KINEMATICAL APPROACH TO THE FACE STABILITY ANALYSIS OF SHALLOW CIRCULAR TUNNELS

Abdul-Hamid Soubra

ENSAIS – 24, Bld de la Victoire – 67084 Strasbourg Cedex – France
Email : Ahamid.Soubra@ensais.u-strasbg.fr

ABSTRACT- The upper-bound method of the limit analysis theory is used to calculate the active and passive limit pressure in front of a pressurized shield. Two translational kinematically admissible failure mechanisms composed of a sequence of rigid cones are considered for the calculation schemes. The numerical results obtained are presented and compared to those given by other authors.

INTRODUCTION: The analysis of the face stability of shallow circular tunnels driven by the pressurized shield requires the determination of the pressure to be applied by the shield to insure the tunnel's face stability. This pressure must avoid both the collapse (active failure) and the blow-out (passive failure) of the soil mass near the tunnel face. In this paper, the collapse and the blow-out failures are investigated by the upper-bound theorem of the limit analysis theory using respectively collapse and blow-out mechanisms. These mechanisms allow the slip surface to develop more freely in comparison with the available mechanisms (see Leca and Dormieux [1990]).

KINEMATICAL APPROACH TO THE FACE STABILITY ANALYSIS: The problem can be idealized, as shown in figure 1, by considering a circular rigid tunnel of diameter D driven under a depth of cover C. A surcharge σ_s is applied at the ground surface and a constant retaining pressure σ_t is applied to the tunnel's face.

M1 (Fig. 1) is an improvement of the two-blocks collapse mechanism presented by Leca and Dormieux [1990]. This mechanism is composed of several truncated rigid cones with circular cross-sections and with opening angles equal to 2ϕ. The geometrical construction of this mechanism is similar to that of Leca and Dormieux [1990]. The upper rigid cone will or will not intersect the ground surface depending on the C/D value. It should be mentioned that *M1* is a translational mechanism. The different blocks of this mechanism move as rigid bodies. These rigid cones translate with velocities of different directions, which are collinear with the cones' axes and make an angle ϕ with the discontinuity surface. The velocity of each cone is determined by the condition that the relative velocity between the cones in contact has the direction that makes an angle ϕ with the contact surface. The present mechanism is completely defined by n angular parameters where n is the number of rigid blocks.

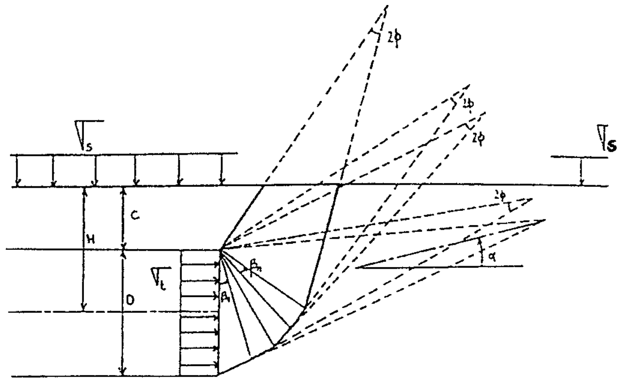


Figure 1 : Failure Mechanism *M1* (Collapse)

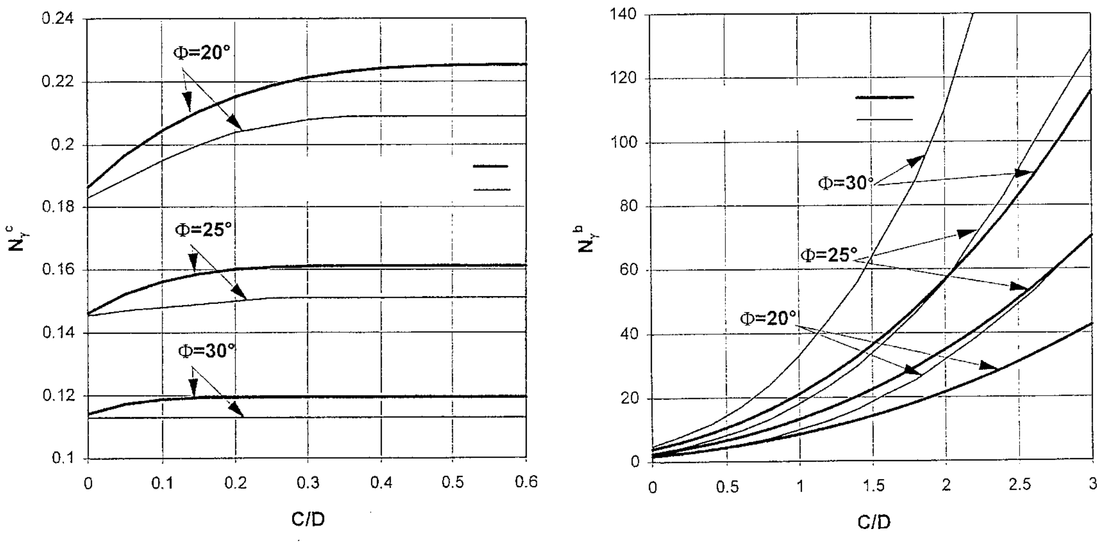
The external forces contributing to the rate of external work consist of (i) the self-weight of the truncated rigid cones; (ii) the surcharge loading σ_s (in case of outcrop of the upper rigid block) and (iii) the pressure σ_t at the face of the tunnel. The rate of energy dissipation occurs along the lateral surfaces and the radial planes of the failure mechanism. The rate of energy dissipation is null in the present case, the soil is assumed to be cohesionless. By equating the total rate of external work to the total rate of internal energy dissipation, one obtains

$$\sigma_t = \gamma D N_\gamma \tag{1}$$

Even though safety against collapse is a major concern during tunneling, the blow-out mechanism may be of interest for very shallow tunnels bored in weak soils, when the pressure σ_t can become so great that soil is heaved in front of the shield.

M2 is a blow-out mechanism. It represents the passive case of the former mechanism. With reference to *M1*, the *M2* mechanism presents an upward movement of the soil mass, thus, the cones with an opening angle 2ϕ are reversed. Contrary to *M1*, the present mechanism always outcrops. As for the *M1* mechanism, by equating the total rate of external work to the total rate of internal energy dissipation, one obtains an equation, which has the same form as equation (1).

NUMERICAL RESULTS AND DISCUSSIONS: Leca and Dormieux [1990] have considered a collapse (respectively blow-out) failure mechanism composed of two (respectively one) truncated rigid cone(s). Fig. (2a) and (2b) show the N_γ values given by the present analysis and the ones given by Leca and Dormieux in both the collapse and the blow-out cases.



(a) (b)

Figure 2 : Comparison of Present N_γ with that of Leca and Dormieux [1990] in the (a) collapse and (b) blow-out cases

These figures clearly show that the present translational failure mechanisms improve the solutions given by Leca and Dormieux [1990] by increasing (respectively reducing) their upper-bound solutions in the collapse (respectively blow-out) case. The present theoretical model improves N_γ factor by 8% in case of collapse when $\phi=20°$ and $C/D>0.55$, the improvement attains 41% in the blow-out case when $\phi=30°$ and $C/D=1.4$.

CONCLUSIONS: The present translational multiblock failure mechanisms allow the slip surface to develop more freely in comparison with the available mechanisms given by Leca and Dormieux [1990] and thus, improve the best upper-bound solutions given by these authors. The improvement is more significant in the case of blow-out.

REFERENCES

Leca, E., and Dormieux, L. 1990, "Upper and lower bound solutions for the face stability of shallow circular tunnels in frictional material". *Géotechnique,* **40**, **4**, pp. 581-606.