A NEW METHOD FOR THE PREDICTION OF SETTLEMENTS DUE TO URBAN TUNNELING IN SOFT GROUND

Nicolas Gilleron
A new method for the prediction of settlements due to urban tunneling in soft ground

INTRODUCTION

Grand Paris project
Need for a new constitutive model

A DEDICATED CONSTITUTIVE MODEL

Confining stress dependency
Deviatoric stress dependency
Cross-anisotropic behavior

DESIGN OF PRESUPPORTS

3D Modelling
Risk Analysis
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CONVENTIONAL TUNNELING

Sandy silt
$E = 30$ Mpa - $c' = 30$ kPa - $\phi = 32^\circ$

Clayey sand
$E = 75$ Mpa - $c' = 42$ kPa - $\phi = 34.6^\circ$
NEED FOR CONSTITUTIVE MODEL

Volume loss parameter in Peck model not convenient with conventional tunneling

Fitting of the empirical curve is impossible with numerical method, even with advanced constitutive law
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A DEDICATED CONSTITUTIVE MODEL

\[ G = f(p) \]

\[ G = f(q) \]

Failure criterion

Cross-anisotropy
CONFINING STRESS DEPENDENCY

In tunneling the confining stress remains quite constant in soil
No need for a specific hardening

Settlement trough slightly narrower

\[ G_0 = G_{\text{ref}} + A \left( \frac{p}{p_{\text{ref}}} \right)^r \]

From Harding & Richart (1963)
DEVIATORIC STRESS DEPENDENCY

Normalized with the initial value and not the failure criterion
Decrease of stiffness with increase of deviatoric stress until failure

No impact on settlement trough width

\[ G_t = G_0 \xi (1 - q / q_i) \]

Bulk Modulus K remains constant to avoid excessive volumetric strains

\[ \nu_t = \frac{1 + \nu_0 - \frac{G_t}{G_0} (1 - 2\nu_0)}{2(1 + \nu_0) + \frac{G_t}{G_0} (1 - 2\nu_0)} \]
CROSS ANISOTROPIC BEHAVIOR

Cross anisotropic parameters $E_h ; E_v ; G_{hv}$

Inspired from Lee & Rowe (1989)
CROSS ANISOTROPIC BEHAVIOR

Settlement trough width directly linked with $G_{hv}$

![Graph showing settlement vs distance from tunnel axis]

- $K = 0.55$, width = 8 m
- $K = 0.35$, width = 6 m
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ROLE OF PRESUPPORTS

Stability of excavation -> Failure criterion

Plastic area without presupports

Plastic area with presupports
ROLE OF PRESUPPORTS

Reduction of settlement -> Deviatoric stress dependency
RISK ANALYSIS

Different design of presupport

Probability distribution of geotechnical parameter

Building vulnerability to settlement

Risk Assessment for each design
CONCLUSION

A method grounded on FE simulations

A new constitutive model for soil

- Four independent mechanisms
- Cross anisotropic behavior
- Convenient for parametric studies

An inclusive software CESARv6 for the design of presupports and prediction of settlement

Thanks to Emmanuel Bourgeois, Adrien Saïtta and the NEWTUN Project
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Nicolas Gilleron
Phd, Tunnel Engineer for Grand Paris Express project
+33 6 49 51 92 40

Emmanuel Bourgeois
Phd, Senior researcher at IFSTTAR

www.egis-group.com