M515/CEN/TC250/SC7

BENCHMARKING EXERCISE FOR CALCULATIONS (Fpr)EN 1997:202x

July 2024

Dear colleagues of the European geotechnical community,

Within the process of testing the 2nd generation of the Eurocode 7 it is planned to have a benchmarking exercise for some basic design calculations using the new generation Eurocode 7 documents (available on CEN SC7 documents or your National Standard Body).

Therefore, we are kindly asking you to solve the exercises below (all or only some of them) and **send the solutions by September 15th, 2024**, to the email address: Geert.Kraijema@nen.nl, starting the SUBJECT line with SC7-BENCHMARK-CALCULATIONS. This is needed for a proper selection of the received solutions.

The solutions will be analysed, and the conclusions will be presented at the conference in Paris (21-22.10.2024).

Please disseminate the exercises in your geotechnical engineering community to be solved by as many engineers as possible.

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1 Design example Spread foundation on clay

The purpose of this example is to design the square spread foundation shown in the figure below. having a thickness of 1 m and being embedded at a depth of 1 m.

The design should be done using the second generation of Eurocodes and the default partial factor values. The limiting value of the foundation settlement is 20 mm and the maximum allowable tilt is 1/150. The desired result is the required width of the foundation.

The soil unit weight density was taken as γ =19 kN/m^3. The undrained shear strength c_u = 32kPa.

The one-dimensional stiffness modulus E_0 is 15 MPa.

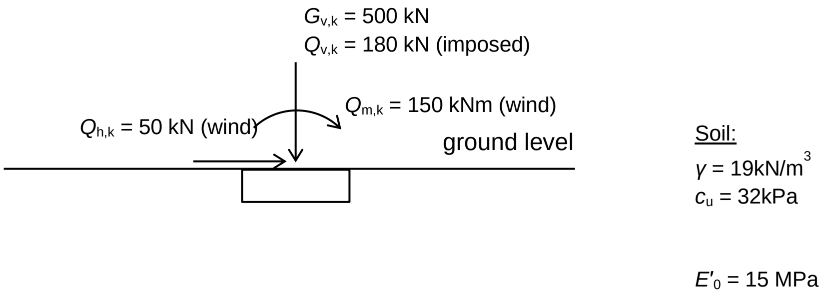

Figure 1 Illustration Example Spread foundation

It is assumed: $K_M = K_F = 1$

The foundation is cast in-place with a rough or ridged base.

The foundation is rigid.

2 Design example Pile foundation designed from static pile load tests

Piles (bored piles, 1.2 m in diameter and 15 m long) are required to support the following loads from a building:

- Characteristic permanent vertical load G_k = 6.0 MN
- Characteristic variable vertical load Q_k = 3.2 MN

The design involves determining the number of piles to support the building according to the 2nd generation of Eurocodes. The number of piles is to be determined on the basis of static pile load tests.

Static pile load tests have been performed on site on four piles of the same diameter and length as the chosen piles.

The results of the load-settlement curves are plotted in the figure below.

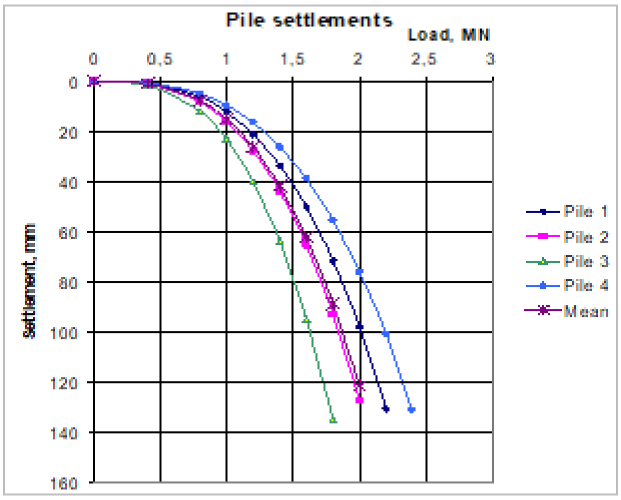

Figure 2 Illustration Example piled foundation

It is assumed K_E = 1

In accordance with 7.6.1.1(3) (actual version of the code EN 1997-1), settlement of the pile top equal to 10% of the pile base diameter s_g = (10/100) x 1.2 x 103 = 120mm has been adopted as the "failure" criterion for the piles. No equivalent regulation could be found in the new version.

3 Design example Pile foundation designed from profiles of ground test results

The load data are the same as in the previous example (2), but the pile resistances have to be calculated based on four ground profiles.0

Piles are required to support the following loads from a building:

Characteristic permanent vertical load Gk = 6.0 MN

Characteristic variable vertical load Qk = 3.2 MN

The design involves determining the number of piles to support the building. The number of piles is to be determined on the basis of calculation and ground test results (Model Pile Method according EN 1997-3, 6.5.3.1 (2)).

It has been decided to use bored piles, 1.2 m in diameter and 15 m long.

It is assumed that the pile resistances are calculated on the basis of four ground profiles.

The calculated pile resistances are as follows:

Profile nr 1 $R_{c,cal,1}$ = 2.14 MN

Profile nr 2 $R_{c,cal,2}$ = 1.96 MN

Profile nr 3 $R_{c,cal,3}$ = 1.73 MN

Profile nr 4 $R_{c,cal,4}$ = 2.33 MN

4 Design example: Gravity wall on silty sand

The purpose of this example is to design, using the 2nd generation of Eurocodes, the width of the mass concrete gravity wall shown in the figure below for adequate ULS against bearing, sliding failures and toppling. Two different design situations are considered:

1) With dry backfill and water table not interfering with the foundation. This design situation is associated to permanent loads and the partial safety factors imposed by default in EC7-1 are to be used.

2) With a given level of water table in the backfill, assuming a malfunctioning of the drainage system behind the wall and the absence or sealing of weep holes.

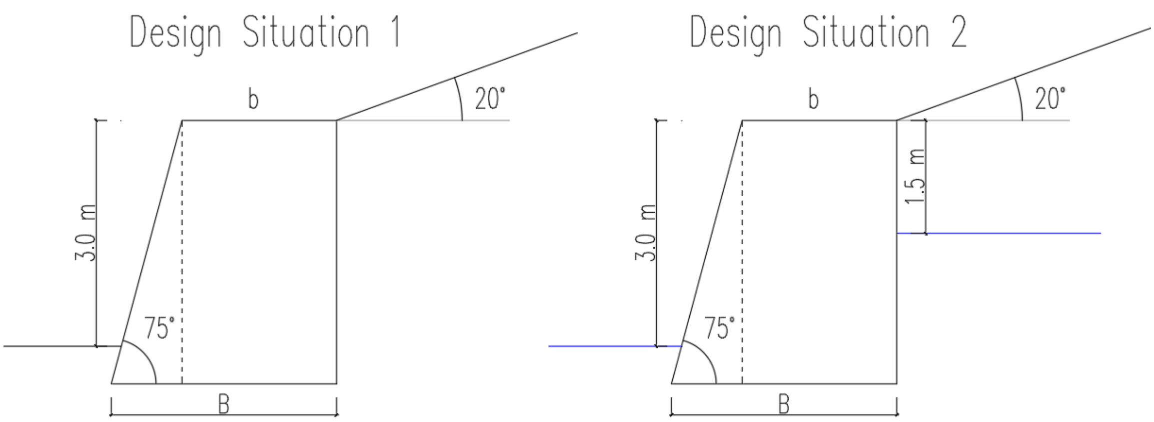

Figure 3 Illustration Example Gravity wall on silty sand

The following assumptions were made for both design situations:

- → weight density of the in-situ and backfill silty sand: $\gamma_t = 17kN/m^3$;
- → weight density of the concrete wall: $\gamma_t = 24\ kN/m^3$;
- → effective angle of internal friction of the ground: $\varphi'_k = 30°$;
- → retaining wall height: $H = 3{,}5\ m$;
- → front face inclination of the wall: $\alpha = 75°$;
- → slope inclination: $\beta = 20°$;
- → depth of wall embedment: $0.5m$;
- → normal consequence class (CC2);
- → back of wall / interface ratio: $\delta/\phi = 0.66$;
- → base of wall / interface ratio: $\delta/\ \phi = 1.0$;
- → no passive earth pressure was considered;

The following additional assumptions were made for design situation 2, where a water table is considered:

- → groundwater at ground level at the forefront of the wall;
- → base uplift water pressure (with trapezoidal distribution);
- → soil in free-draining condition;
- → seepage water flow under the effect of a hydraulic gradient;
- → no passive water pressure was considered;

5 Design example: Single propped embedded retaining wall - Drained conditions

The purpose of this example is to design, using the 2nd generation of EN 1990, EN 1997-1 and EN 1997-3 the embedded retaining wall shown in the figure below. The design requires the determination of an embedment depth, *d* and structural forces including bending moment, shear force and prop force. The design will be undertaken using the material factor approach (MFA) and the resistance factor approach (RFA).

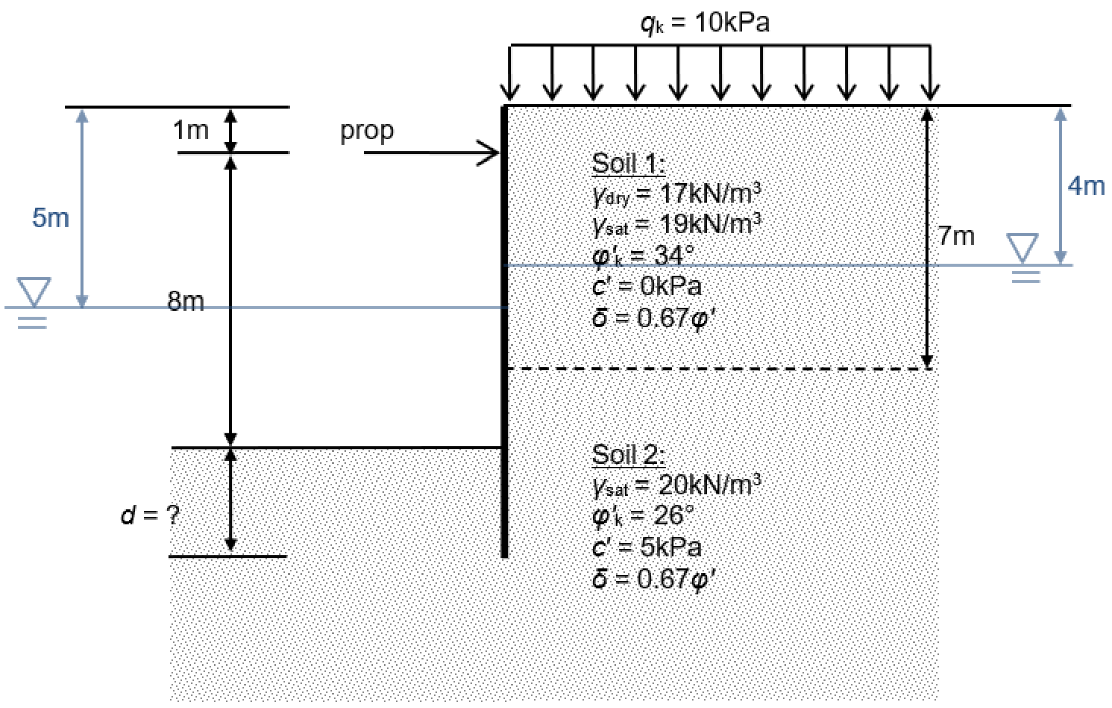

Figure 4 Illustration Example Embedded retaining structure

The wall can be analysed using the limit equilibrium calculation and/or a soil structure interaction analysis (SSI).

The soil parameters given in the problem definition are assumed to be representative values. The water level is assumed to be 4m below ground level on the retained side and 5m below ground level of the excavation side. As the excavation depth is 9m, a 4m depth of standing water is assumed on the excavation side.

For the SSI analysis the following additional parameters are required:

- Soil 1
  - Young's modulus = 25+2.5z MPa, where z is the depth below top of layer
  - K_0 = 0.44, based on Jaky formula
  - ν' = 0.2
- Soil 2

    - Young's modulus = 25+2.5z MPa, where z is the depth below top of layer
    - K_0 = 1.0, assuming over consolidated clay
    - v' = 0.2
- Structural properties
    - Wall bending stiffness EI = 1,700 MNm^2
    - A constant wall length of 18m was assumed for the SSI analysis
    - Prop stiffness = $1x10^5$ kN/m/m

The design example is defined as a drained analysis (with effective strength parameters).

6 Design example: Spread foundation on rock mass

The purpose of this example is to design a strip footing with an assumed thickness of 1.0 m, founded on a rock mass considered as a continuum medium, to support the actions shown in the figure below, applied at the top of the foundation. No ground inclination is present near the foundation. Nominal width of the foundation is assumed to be 4.0 m. The footing is composed of reinforced concrete with a unit weight of 25 kN/m^3. The permanent action is a vertical force, and the variable actions are a vertical force and a variable moment. No measures are specified for controlling the dimensions of the foundation during execution (assuming a possible deviation of 0.1 m).

The structure is assigned to consequence class CC3.

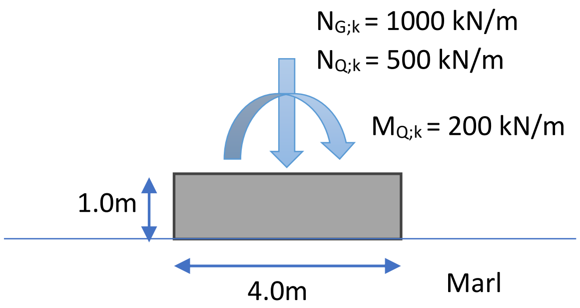

Figure 5 Illustration Example Spread foundation on rock mass

The design is based on the second generation of EN 1997 with recommended values of partial factors. No requirements for settlement limitation were defined.

The ground at the site is composed of a homogeneous marl rock mass to a significant depth, beyond the expected zone of influence of the foundation, with no water table. No relevant individual rock discontinuities occur in the zone of influence of the foundation that could form a failure mechanism, and thus the rock mass is considered as an equivalent continuous medium.

The Hoek-Brown strength envelope and the Geological Strength Index (GSI) were considered to characterize the rock mass. The following characteristic values of parameters for the rock material within the zone of influence of the foundation were assumed as representative in the design:

Geological Strength Index	GSI	40	[-]
Uniaxial compressive strength of intact rock	σ_{ci}	5.0	[MPa]
Non-dimensional material parameter	m_i	7	[-]
Disturbance factor	D	0	[-]