Analysis of Tunnel in Weak Rock

Tunnels in Weak Rock

This presentation is based on paper by Hoek :
Tunnels in weak rocks

Based on basic concepts:

- How rock mass surrounding tunnel deforms.
- How support systems acts to control this deformation.

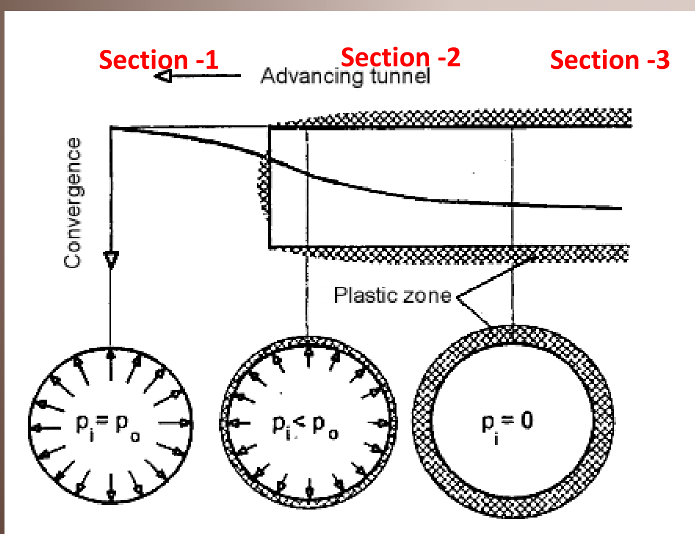
Advancement Stages of Tunnel – Section-1

Tunnel Shape – Circular

Tunnel is advancing in weak rockmass

In-situ Stress – Hydrostatic Stress Field ($\sigma_v = \sigma_h = \sigma_0$)

Advancement Stages of Tunnel



Section 1- in front of the excavation face.

<u>In-situ Stress</u> - Rock mass with no excavated induced stresses.

$$p_i = p_0$$

Internal Pressure = In-situ Stresses

<u>Deformation</u> $\delta = 0$

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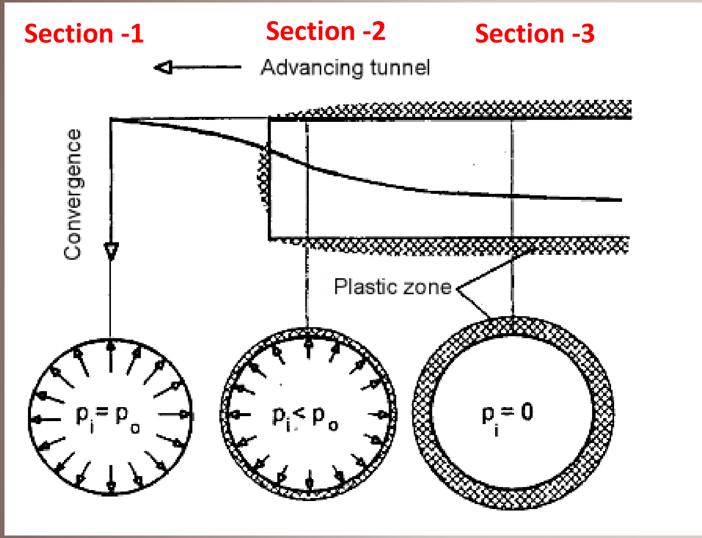
Advancement Stages of Tunnel Section-2



Section 2 –behind the tunnel face, between the face and tunnel lining. Internal pressure < in-situ stress

$$p_i \neq 0 \text{ but } < p_0$$

(There is support from tunnel face) Deformations start from front of the tunnel face but not to full extent behind the tunnel face.

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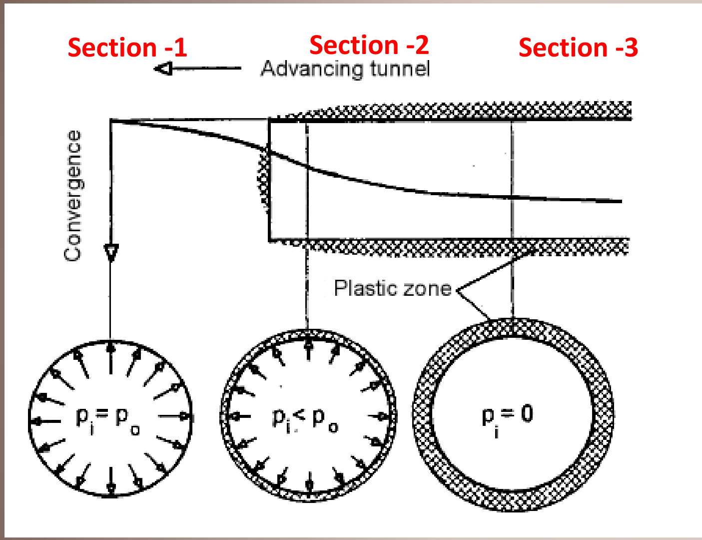
Advancement Stages of Tunnel Section-3



Section 3 – far away from and behind the tunnel face.

The support from tunnel face no longer provided. Therefore now the provided internal pressure is zero and so the deformation is to its full extent.

pi = 0

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Tunnel deformation analysis

In this analysis it is assumed

- The surrounding heavily jointed rock mass
- Mass behaves as an elastic-perfectly plastic material
- Failure involving slip along intersecting discontinuities is assumed to occur with zero plastic volume change (Duncan Fama, 1993)

Support is modelled as an equivalent internal pressure and, although this is an idealised model, it provides useful insights on how support operates.

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Failure Criterion

Mohr Coulomb Criterion

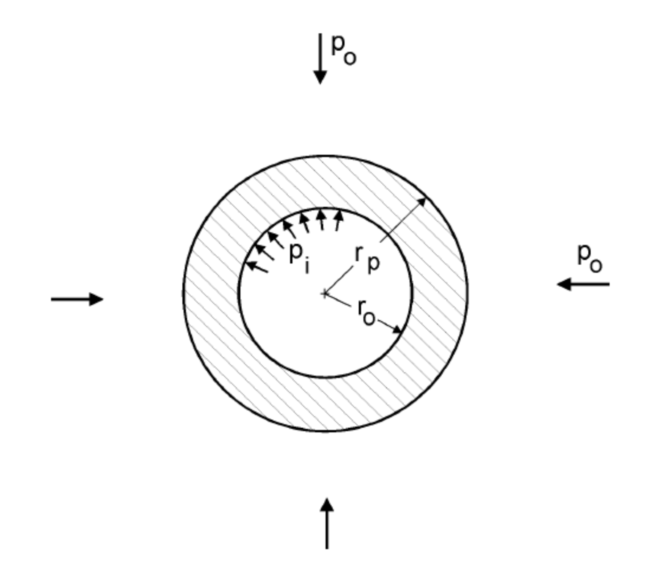

Figure 3: Plastic zone surrounding a circular tunnel.

$$\sigma_1' = \sigma_{cm} + k\sigma_3'$$

This criterion is determined through Triaxial test which is conducted over intact rock.

where σ_1' is the axial stress at which failure occurs

σ_3' is the confining stress

c' is the cohesive strength and

ϕ' is the angle of friction of the rock mass

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Failure Criterion

increment δσ	σ3	σ1	σ1σ3	σ3²
0	1E-10	0.00	0.00	0.00
1	0.36	1.78	0.64	0.13
2	0.71	2.77	1.98	0.51
3	1.07	3.61	3.87	1.15
4	1.43	4.38	6.26	2.04
5	1.79	5.11	9.12	3.19
6	2.14	5.80	12.43	4.59
7	2.50	6.46	16.16	6.25
Sum	10	29.92	50.46	17.86

and the slope k of the σ_1' versus σ_3' line as:

$$k = \frac{(1+\sin\phi')}{(1-\sin\phi')}$$

The value of k is determined from slope σ_1 and σ_3

K = 2.44

The value of friction angle of rockmass was determined from the equation given below

$\phi = 24.72°$

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Failure Criterion

increment $\delta\sigma$	$\sigma 3$	$\sigma 1$	$\sigma 1 \sigma 3$	$\sigma 3^2$
0	1E-10	0.00	0.00	0.00
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Determination of global rockmass strength σ_{cm} Is determined through triaxial test using below equation

$$\sigma_1' = \sigma_{cm} + k\sigma_3'$$

σcm = 0.69MPa

Determination of cohesion value of rockmass

$$\sigma_{cm} = \frac{2c' \cos\phi'}{(1-\sin\phi')}$$

C= 0.22Mpa

Determination Modulus of deformation of rockmass

$$Em = \sqrt{\frac{\sigma_c}{100}} \times 10^{\left(\frac{GSI-10}{40}\right)} \qquad \text{for } \sigma_c < 100 \text{ MPa}$$

Em = 750MPa

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Support Pressure

Failure of the rock mass surrounding the tunnel occurs when the internal pressure provided by the tunnel lining or tunnel face is less the critical support pressure.

$$p_{cr} = \frac{2p_o - \sigma_{cm}}{1+k}$$

pcr = 0.96Mpa

Therefor to support the tunnel or to stop rockmass failure the support measures Shall be more that this critical pressure

Support Pressure

When the internal support pressure *pi* is less than the critical support pressure *pcr*

If pi < pcr

- Failure occurs around the excavated tunnel
- Plastic zone forms around the tunnel with radius r_p

$$r_p = r_o \left[\frac{2(p_o(k-1)+\sigma_{cm})}{(1+k)((k-1)p_i+\sigma_{cm})} \right]^{\frac{1}{(k-1)}}$$

Actual radius of tunnel r_0 = 3m

rp = 6.43m

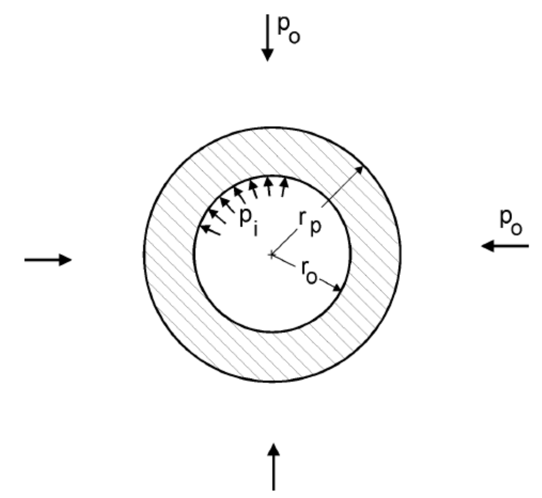

Figure 3: Plastic zone surrounding a circular tunnel.

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Radial deformation

If pi < pcr

For plastic failure, the total inward radial displacement of the walls of the tunnel is:

$$u_{ip} = \frac{r_o(1+\nu)}{E}\left[2(1-\nu)(p_o - p_{cr})\left(\frac{r_p}{r_o}\right)^2 - (1-2\nu)(p_o - p_i)\right]$$

u_{ip} = 30.60mm

If pi > pcr   No plastic failure

Support Measures

The above study and calculation has been adopted from article "Tunnels in Weak Rock"

- From this article we have only studied about the analysis of tunnel behavior.
- Determination of support measures from the analysis of tunnel behavior will be studied next presentation.

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THANK YOU