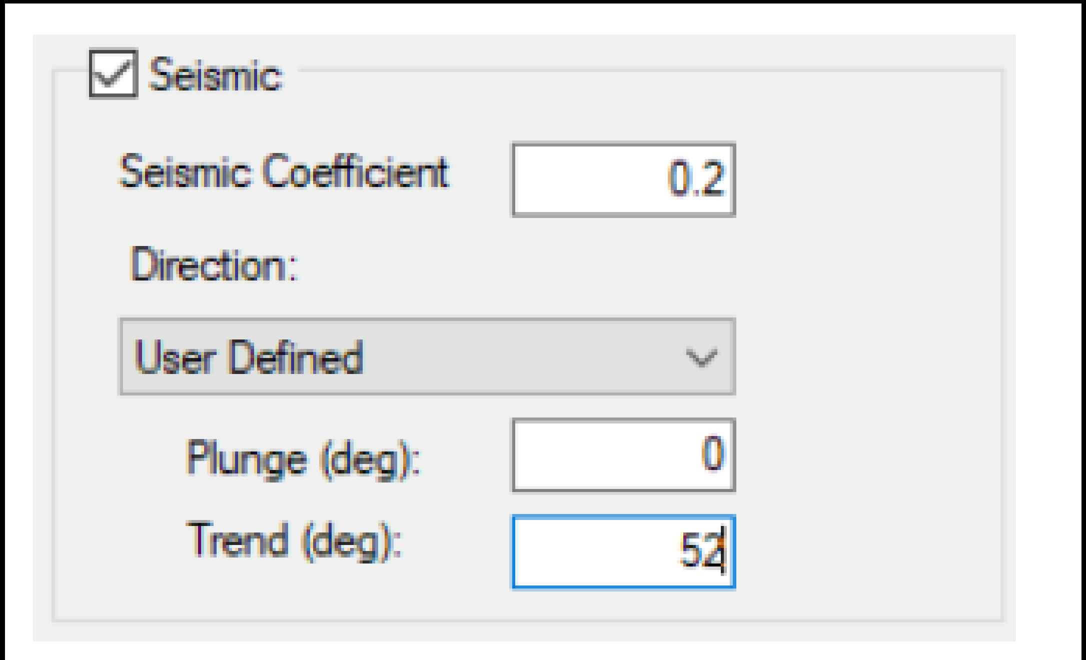




SEISMIC FORCE

- Seismic Coefficient of 0.2 and direction of seismicity has be adopted
- at Plunge = 0° and Trend = 52°
- On applying seismicity the FOS **will further reduced to 0.48**



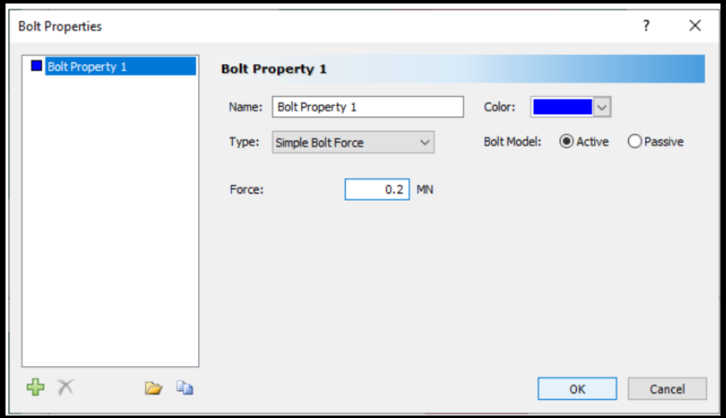


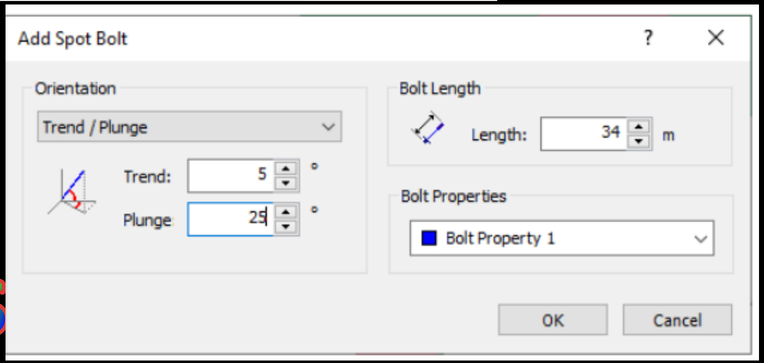
SUPPORT MEASURES-ROCK BOLT

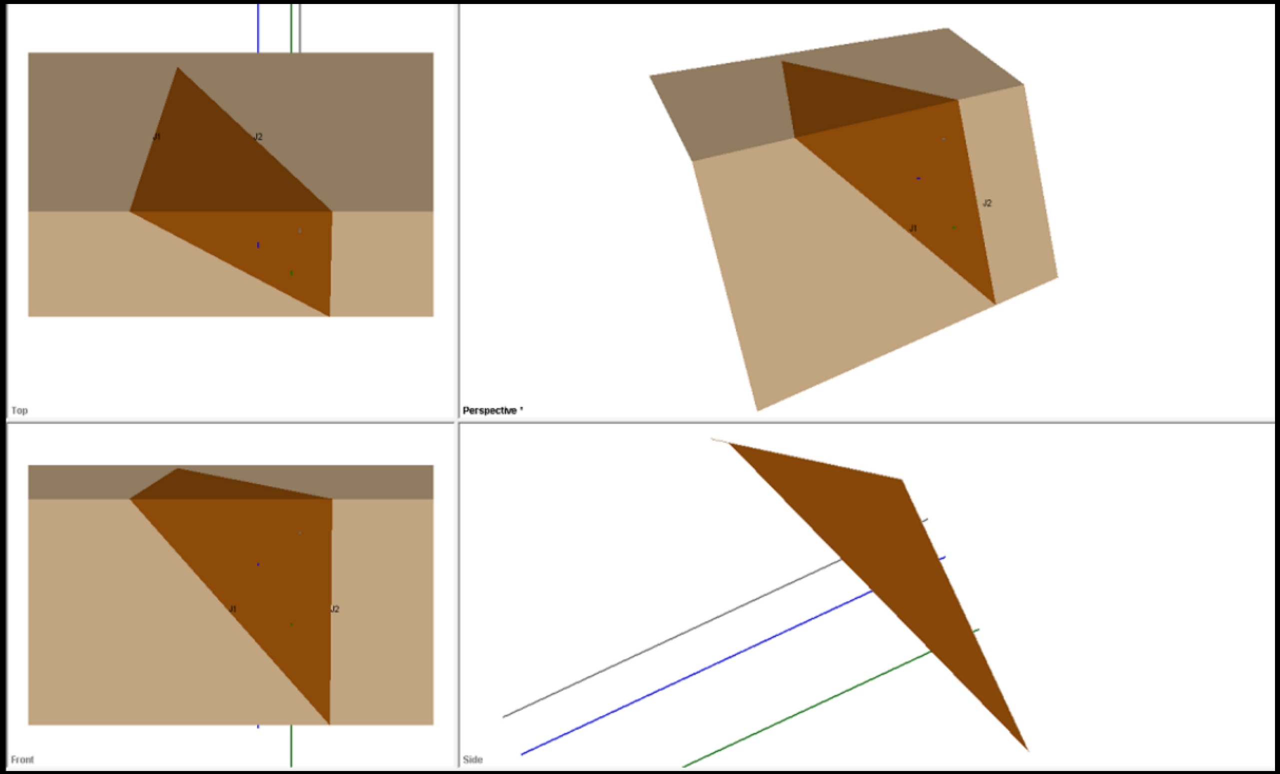
To increase FOS of Slope ,we are providing Rock Bolt and Shotcrete of following parameters:

ROCK BOLT

- Rock Bolt capacity = 0.2 MN
- Length 35m (can be reduced)
- Direction of Rock Bolts





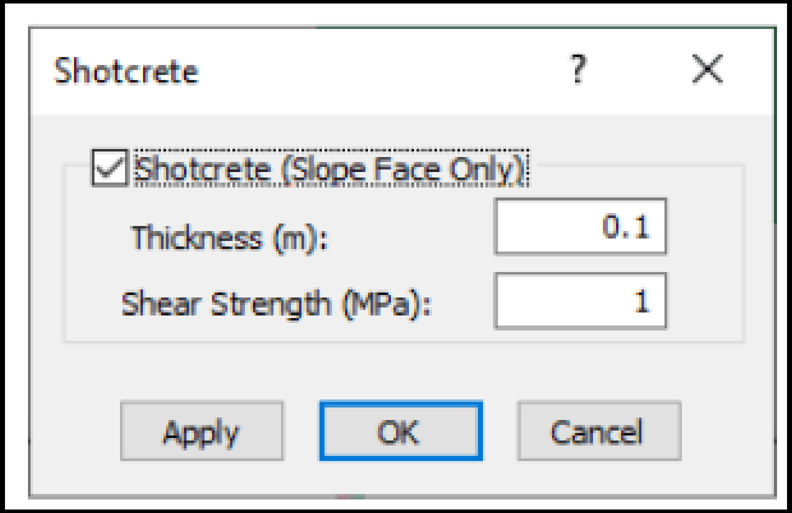


SUPPORT MEASURES-SHOTCRETE

To increase FOS of Slope ,we are providing Rock Bolt and Shotcrete of following parameters:

Shotcrete

- Shotcrete Thickness = 100mm
- Shear Strength of Shotcrete = 1MPa
- Direction of Rock Bolts



FACTOR OF SAFETY AFTER SUPPORT MEASURES (FOS 1.525)

Factor of safety increase from 0.48 to 1.525 after applying

- Rock Bolts
- Shotcrete

Therefore it is very important to provide **support system** to counter act forces

- Water Pressures
- Seismicity and
- Sliding force of Wedge

THANKS FOR WATCHING PRESENTATION

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