EXCEL spreadsheet for the calculation of the convergence – confinement curve

Input data: R , p_o , σ_{cm} , φ , δ , G

$$N_s = \frac{2\,p_o}{\sigma_{cm}} \qquad k = \tan^2\left(45 + \frac{\phi}{2}\right)$$

Calculate N_s , k , K and λ_{cr}

$$K \equiv \frac{1+\tan\delta}{1-\tan\delta} \qquad \lambda_{cr} = 1 - \left(\frac{2}{1+k}\right)\left(\frac{N_s - 1}{N_s}\right)$$

Col 1: p/p_o between 1 ... 0

Col 2: λ (between 0 ... 1)

$$\lambda = 1 - \frac{p}{p_o}$$

Col 3: Plastic region ? (Y/N) ⟶ If $\lambda > \lambda_{cr}$ then Y else N

Col 4: r_p /R ⟶ If N then r_n/R = 1 else:

If φ = 0 :
$$\frac{r_p}{R} = \exp\left[\frac{1}{2}\left(\lambda\, N_s - 1\right)\right]$$

If φ > 0 :
$$\frac{r_p}{R} = \left\{\left(\frac{2}{k+1}\right)\left[\frac{2 + N_s(k-1)}{2 + N_s(k-1)(1-\lambda)}\right]\right\}^{\frac{1}{k-1}}$$

Col 5: u_p /R ⟶ If $\lambda < \lambda_{cr}$ then u_p = n/a else: $\dfrac{u_p}{R} = \lambda_{cr}\left(\dfrac{r_p}{R}\right)\left(\dfrac{p_o}{2G}\right)$

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Col 6: u_R /R ⟶ If $\lambda < \lambda_{cr}$ (no plastic region): $\dfrac{u_R}{R} = \lambda \left(\dfrac{p_o}{2G} \right)$

Else (there is plastic zone): $\dfrac{u_R}{R} = \dfrac{u_p}{R} \left(\dfrac{r_p}{R} \right)^K$

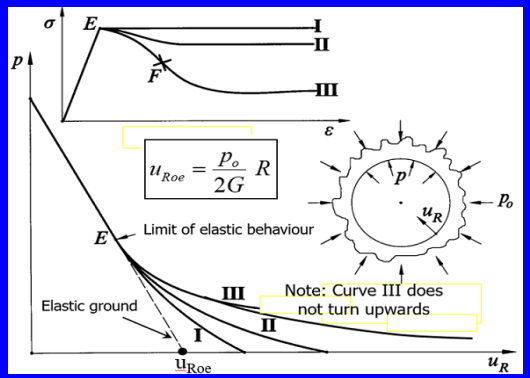
Calculate $u_{R\infty}/R$: u_R/R for $\lambda=1$

Col 7: $u_R / u_{R\infty}$ ⟶ $(u_R /R) / (u_{R\infty}/R)$

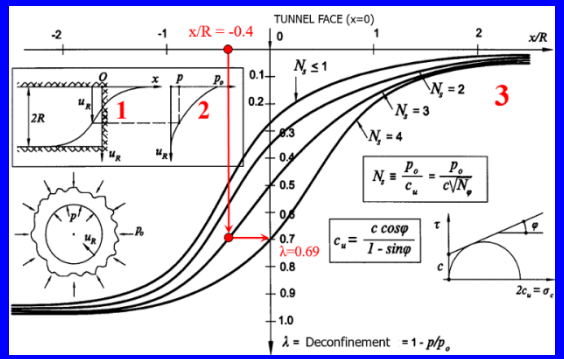
Col 8: x / R ⟶ $\dfrac{x}{R} = 1.10 \ln \left[\left(\dfrac{u_R}{u_{R\infty}} \right)^{-0.588} - 1 \right]$

Plot curves: (u_R /R) vs (p/p_o) , (r_p /R) vs (p/p_o) , (x/R) vs (p/p_o) or (u_R /R)

Convergence-confinement (GRC)



Confinement along axis (LDP)



EXCEL spreadsheet for the calculation of the convergence – confinement curve

Col 9: σ_r / p_o (at r=R): $\longrightarrow \dfrac{\sigma_r}{p_o} = (1 - \lambda)$

Col 10: σ_θ / p_o (at r=R): $\longrightarrow$ If $\lambda < \lambda_{cr}$ then: $\dfrac{\sigma_\theta}{p_o} = (1 + \lambda)$

else: $\dfrac{\sigma_\theta}{p_o} = k\left(\dfrac{\sigma_r}{p_o}\right) + \dfrac{2}{N_s}$

Plot curves: (σ_r / p_o & σ_θ / p_o) vs (p/p_o)