IN-SITU AND INDUCED STRESSES

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INTRODUCTION

Rock at depth is subjected to stresses due to following reasons:

1. Weight of overlying overburden pressures
2. Due to tectonic pressures

Stresses around tunnel opening

When opening is excavated in such rock there are redistribution of these in-situ stresses and new set of stresses induced around the opening

VERTICAL STRESSES

- **Vertical Stress is usually governed by weight of the overburden at certain rock element at certain depth.**

$$\sigma_v = \gamma z$$

σ_v is the vertical stress

γ is the unit weight of the overlying rock and

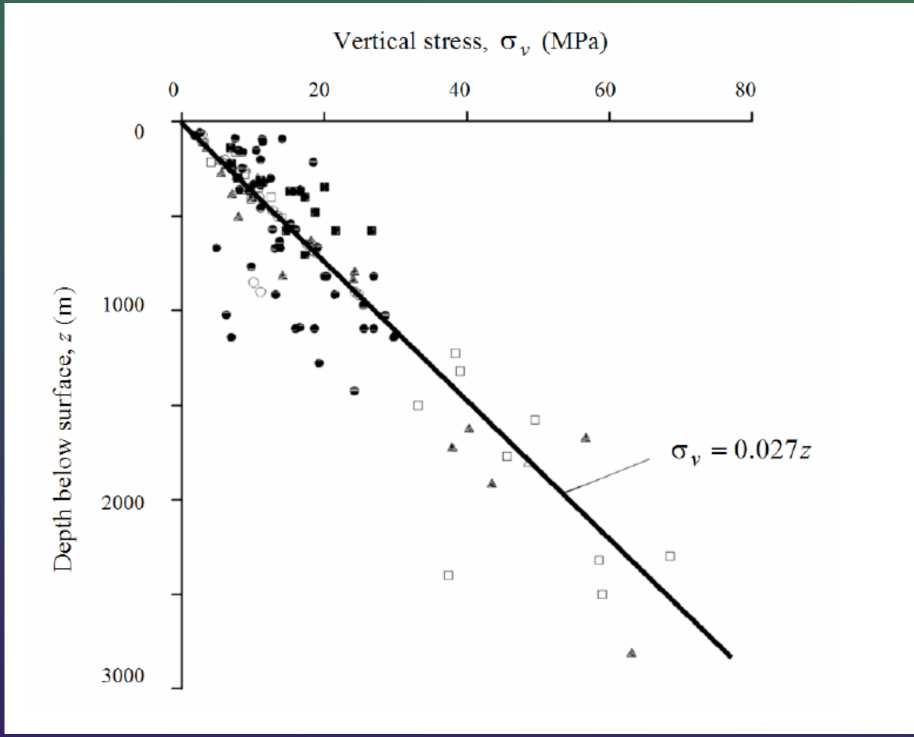
z is the depth below surface.

- Example :
- Z = 1000m (overburden depth at certain rock element)
- γ = 0.027MN/m^3

The vertical stress σ = 27MPa

VERTICAL STRESSES

Measurements of vertical stress at various mining and civil engineering sites around the world confirm that this relationship is valid although, as illustrated in **Figure 1**, there is a significant amount of scatter in the measurements.



HORIZONTAL STRESSES

Horizontal Stresses are more difficult to determine that vertical stresses.

Normally, the ratio of the average horizontal stress to the vertical stress is denoted by the letter *k* such that:

$$\sigma_h = k\sigma_v = k\,\gamma\,z$$

Sheorey Equation:

z (m) is the depth below surface

Eh (GPa) is the average deformation modulus of the upper part of the earth's crust measured in a horizontal direction.

$$k = 0.25 + 7E_h\left(0.001 + \frac{1}{z}\right)$$

HORIZONTAL STRESSES

- **Sheorey Equation:** The curves relating *k* with depth below surface z are similar to those published by Brown and Hoek (1978), Herget (1988) and others for measured in situ stresses.

Hence the above equation is considered to provide a reasonal basis for estimating the value k.

But there are **few short comings** in this methods because measured vertical and horizontal stresses are seldom equal to the one measure at near by locations and horizontal stresses are different due to different tectonic stresses.

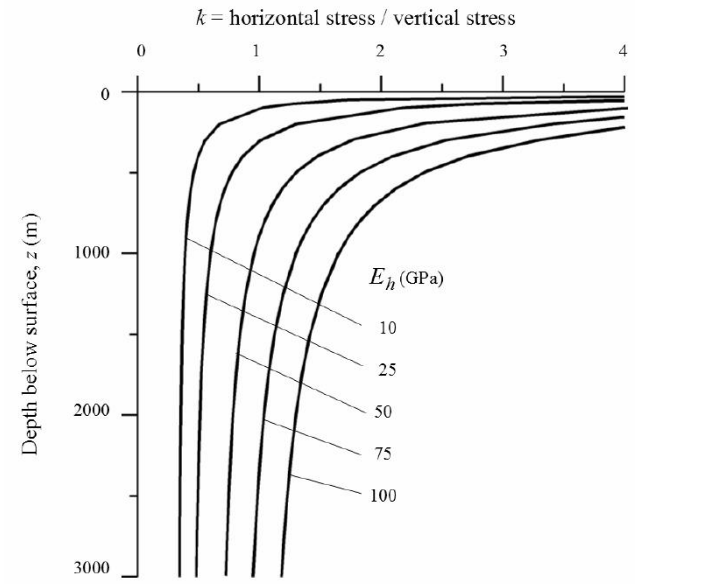


Figure 2: Ratio of horizontal to vertical stress for different deformation moduli based upon Sheorey's equation. (After Sheorey 1994).

HORIZONTAL STRESSES

Methods for measuring in-situ stresses

The most popular and reliable method of measuring in-situ stresses are considered are:

1. Overcoring method
2. Hydraulic Fracturing Tests

I am not addressing these methods in this presentation.

It is very important to have measured in-situ stresses for underground structures like tunnels , caverns and other type of openings for hydropower projects and mining projects.

STRESSES AROUND TUNNEL

When an underground opening is excavated into a stressed rock mass, the stresses in the vicinity of the new opening are re-distributed.

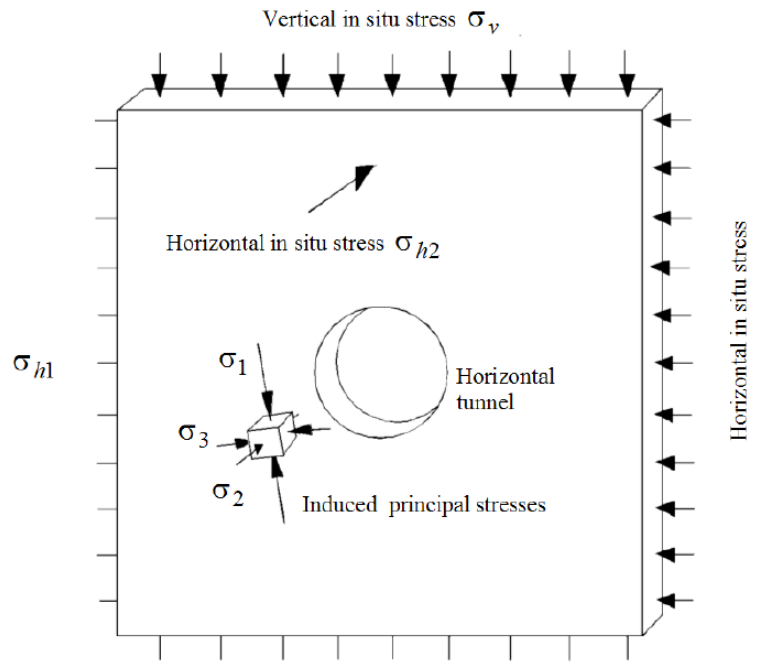


Figure 5: Illustration of principal stresses induced in an element of rock close to a horizontal tunnel subjected to a vertical in situ stress σ_v, a horizontal in situ stress σ_{h1} in a plane normal to the tunnel axis and a horizontal in situ stress σ_{h2} parallel to the tunnel axis.

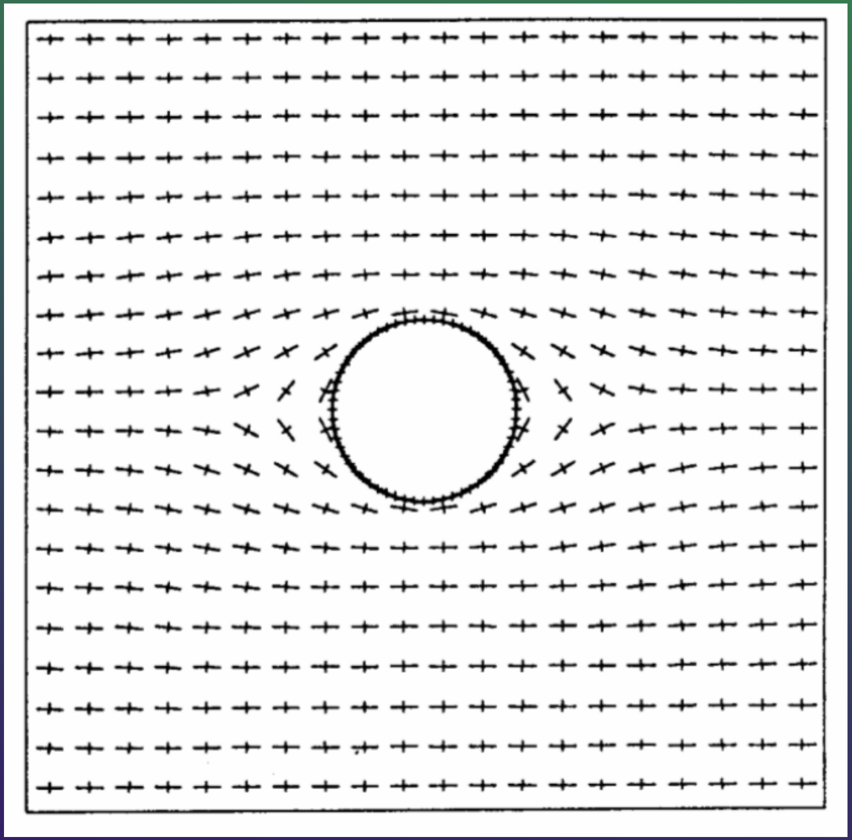
σv, $\sigma h1$, $\sigma h2$ are in-situ stresses Before the excavation of tunnel

After removal of the rock from within the tunnel, the stresses in the immediate vicinity of the tunnel are changed and new stresses are induced.

$\sigma 1$, $\sigma 2$, $\sigma 3$ are principal stresses at Rock element near to the opening.

STRESSES AROUND TUNNEL

Principal Stresses around the tunnel opening

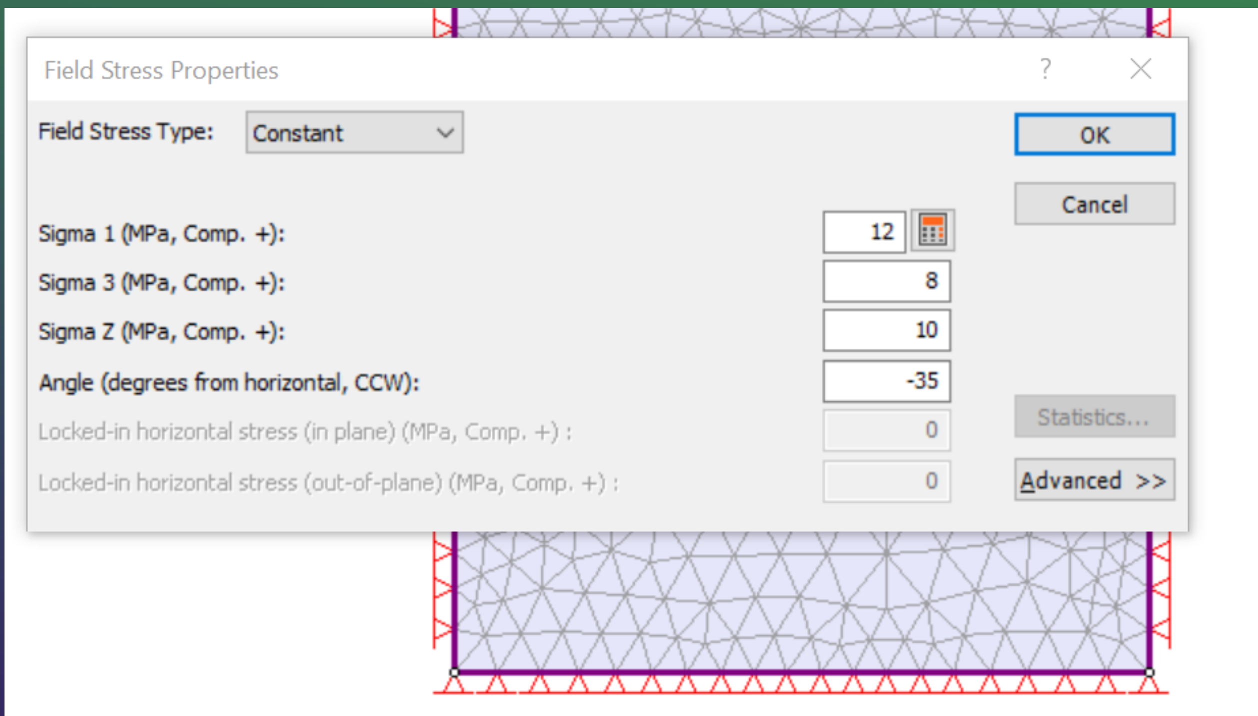


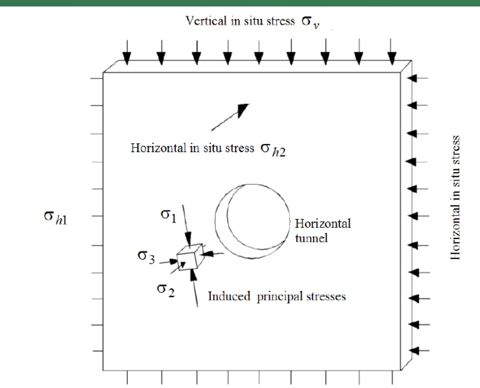
1. The longer bars in this figure represent the directions of the maximum principal stress $\sigma 1$,

2. The shorter bars give the directions of the minimum principal stress $\sigma 3$.

NUMERICAL ANALYSIS – STRESSES AROUND TUNNEL

$\sigma 1$,$\sigma 3$, σz are in-situ principle stresses before the excavation of tunnel





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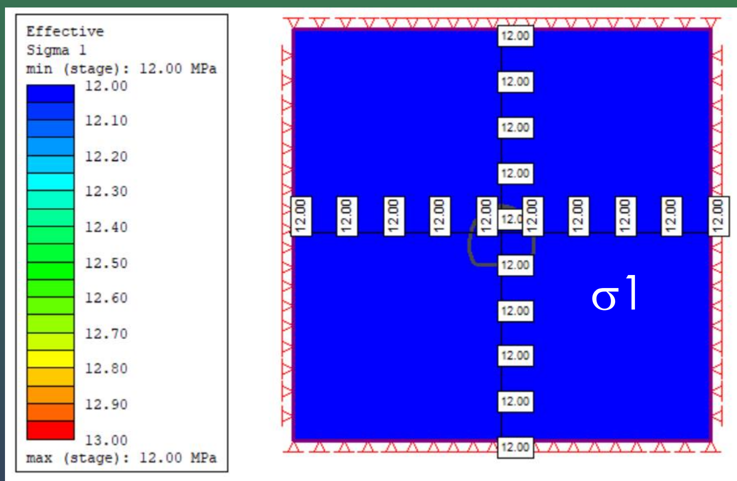
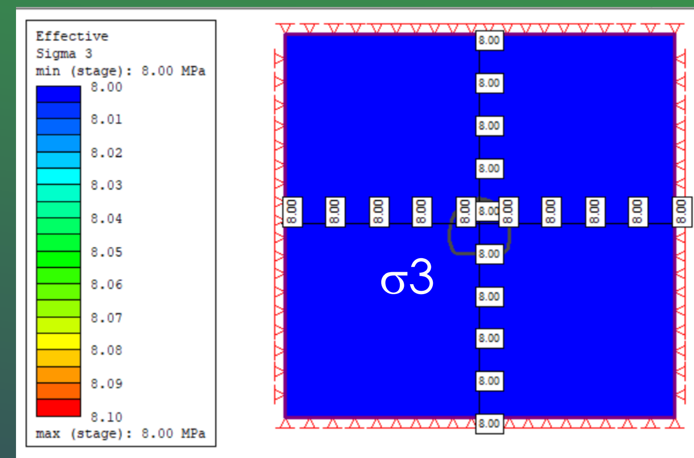
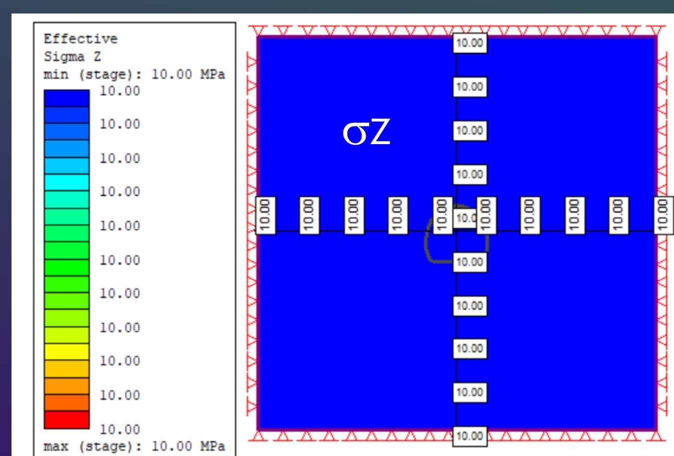
NUMERICAL ANALYSIS – STRESSES AROUND TUNNEL

σ1,σ3, σz are in-situ principle stresses **before the excavation of tunnel**

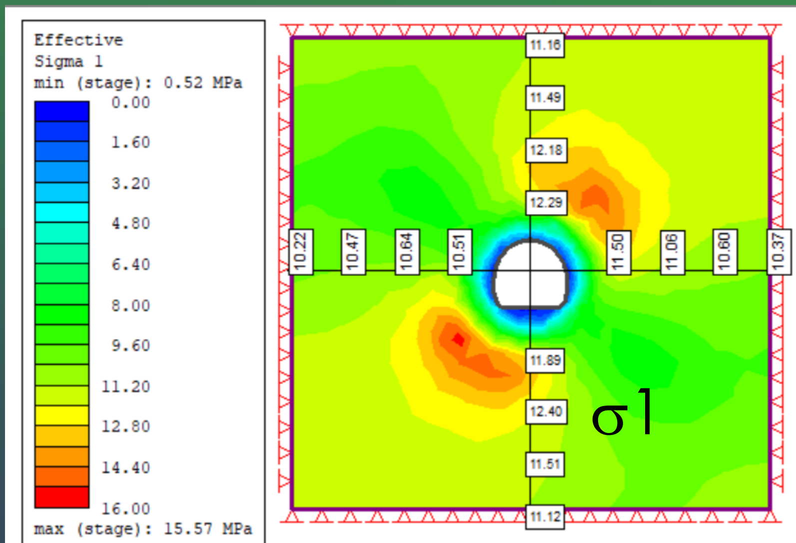


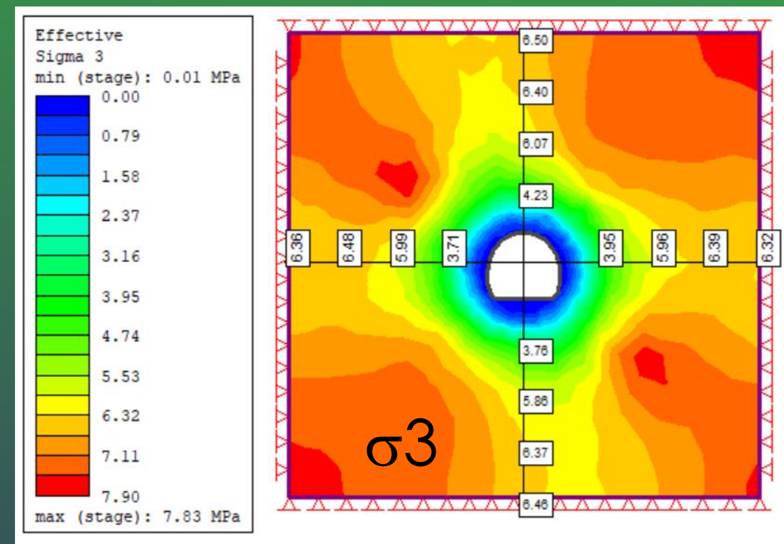


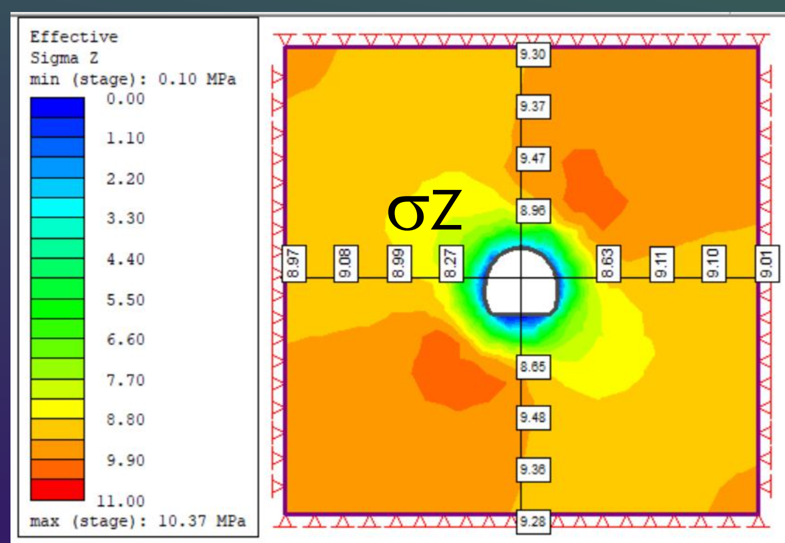


NUMERICAL ANALYSIS – STRESSES AROUND TUNNEL

σ1,σ3, σz are in-situ principle stresses **after the excavation of tunnel**

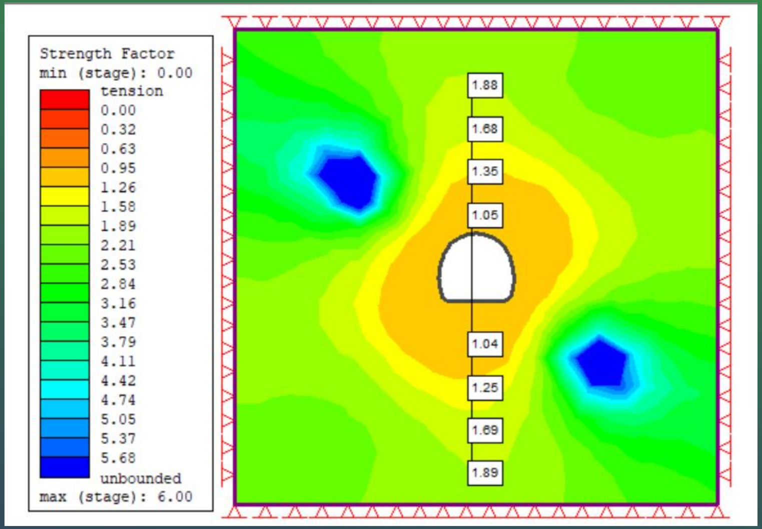




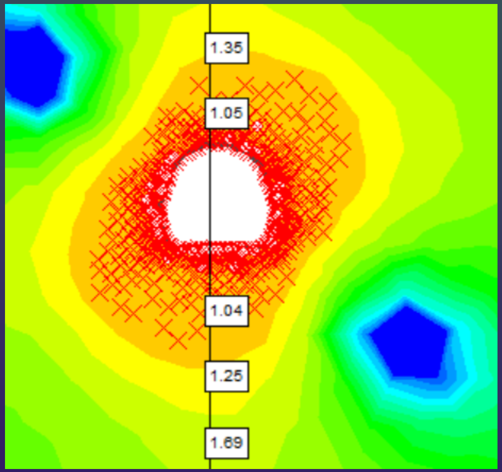


NUMERICAL ANALYSIS – STRENGTH FACTOR

Strength factor represents the ratio of available rock mass strength to induced stress at a given point.



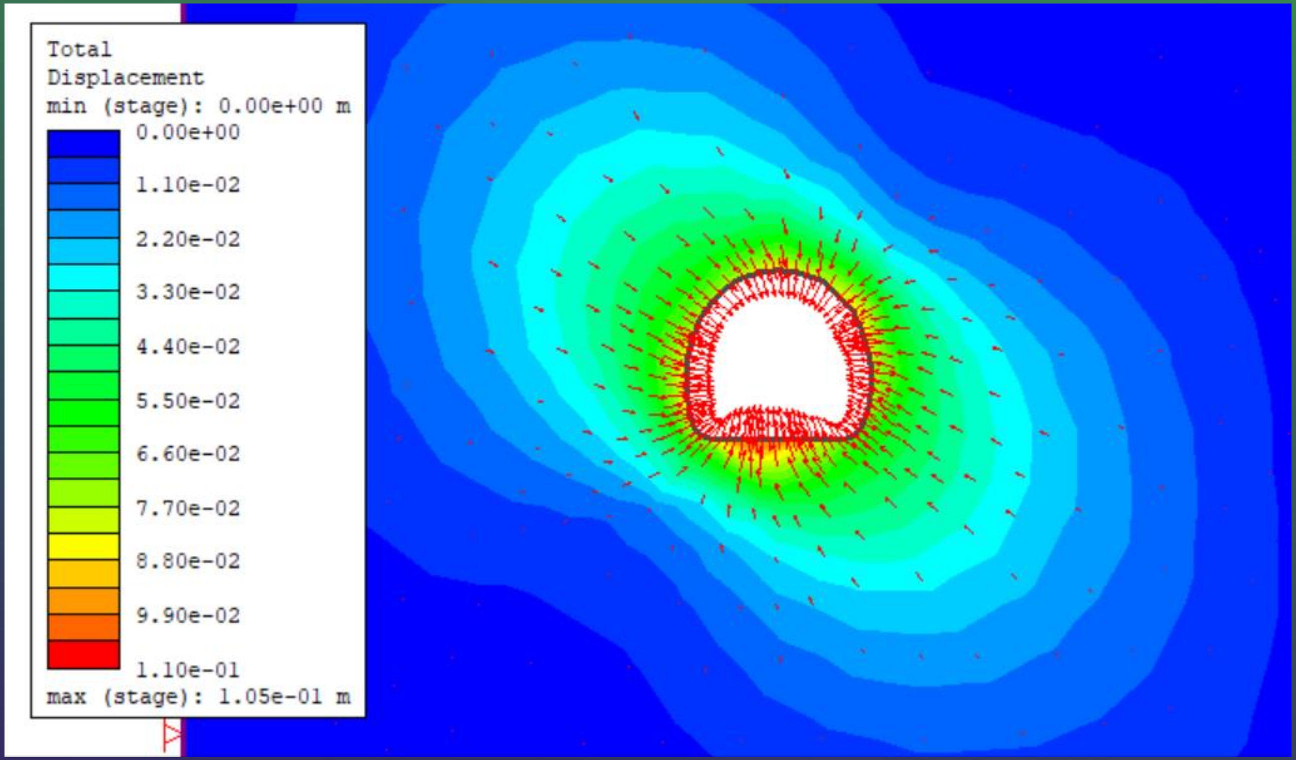
There is a large zone of overstress surrounding the tunnel. All the rock with the contour marked around 1 will fail if left unsupported.



Observe the zone of plastic yielding (X = shear failure, O = tensile failure) around the excavation. Notice that the yielded zone roughly corresponds with the zone of strength factor about SF = 1

NUMERICAL ANALYSIS – MAXIMUM DISPLACEMENT

The maximum displacement is occurring in the floor of the tunnel. This suggests the casting of a thicker concrete slab on the tunnel floor.



CONCLUSIONS

In this presentation I have talked about in-situ stresses in rock at certain depth. If a tunnel is excavation in this present stresses, there will be redistribution of stresses around the tunnel opening. Some where there will be release of stresses (at opening) and somewhere there will be concentration of stresses.

Due to this the strength of rock mass around the opening reduces below the available in-situ stresses and therefore large deformations will occur around the opening and now here the support system comes into picture to support the tunnel from collapsing.

To restrict the deformation to certain level we need support system, which we will cover in another presentation.

THANK YOU
FOR
YOUR PRECIOUS TIME