Benchmark Example No. 20

Passive Earth Pressure I

SOFiSTiK | 2024

VERiFiCATiON
BE20 Passive Earth Pressure I

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SOFiSTiK AG

HQ Nuremberg
Flataustraße 14
90411 Nürnberg
Germany

T +49 (0)911 39901-0
F +49(0)911 397904

Office Garching
Parkring 2
85748 Garching bei München
Germany

T +49 (0)89 315878-0
F +49 (0)89 315878-23

info@sofistik.com
www.sofistik.com

Front Cover

6th Street Viaduct, Los Angeles Photo: Tobias Petschke

Overview	
Element Type(s):	C2D
Analysis Type(s):	STAT, MNL
Procedure(s):	LSTP
Topic(s):	SOIL
Module(s):	TALPA
Input file(s):	passive_earth_pressure.dat

1 Problem Description

The problem consists of a soil mass retained by a wall as shown in Fig. 1. The horizontal passive earth pressure is determined and is compared to the value obtained for the case of the soil mass externally forced to its limiting strength.

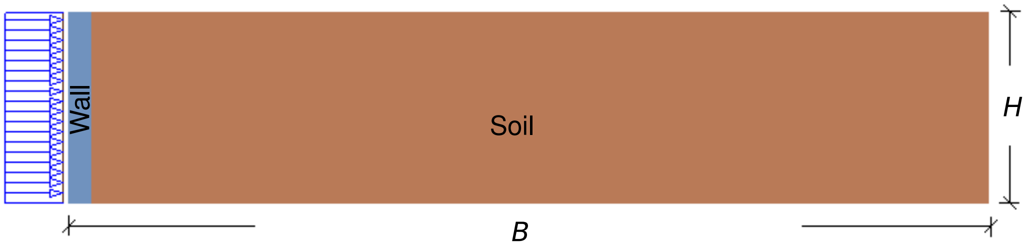

Figure 1: Problem Description

2 Reference Solution

When a retaining wall is forced against a soil mass, lateral passive earth pressure is exerted from the soil to the wall. In order to describe the horizontal component of the pressure the soil will exert, an earth pressure coefficient K_{ph} according to Coulomb theory is used:

$$K_{ph} = \frac{cos^2\,(\phi - \alpha)}{\left(1 - \sqrt{\frac{sin(\phi+\delta_p)\cdot sin(\phi+\beta)}{cos(\alpha+\delta_p)\cdot cos(\alpha+\beta)}}\right)^2 cos^2\alpha}, \tag{1}$$

where the parameters α, ϕ, δ_p and β are defined in Fig. 2. The wall friction angle is denoted by δ_p and the soil friction angle by ϕ. The horizontal passive earth pressure resultant is [1]:

$$E_{ph} = \frac{1}{2}\,\gamma\,H^2\,K_{ph}. \tag{2}$$

In order to account for the development of irreversible strains in the soil, under the action of the passive load, a plasticity model has to be utilised. Whether plasticity occurs in a calculation, can be evaluated with a yield function f, where the condition $f = 0$ stands for the plastic yielding. This condition can be represented as a surface in principal stress space. In this Benchmark, the Mohr-Coulomb model is adopted, which represents an elastic perfectly-plastic behaviour. A perfectly-plastic model corresponds to a fixed yield surface, i.e. a yield surface that is fully defined by model parameters and is not affected by plastic straining. Moreover, for stress state within the yield surface, the behaviour is purely elastic and all strains are reversible. Hence, the Mohr-Coulomb model requires the input of a total of five parameters, the Young's modulus E and Poisson's ratio ν for the definition of the elasticity, and three for the plasticity, the friction angle ϕ, the cohesion c and the dilatancy angle ψ. The dilatancy angle is involved in the plastic potential function and controls the evolution of plastic volumetric strain increments [2].

$$f = \sigma_1 - \frac{1 - sin\phi}{1 + sin\phi} \cdot \sigma_3 - \frac{2c\, cos\phi}{1 + sin\phi}, \tag{3}$$

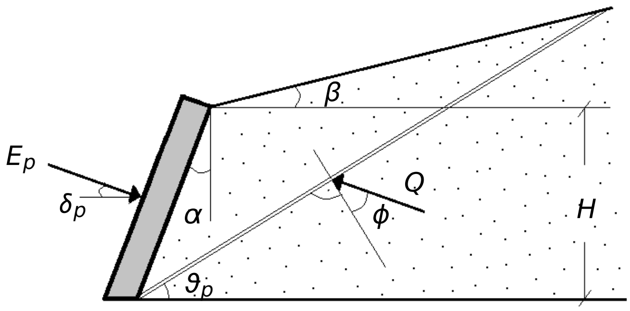

Figure 2: Passive Earth Pressure by Coulomb

The yield function for the Mohr-Coulomb model [2] is defined by Eq. 3, where σ_1 and σ_3 are the principal stresses, and its yield surface is shown in Fig. 3.

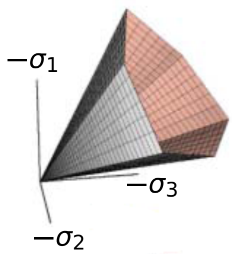

Figure 3: Mohr-Coulomb Yield Surface in Principal Stress Space

3 Model and Results

The properties of the model are defined in Table 1. The Mohr-Coulomb plasticity model is used for the modelling of the soil behaviour. The load is defined as a unit support displacement in the x-direction and is increased gradually until a limit value. It is applied at node 405, which is kinematically coupled with the wall nodes as shown in Fig. 4, and therefore corresponds to a uniformly applied load at the wall nodes. Maximum displacement is recorded for each loading increment, and the curve of horizontal passive earth pressure-displacement (Fig. 5) is plotted against the reference solution according to Coulomb theory.

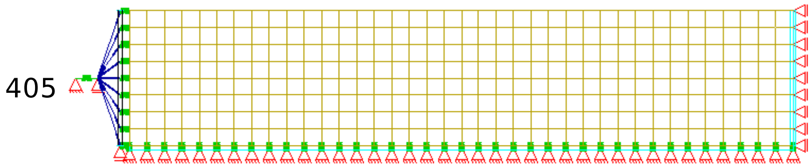

Figure 4: Finite Element Model

Table 1: Model Properties

Material Properties		Geometric Properties		Loading
Wall	Soil	Wall	Soil	
$E = 30000\,MPa$	$E = 300\,MPa$	$B = 0.1\,m$	$B = 30\,m$	$W_x = 1\,mm$
$\nu = 0.18$	$\nu = 0.20$	$H = 0.8\,m$	$H = 6\,m$	
$\gamma = 24\,kN/m^3$	$\gamma = 19\,kN/m^3$			
	$c = 1\,kN/m^2$			
	$\phi = 38°$			
	$\psi = 6°$			
$\delta_p = \phi/3$				

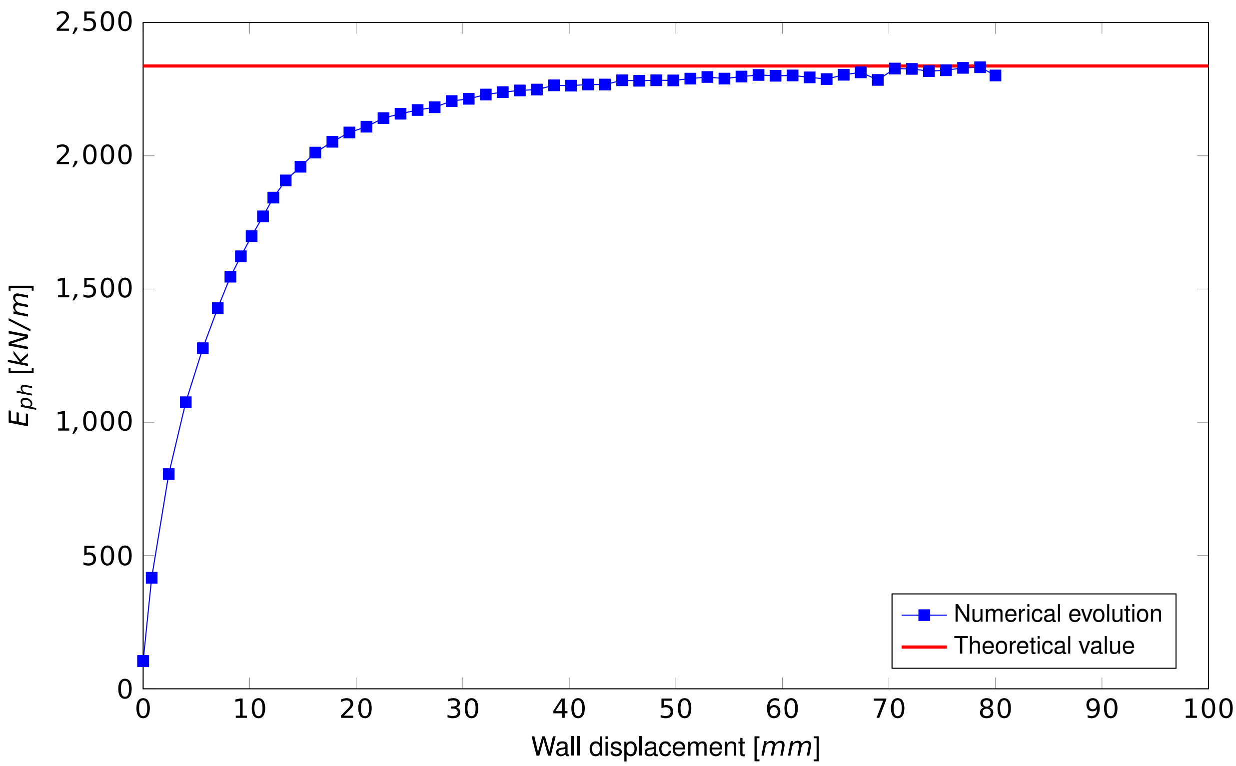

Figure 5: Horizontal Passive Earth Pressure-Displacement Curve

4 Conclusion

This example examines the horizontal passive earth pressure determination for a soil mass retained by a wall. The Mohr-Coulomb model for the definition of the soil material behaviour is adopted. It has been shown that the behaviour of the soil is captured accurately.

5 Literature

[1] K. Holschemacher. *Entwurfs- und Berechnungstafeln für Bauingenieure*. 3rd. Bauwerk, 2007.
[2] *AQUA Manual: Materials and Cross Sections*. Version 18-0. SOFiSTiK AG. Oberschleißheim, Germany, 2017.