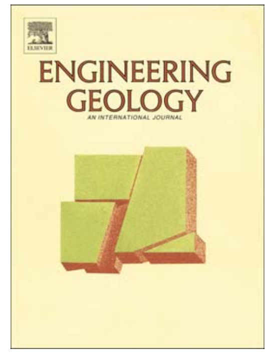
Accepted Manuscript



Analytical and numerical study of the stability of shallow underground circular openings in cohesive ground

Carlos Carranza-Torres, Tyler Reich

PII: S0013-7952(17)30152-7
DOI: doi:10.1016/j.enggeo.2017.05.013
Reference: ENGEO 4576

To appear in: *Engineering Geology*

Received date: 27 January 2017
Revised date: 4 May 2017
Accepted date: 25 May 2017

Please cite this article as: Carranza-Torres, Carlos, Reich, Tyler, Analytical and numerical study of the stability of shallow underground circular openings in cohesive ground, *Engineering Geology* (2017), doi:10.1016/j.enggeo.2017.05.013

Analytical and numerical study of the stability of shallow underground circular openings in cohesive ground

Carlos Carranza-Torres[a,*], Tyler Reich[b]

[a]*Department of Civil Engineering, University of Minnesota Duluth, Minnesota, USA*
[b]*Braun Intertec, Minneapolis, Minnesota, USA*

Abstract

This paper addresses the problem of assessing the stability conditions of shallow excavations of circular shape, namely circular sections of long cylindrical tunnels or spherical cavities, in purely cohesive ground by means of a scalar factor of safety as it is traditionally done for the case of slopes in the practice of geotechnical engineering. The paper presents a closed-form statically admissible solution for cavities in *dry* ground that allows a conservative estimation of the scalar factor of safety to be made. The effects of the geometry of the excavation, whether a section of cylindrical tunnel or a spherical cavity, the depth of the cavity in relation to its radius, and the effect of the support pressure and ground surcharge load in relation to the cohesion of the ground, on the factor of safety are examined. A quantitative analysis for determining how conservative the results from the analytical solution are with respect to results obtained with a commercial software implementing the finite-difference method is presented. The analysis indicates that the values of factors of safety predicted with the analytical solution are within 80% of the values of factors of safety predicted with the numerical (finite-difference) solution. A quantitative comparison of values of factors of safety and required support pressure obtained with the analytical solution and with other published solutions is presented. Factors of safety obtained with Terzaghi (1943) limit equilibrium model are shown to be both conservative and non-conservative depending on the combination of input values considered for the model. Values of required support pressure predicted with the proposed analytical solution are shown to be similar to the ones predicted numerically by Davis et al. (1980). An extension of the proposed statically admissible model to account for water in the ground is also presented. Cases of shallow cavities of circular shape in *saturated* cohesive ground with a water surface at or above the ground surface, and limiting conditions of *flooded* and *dry* openings are considered. Stability conditions for *flooded* openings in saturated ground are shown to generally improve, while stability conditions for *dry* openings in saturated ground are shown to worsen, in comparison with the same equivalent cavities in dry ground.

Keywords: Shallow cavities, stability, factor of safety, limit analysis, limit equilibrium

*Corresponding author
Email address: carranza@d.umn.edu (Carlos Carranza-Torres)