Influence of earth pressure coefficient at rest for overconsolidated soils subjected to shallow overburden tunneling

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1. INTRODUCTION

The stresses currently experienced by soil are governing factors in soil behavior, and the initial stress state is an integral and essential element in determining the soil properties. Donath (1891) first introduced the concept of a stationary pressure of unlimited ground. In situ effective vertical stress(σ'_{Vo}), can be estimated easily from the weights of the soils located at higher levels in the soil column and the soil pressure. In contrast, the effective horizontal stress(σ'_{Ho}), are difficult to estimate and often determined based on prior experience and knowledge. When horizontal displacement is not permitted in a homogeneous natural soil deposit, the in situ relation between effective horizontal and vertical stress, known as the coefficient of earth pressure at rest K_0, is a constant given by: $K_0 = \sigma'_{Ho}/\sigma'_{Vo}$. This coefficient is often used to estimate horizontal stresses on structures in soils, including but not limited to, piles, sheet pile walls, and underground tunnels. There are several methods for estimating the normally consolidated K_0, K_0(nc), based on, for example, the plasticity index (see Equ. (1); Brooker and Ireland, 1965) or the friction angle (see Equ. (2); Jacky, 1944).

$$K_{0(nc)} = 0.44 + 0.42\left({}^{I_p}/_{100}\right) \quad (1) \qquad K_{0(nc)} = 1 - \sin(\emptyset) \quad (2)$$

Meyerhof (1976) estimated the K_0 in an overconsolidated state, K_0(oc), with the overconsolidation ratio, *OCR*:

$$K_{0(oc)} = K_{0(nc)} * OCR^{\alpha} \quad (3).$$

Schmidt (1996) suggested the following expression for "α" i.e. $\alpha = sin(\varphi)$. The current paper investigates the effect of variation in K_0 for overconsolidated soils subjected to the shallow overburden tunneling through the series of finite difference simulations. In this research the mechanical behavior of a shallow overburden tunnel (i.e. H = 1.5D) has been investigated by the means of the ground reaction curve (GRC) in conjunction with the stress path during the progressive relaxation by varying the K_0 for an overconsolidated soil (i.e. *OCR =2*).

2. OUTLINE OF NUMERICAL ANALYSES

2D finite difference analyses were carried by using a circular shape of tunnel with diameter of 10m. The gravity loading scenario was considered in the analyses. The ground was assumed to be composed of loose sandy material with SPT (*N-11)* and obeys the Modified Cam Clay model. The yield function in MCC model corresponding to a particular value of P_c of the consolidation pressure has the form: $f = q^2 + M^2 p(p - p_c)$, Where M is the frictional constant and P_c is the pre-consolidation pressure. The metrical parameters and analyzed section are shown in Table.1 and Figure.1 respectively.

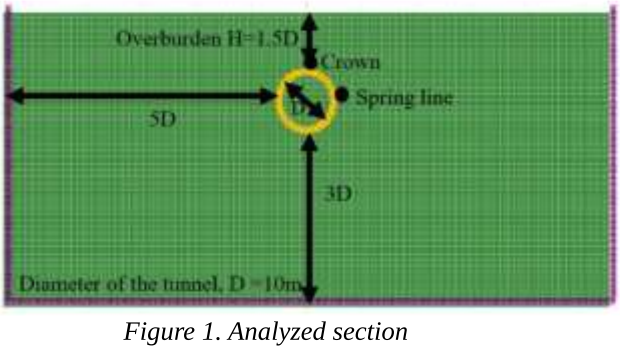

Figure 1. Analyzed section

Table 1. Material Parameters for MCC model

Parameters	Value	Unit
Frictional constant (*M*)	1.2	
Slope of swelling line (*k*)	0.0022	
Slope of normal consolidation line (λ)	0.03	
Over consolidation ratio *(OCR)*	2	
Reference pressure (P_1)	100	kPa
Specific volume at reference pressure (v_λ)	1.43	

Density (ρ) = 1805 Kg/m^3, and Poisson's ratio ν = 0.33.

3. RESULTS OF NUMERICAL ANALYSES

The GRC is shown in the Figure. 2 below which correlates the normalized support pressure and crown or spring line normalized displacement. It is evident that there is remarkable difference in terms of normalized displacement due to the variation in K_0. The maximum displacement occurs at the crown for K_0*=0.5 and 1.* Whilst for the case of K_0*=1.5*, the maximum displacement occurs at the spring line. The displacement magnitude decreases with the increase in K_0 value. Surface settlement has a prime importance in the case of shallow overburden tunnels, due to their proximity to the existing infrastructure. The settlement profile at the 41% of relaxation is shown in the Figure. 3 below. The magnitude and settlement gradient is maximum in the case of K_0*=0.5,* which is due to the fact that during the excavation the horizontal arching is not strong enough to resist the ground settlement. While the gradient is fairly gentle in the case of higher K_0*=1.5*, as in this case the magnitude of horizontal stresses is higher which essentially contributes in the strong arching effect.

Keywords: Shallow overburden tunnel, Convergence confinement method, Stress path
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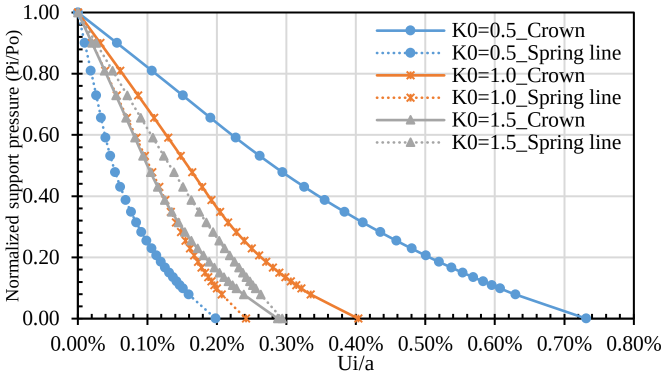


Figure 2. Ground reaction curve for various K_0

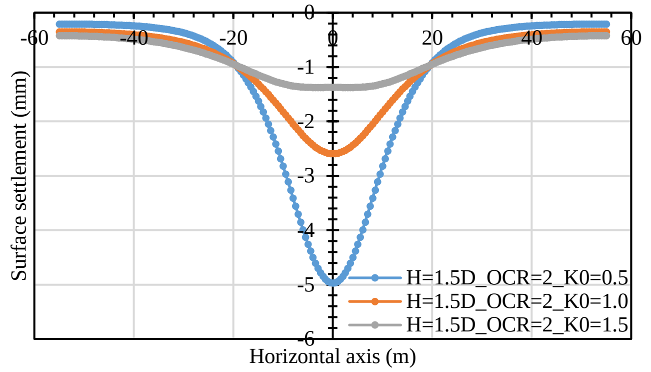
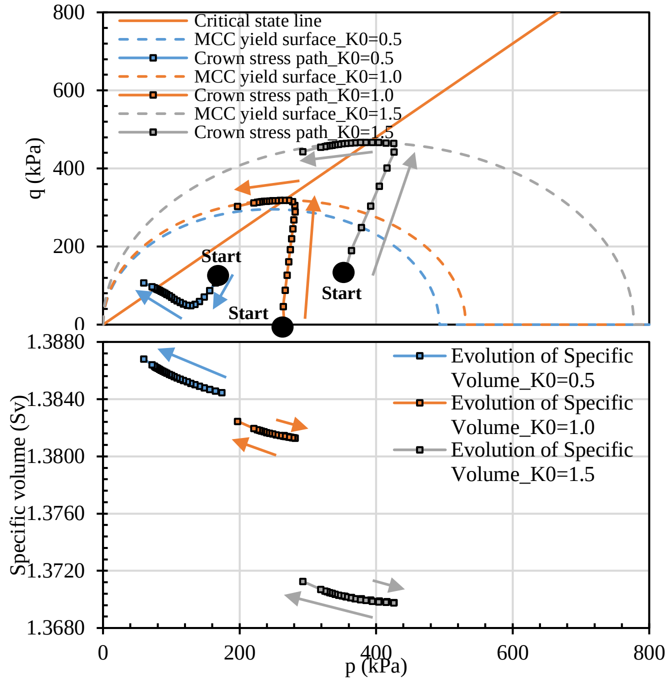


Figure 3. Surface settlement profile at 41% relaxation

The stress path in p,q space for the crown and spring line is shown in the Figure 4 and 5 respectively. When tunnel



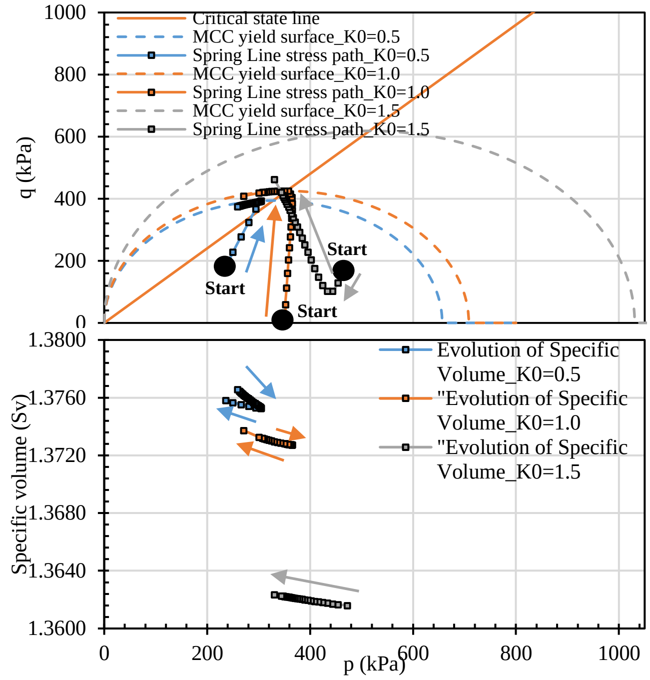


Figure 4. Stress path in p,q space with specific volume change Figure 5. Stress path in p,q space with specific volume change

excavation is carried out the stresses tend to re-orientate itself depending upon the assigned K_0 value. In the case of crown for $K_0=0.5$, the material remains within elastic range, whilst in the case of $K_0=1.0$, until the 69% relaxation the material remains within the elastic range after that there is slight hardening of the yield surface followed by the softening trend which initiates ta the 75% relaxation. In the case of $K_0=1.5$, the stress path intersects the existing yield surface at the 47% relaxation and hardening of the yield surface starts, this continuous until the 65% relaxation followed by the softening trend which is shown in the specific volume evolution as well. The behavior ta the spring line in the case of K_{0} =05 is elastic until the 41% relaxation then follows the softening trend whilst in case of K_0=1.0, the material remains within elastic limit until the 69% relaxation and then hardening continuous until the 75% relaxation followed by the softening trend which is quite similar to the behavior at the crown. In the case of $K_0=1.5$, the ground remains purely elastic.

4. CONCLUSION

It can be concluded that impact of variation in K_0 is very high in terms of GRC and stress path. In case of $K_0=0.5$ and *1.5* the behavior became reverse as yielding initiation point switches from the crown to spring line respectively. Whilst for the case of $K_0=1.0$, the behavior at the crown and spring line is approximately the same as yielding initiates at the crown and spring line at the same relaxation approximately. So it is important to check the design sensitivity by varying the K_0 value.

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