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Effects of Soil Structural Models Selection on Generated Stresses in Tunnel

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ABSTRACT

Background: In recent years, with developing of laboratory and Tunneling equipments and numerical analysis of software, the anticipation of tunnels structural treatment in short and long term has performed. Instrumentation and monitoring in construction and post construction stage to some extent has an important rule. While, it is better to analyze and regard the soil mass that encompass the environmental body of tunnel for evaluation of soil behavior and its rule on the stress path and controlling of stresses have generated in tunnel. **Objective:** In this research with using of plain strain analysis in Plaxis finite element software, the Effects of Soil structural Models Selection on generated stresses in Tunnel with using of Mohr-Coulomb and Hardening- Soil Models has assessed. **Results:** From the results can observe that less displacements and lateral strains have generated in ceiling of tunnel in advanced soil structural model rather than initial soil structural model. **Conclusion:** We have proposed a Finite element analysis with selection of Hardening soil structural model rather than Mohr-Coulomb and shown more accurate results from stress variation around the tunnel that this matter is important in selection of tunnel concrete lining or types and amount of forces has generated in supports.

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INTRODUCTION

Nowadays, the construction and performance of Tunnels with using of modern mechanical vehicles and equipments have became easier. The construction of tunnel with various shapes in soil and rock has adapted depend on their applicability aim. One of the most important factors in construction and maintenance periods is the confidence of sufficient stability in tunnels structure. (Salehzadeh, H., 1388).

This importance is a function of the stresses have generated in various points of tunnel's wall and ceiling. Instrumentation and monitoring in construction and post construction stage to some extent has an important rule. While, it is better to analyze and regard the soil mass that encompass the environmental body of tunnel for evaluation of soil behavior and its rule on the stress path and controlling of stresses have generated in tunnel. In recent years, with developing of laboratory and Tunneling equipments and numerical analysis of software, the anticipation of tunnels structural treatment in short and long term has performed. In this research with using of plain strain analysis in Plaxis finite element software, the Effects of Soil structural Models Selection on generated stresses in Tunnel with using of Mohr-Coulomb and Hardening- Soil Models has assessed.

MATERIALS AND METHODS

While a shell tunnel has constructed with Tunnel Boring Machine (TBM), such as construction of urban underground tunnel and the portion of section that encompassed with final cover, always is less than the excavated portion of soil. The stresses redistribution and soil deformations due to tunnel excavation cannot ignore. In this respect, for avoidance from exist structures or foundation collapsing, it is necessary to study about the soil treatment and selection of appropriate structural model for the soil condition and assessment of its effects on stresses have generated in tunnel's wall and ceiling that has an important rule on tunnel stability. For this reason, the soil structural models that are useful for this research have introduced as follows: (Schanz and Vermeer and Bonnier, 1999).

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A) Mohr-Coulomb Elasto Plastic Structural Model:

As an initial structural model with five parameters that conation: two elastic parameters E , ν that are Poisson Ration and elastic modulus as respected and three plastic parameters C , ϕ , ψ that present the resistant portion of soil which are cited as cohesion coefficient, internal frictional angle and Dilatation Angle.

B) Hardening Soil Structural Model:

This model is one of the advanced models for simulation of soil treatment. In this structural model, the stiffness modulus is function of stress, this mean is that all stiffness increasing with pressure. In this structural model also three plastic parameters C , ϕ , ψ that present the resistant portion of soil witch cited as cohesion coefficient, internal frictional angle and Dilatation Angle. Furthermore three stiffness parameters consist of E_{50} , E_{ur} and E_{oed} which are cited as triaxial loading stiffness modulus, triaxial unloading stiffness modulus and Odometer loading stiffness modulus. Each of three entrance stiffness is depend on the reference stress with 100 kpa magnitude. Also the mean of stiffness for all types of soils described as a form of equation 1.

$$E_{oed}^{ref} = E_{50}^{ref}, \quad E_{ur}^{ref} = 3E_{50}^{ref} \quad (1)$$

The selection of appropriate and accurate of the parameters has cited in pervious section is another important factors and effective on soils treatment and structural analysis. In as follows with using of described structural models analysis results, the comparison between deformation and lateral strains and stresses in tunnel has evaluated.

Modeling and Analysis of Tunnel Section:

The supposed tunnel has 10 meters diameter. The excavation method of this tunnel project has performed with TBM Shield and a little after excavation, the concrete lining has installed. This tunnel has excavated in approximate loosen soil and the excavated portion of soil has not achieve convergence in natural and will collapse. The soil of excavation area has stratum in 3 various layers. That upper layer is very loose clay and the second layer is deep clay with increasing in elastic modulus with depth of soil and the lower layer is sand. The excavation is performing in the interface boundary of clay and sand. The water table is 3 meters under the ground surface and the water pressure has regarded as hydrostatic and the confined flow of water in tunnel has negligible.

Boundary Conditions:

The meshing of finite element has regarded as an average size and in the round of tunnel for avoiding of stress concentration, mesh has refined in several times. For Physical stabilizing of model, the rigid motion of model should avoid with supporting condition that are conformed with real condition. In this research soil in right and left boundary is able to motion in vertical direction, but the motion has confined toward to lateral displacements. The displacements on bottom of boundary have restricted in both vertical and horizontal directions and the plain strain condition has used to analyze the model.

The material properties of soil based on Mohr-Coulomb and Hardening soil structural models and accompanied whit Concrete lining conform to tables 1, 2 have introduced as follows:

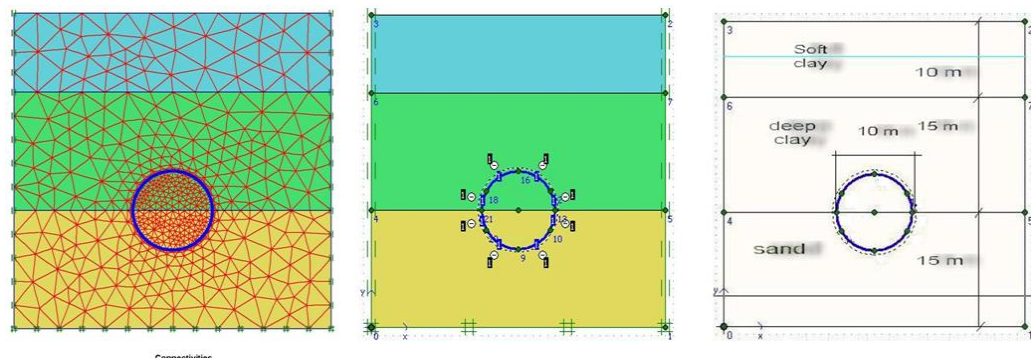


Fig. 1: As respected from right to left: a) Model Geometry Specification b) Boundary condition c) Finite element mesh.

Material properties:

The material properties of soil based on Mohr-Coulomb and Hardening soil structural models and accompanied whit Concrete lining conform to tables 1, 2 have introduced as follows:

Table 1. Material Properties of Soils Structure (Plaxis BV, Delft, the Netherlands, 2002).

Mohr-Coulomb Structural Model – Drained Material Properties										
Parameter	Local frictional angle	Cohesion	Dilatation Angle	Dry Unit Weight	Wet Unit Weight	Horizontal penetration coefficient	Vertical penetration coefficient	Elastic Modulus	Poisson Ration	Interface Reduction Factor
Abbreviation	ϕ	C	ψ	γ_{dry}	γ_{wet}	K_x	K_y	E^{ref}	ν	R_{int}
Unit	(deg)	kn/m ²	(deg)	kn/m ³	kn/m ³	m/day	m/day	kn/m ²	-	(deg)
Loose clay	24	5.5	0	15	18	0.0001	0.0001	1000	0.33	rigid
Deep clay	25	4	0	16	18.5	0.01	0.01	10000	0.33	0.7
sand	33	1	3	17	21	0.5	0.5	120000	0.33	0.7
Hardening Structural Model – Drained Material Properties										
Parameter	Local frictional angle	Cohesion	Dilatation Angle	Triaxial loading stiffness	Oedometer loading stiffness	Triaxial unloading stiffness	Power's law	Reference Pressure	Poisson Ration	At rest condition soil pressure coefficient
Abbreviation	ϕ	C	ψ	E_{50}^{ref}	E_{oed}^{ref}	E_{ur}^{ref}	M	P_{ref}	ν_{ur}	K_0^{NC}
Unit	(deg)	kn/m ²	(deg)	kn/m ²	kn/m ²	kn/m ²	-	kn/m ²	-	-
Loose clay	24	5.5	0	2500	2500	7500	1	100	0.2	0.59
Deep clay	25	4	0	10000	10000	30000	0.9	100	0.2	0.58
sand	33	1	3	120000	120000	360000	0.5	100	0.2	0.46

Table 2. Material Properties of Concrete Lining (Plaxis BV, Delft, the Netherlands, 2002).

Concrete Lining Properties					
Parameter	Axial Stiffness	Bending Rigidity	Equivalent Thickness	Unit Weight	Poisson Ration
Abbreviation	EA	EI	d	w	ν
Unit	kn/m	kn/m ² /m	m	kn/m/m	-
Magnitude	1.4×10^7	1.43×10^5	0/35	8.4	0.15

Initial Conditions:

After modeling and meshing of finite element, the initial stress status and initial condition should be determined. The initial conditions consist of two various modes:

One mode for initial water pressure generation (water conditions mode) and another mode for determining of total initial geometry and generate of initial effective stress field. With consideration that the water table is 3 meters under the ground surface, in this model water pressures have generated based on global water level and the water unit weight has adapted as 10 kn/m³.

Calculations:

In this research for tunnel calculations two computational phases has considered:

Phase 1: Select of Staged construction status and activation of concrete lining and eliminate of soil mass in tunnel region.

Phase 2: Consideration of two percentage contraction of tunnel lining.

With consideration that the contraction of tunnel lining action not merely generate in tunnel lining. Extra variation in lining forces due to contraction results in stress redistribution or variation of external forces.

RESULTS AND DISCUSSION

As mentioned in pervious sections, in tunnel excavation projects and underground maintenance, stress redistribution and soil deformations due to tunnel excavation cannot negligible. Indeed the programs in construction and post construction stage are affected from this matter. From these observation in this research with selection of Mohr-coulomb model and Hardening soil structural models, the relation between stresses and deformations have generated in soil round the tunnel has assessed. Also with non-homogeneous layers selection of soil (special in deep and loose clay), effect of elastic modulus with soil depth in described structural models has considered and comparison of Mohr-coulomb model and Hardening soil structural models results conform to figures 2 , 3 , 4 has performed as follows:

After construction phase, the differences between structural models has assessed as follows:

- In Hardening soil model because of the stiffness modulus is function of stress; this mean is that all stiffness increasing with pressure and due to this matter the soil settlement round the tunnel diminish.
- In Hardening soil model under the tunnel less uplift pressure has observed.
- In Hardening soil model the soil around the tunnel has fewer strains.
- In Hardening soil model due to decrease in lining deformation, a little bending moments has generated in lining's ceiling of tunnel.

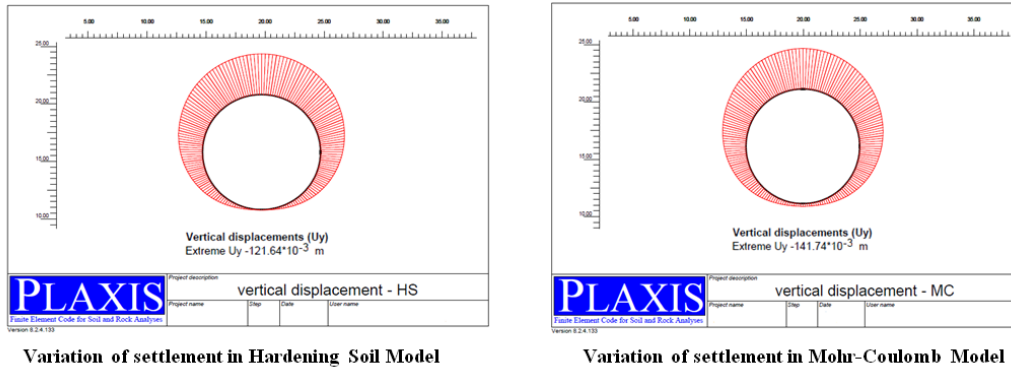


Fig. 2: Variation of settlement on Tunnel’s wall and ceiling in Structural Models.

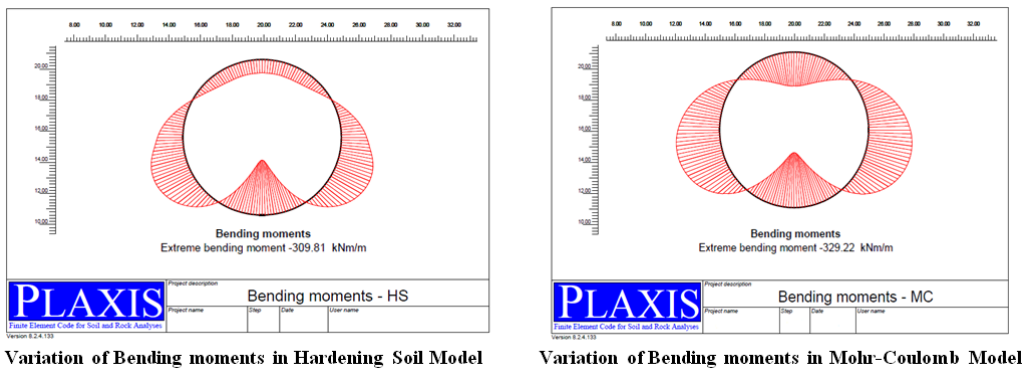


Fig. 3: Variation of Bending moments on Tunnel’s wall and ceiling in Structural Models.

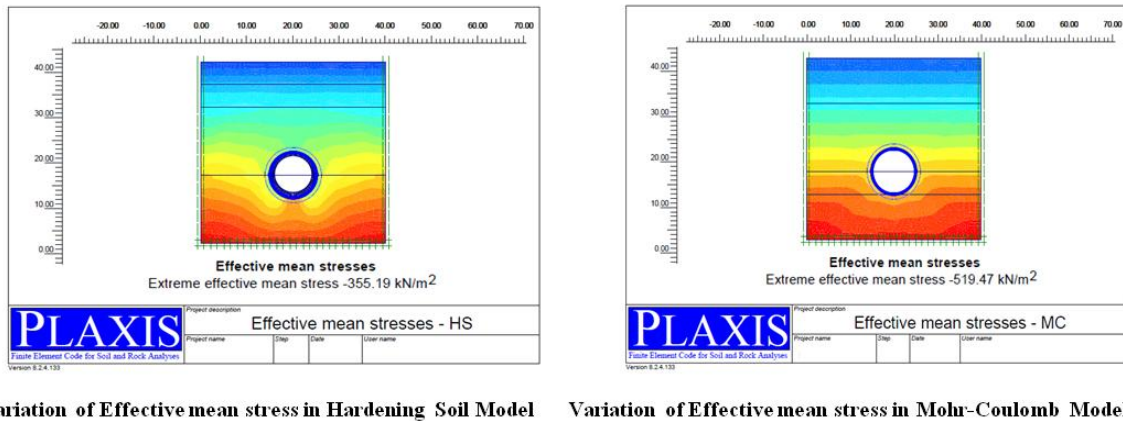


Fig. 4: Variation of Effective mean stress on Tunnel’s wall and ceiling in Structural Models.

Conclusion:

We have proposed a Finite element analysis and shown in Hardening Soil Model the effective stress on Tunnel wall and ceiling decrease than Mohr-Coulomb Model that is due to soil settlement reduction around the tunnel. For this reason a few factor of safety against the stability has achieved rather than Mohr-Coulomb soil structural model, which this matter is significant in evaluation of forces that generate in supports.

Also, with selection of Hardening soil structural model rather than Mohr-Coulomb, demonstrate more accurate results from stress variation around the tunnel that this matter is important in selection of tunnel concrete lining or types and amount of forces has generated in supports.

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