NATIONAL TECHNICAL UNIVERSITY OF ATHENS
SCHOOL OF CIVIL ENGINEERING – GEOTECHNICAL DEPARTMENT
COURSE : Computational Methods in the Analysis of Underground Structures
Programs: DCUS & ADS Acad. Year : 2023-24

Solution for Problem Set 3

For Soil Unit (TE-1):

1. Using the RocSupport – Rocscience software and based on the Ducan Fama (1993) convergence – confinement method, the convergence-confinement curve (λ – u) calculated and is presented on the following *Figure 1.*

   The export data of the software are the tunnel convergence (ε) and the internal pressure (p). Thus the tunnel radial displacement (u_r), can be calculated as follow:

   $\varepsilon = \frac{u_r}{R} \times 100\% \rightarrow u_r = \frac{\varepsilon \times R}{100\%}$, where R: tunnel radius

   Moreover, the deconfinement factor (λ), can be calculated as follow:

   $\lambda = 1 - \left(\frac{p}{p_o}\right)$, where p_o: geostatic field stress

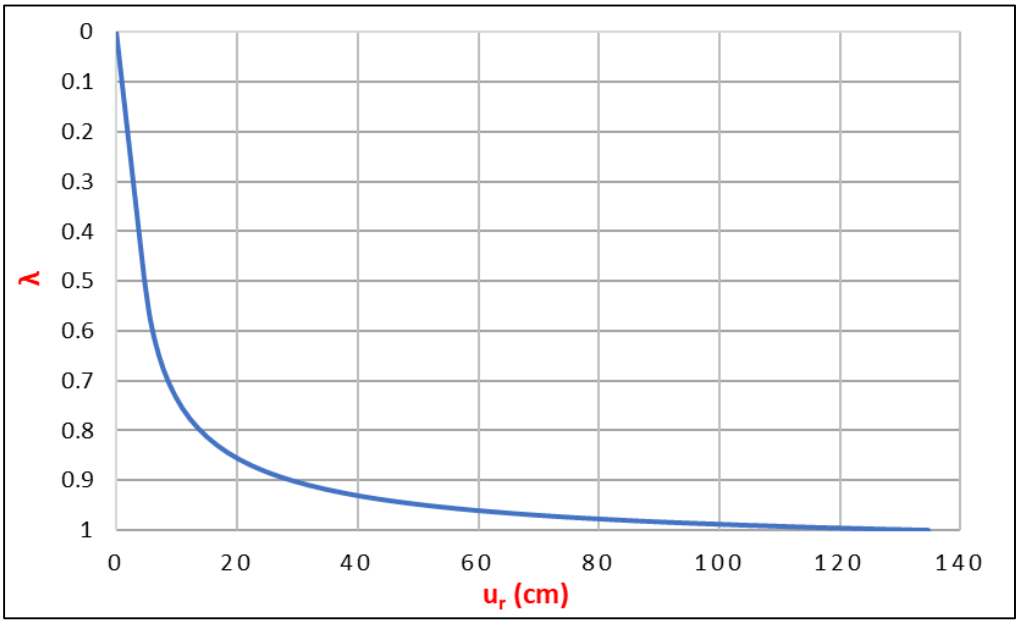

Figure 1. Convergence-confinement curve, based on Ducan Fama (1993) method.

2. In case of install tunnel support at a distance of 2m of the tunnel face, which consist of shotcrete and rockbolts, the calculated values are presented on the following *Table 1*.

Table 1. Characteristic calculated values after installation of tunnel support.

Radial displacement (u_r)	Radius of plastic zone (R_{pl})	Safety factor of tunnel support (SF)
11,2cm	16,25m	25,2

Note that the radial displacement (u_r) which will be recorded by the surveying engineer on the construction site, is the difference between the wall displacement on the position of 2m back of the tunnel face (inside tunnel), which is 52,7cm and the wall displacement on tunnel face, which is 41,5cm.

3. Now, reinforce the previous tunnel support with steel sets HEB 140 at an axial distance s= 1.5m, the calculated values are presented on the following *Table 2*.

Table 2. Characteristic calculated values after installation of tunnel support (plus steel sets HEB 140).

Radial displacement (u_r)	Radius of plastic zone (R_{pl})	Safety factor of tunnel support (SF)
11,2cm	16,25m	27,9

Comparing the previous Table 1 & 2, it is obvious that the effect of the tunnel support reinforcement by steel sets, is only the increment on the tunnel support safety factor (SF).

For Rock Unit (TE-2):

1. Using the RocSupport – Rocscience software and based on the Carranza - Torres (2004) convergence – confinement method, the convergence-confinement curve (λ – u) calculated and is presented on the following *Figure 2.* In order to takes in to account the coefficient of the horizontal stress (Ko) in the in-situ field stress (p_o), the in-situ field stress (p_o) can be calculated by the following formula:

$$p_o = \gamma \times H \times 0.5 \times (1 + K_o) = 26kN/m^3 \times 260m \times 0.5 \times (1 + 0.6) = 5408KPa = 5.41MPa$$

, where γ: ground unit weight and H: tunnel overburden height

The export data of the software are the tunnel convergence (ε) and the internal pressure (p). Thus the tunnel radial displacement (u_r), can be calculated as follow:

$\varepsilon = \frac{u_r}{R} \times 100\% \rightarrow u_r = \frac{\varepsilon \times R}{100\%}$, where R: tunnel radius

Moreover, the deconfinement factor (λ), can be calculated as follow:

$\lambda = 1 - \left(\frac{p}{p_o}\right)$, where p_o: geostatic field stress

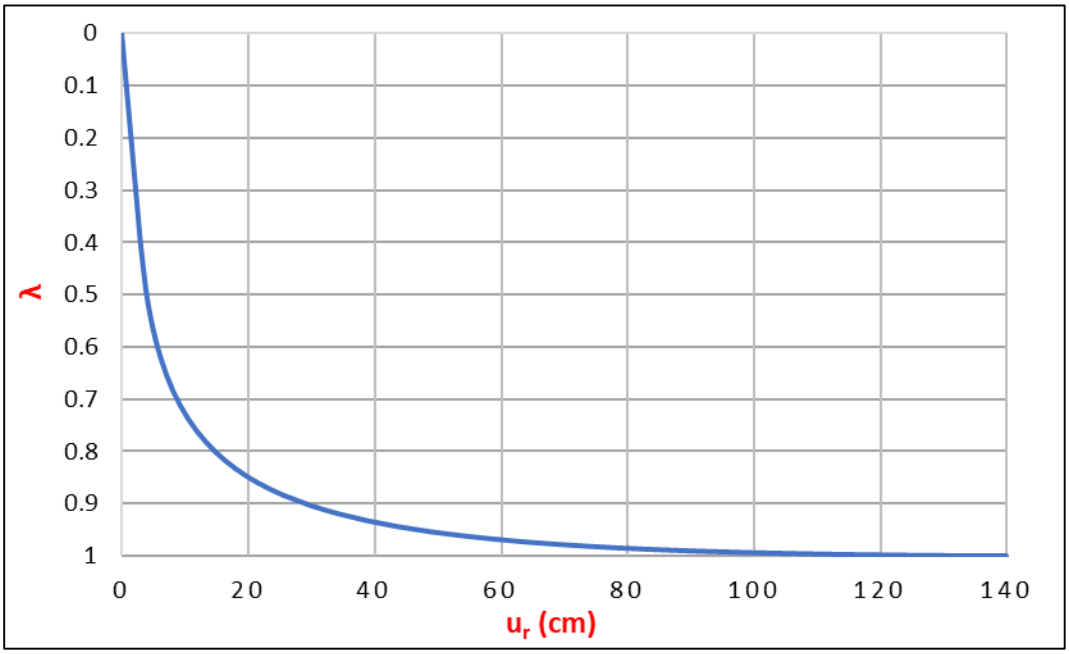

Figure 2. Convergence-confinement curve, based on Carranza - Torres (2004) method.

2. In case of install tunnel support at a distance of 2m of the tunnel face, which consist of shotcrete and rockbolts, the calculated values are presented on the following *Table 3*.

Table 3. Characteristic calculated values after installation of tunnel support.

Radial displacement (u_r)	Radius of plastic zone (R_{pl})	Safety factor of tunnel support (SF)
11,8cm	19,3m	5,32

Note that the radial displacement (u_r) which will be recorded by the surveying engineer on the construction site, is the difference between the wall displacement on the position of 2m back of the tunnel face (inside tunnel), which is 54,9cm and the wall displacement on tunnel face, which is 43,1cm.

3. Now, reinforce the previous tunnel support with steel sets HEB 140 at an axial distance s= 1.5m, the calculated values are presented on the following *Table 4*.

Table 4. Characteristic calculated values after installation of tunnel support (plus steel sets HEB 140).

Radial displacement (u_r)	Radius of plastic zone (R_{pl})	Safety factor of tunnel support (SF)
11,8cm	19,3m	5,9

Comparing the previous Table 3 & 4, it is obvious that the effect of the tunnel support reinforcement by steel sets, is only the increment on the tunnel support safety factor (SF).

***Note that in all cases, the dilation angle (δ) is set to: δ=φ/4, where φ is the ground friction angle.**