Geotechnical Design to Eurocode 7

Session 6:

Spread Foundations Design

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Consulting

Spread foundations design

Covered in Section 6 of Eurocode 7 Part 1

The limit states to be considered are listed in § 6.2(1)P and are:

- loss of overall stability;
- bearing resistance failure, punching failure, squeezing;
- failure by sliding;
- combined failure in the ground and in the structure;
- structural failure due to foundation movement;
- excessive settlements;
- excessive heave due to swelling, frost and other causes;
- unacceptable vibrations.

EN 1997-1:2004 § 6.2(1)P

Spread foundations design

- ultimate limit state design – bearing resistance
- serviceability limit state design – settlement

Note the use of the term ***bearing resistance*** as opposed to ***bearing capacity***

Spread foundations design

1 of 3 design methods to be used for spread foundations:

(5)P One of the following design methods shall be used for spread foundations:
— a **direct method**, in which separate analyses are carried out for each limit state. When checking against an ultimate limit state, the calculation shall model as closely as possible the failure mechanism, which is envisaged. When checking against a serviceability limit state, a settlement calculation shall be used;

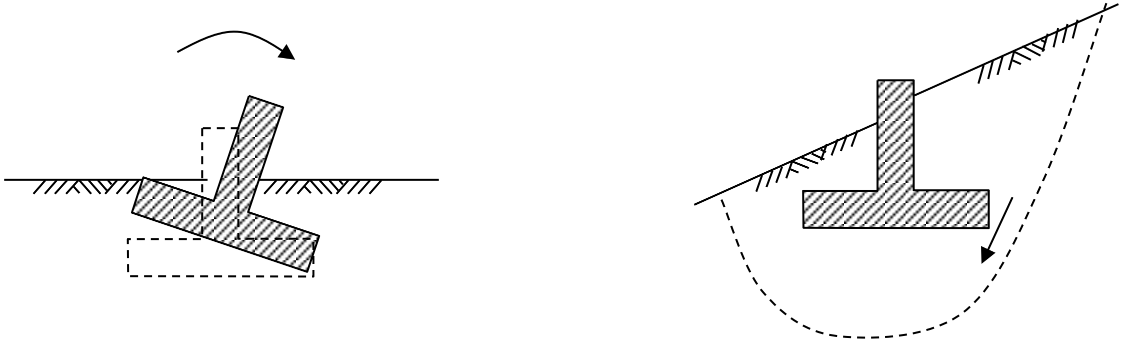
— an **indirect method** using comparable experience and the results of field or laboratory measurements or observations, and chosen in relation to serviceability limit state loads so as to satisfy the requirements of all relevant limit states;

— a **prescriptive method** in which a presumed bearing resistance is used (see 2.5).

EN 1997-1:2004 § 6.4(5)P

Ultimate limit states

Overall stability

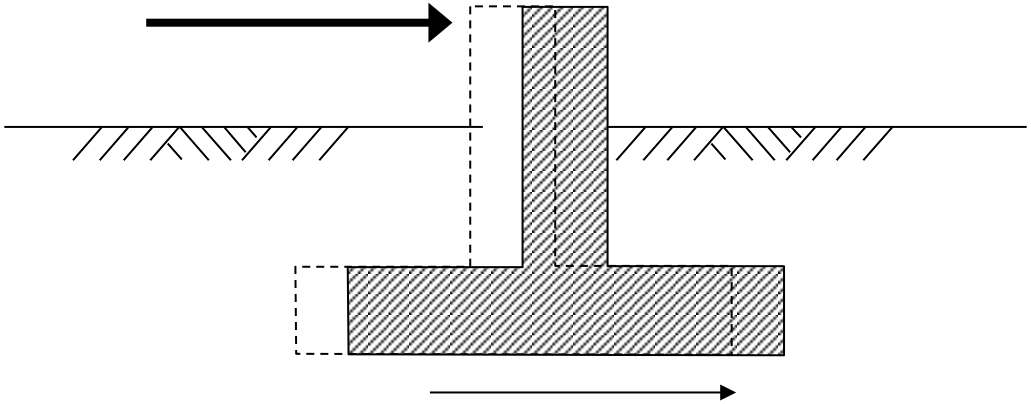


(a) localised loss of stability

(b) failure of ground mass

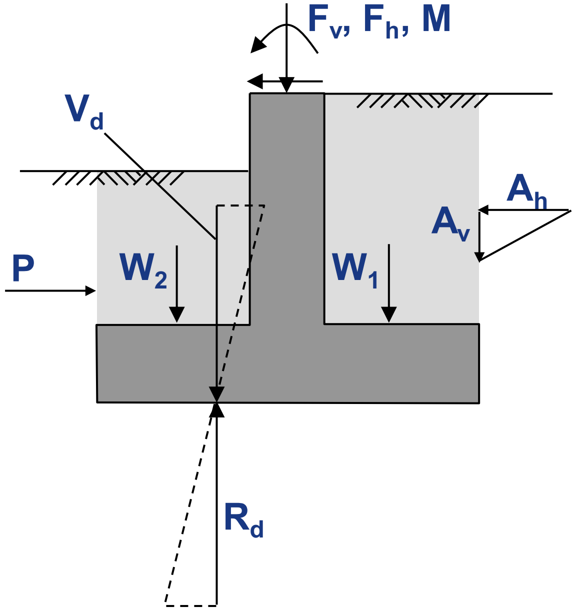
Ultimate limit states

Sliding



Ultimate limit states

Bearing resistance



GEO Limit state: $V_d \leq R_d$

Revision: bearing capacity

General bearing capacity equation

$$q_u = cN_c s_c i_c d_c + \gamma z N_q s_q i_q d_q + \tfrac{1}{2}\gamma B N_\gamma s_\gamma i_\gamma d_\gamma$$

where

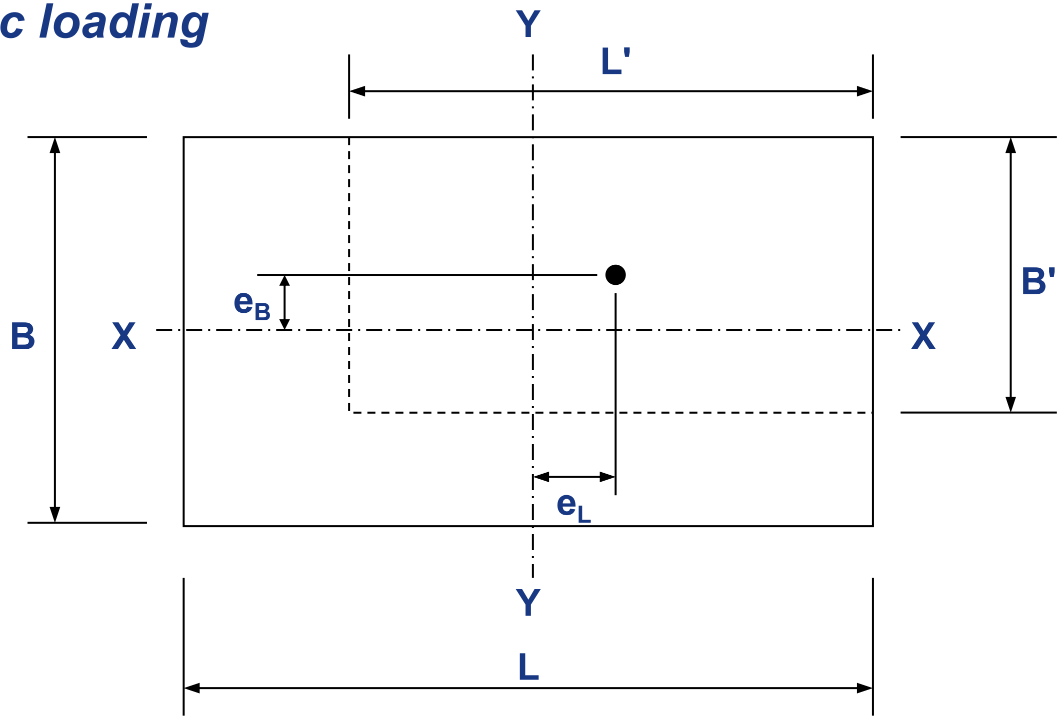
q_u is the ultimate bearing capacity of the soil;
N_c, N_q and N_γ are the bearing capacity factors (related to ϕ);
c is the apparent cohesion;
B is the foundation width;

s_c, s_q, s_γ are shape factors;
i_c, i_q, i_γ are inclination factors; and
d_c, d_q, d_γ are depth factors.

Formulae exist to determine N_c, N_q and N_γ.

Revision: bearing capacity

Eccentric loading



$$A' = L' \times B'$$
$$L' = L - 2e_L$$
$$B' = B - 2e_B$$

$$e = \frac{P \times e_P}{P + W}$$

Bearing resistance: Annex D

Undrained:

$$R = A'\left((\pi + 2)c_u b_c s_c i_c + q\right)$$

Drained:

$$R = A'\left(c'\ N_c\ b_c\ s_c\ i_c + q'\ N_q\ b_q\ s_q\ i_q + 0.5\ \gamma\ B'\ N_\gamma\ b_\gamma\ s_\gamma\ i_\gamma\right)$$

Bearing capacity factors

ϕ (°)	N_c	N_q	N_γ
0	5.14	1.00	0.00
5	6.49	1.57	0.1
10	8.34	2.47	0.52
15	10.98	3.94	1.58
20	14.83	6.40	3.93
25	20.72	10.66	9.01
30	30.14	18.40	20.09
35	46.12	33.30	45.23
40	75.31	64.20	106.05
45	133.87	134.87	267.75
50	266.88	319.06	758.09

Example 6.1: GEO, DA1

Example 9.5 from Elements of soil mechanics, 9th Edition

Bearing resistance: Undrained

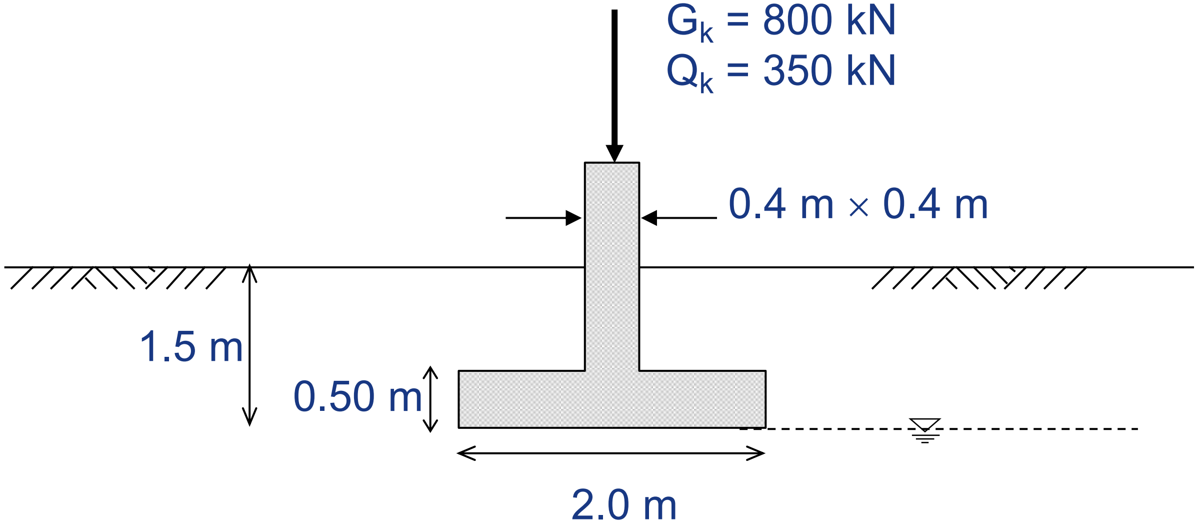
A continuous footing is 1.8 m wide by 0.5 m deep and is founded at a depth of 0.75 m in a clay soil of unit weight 20 kN/m^3 with $\phi_u = 0^\circ$ and $c_u = 30$ kPa. The foundation is to carry a vertical line load of magnitude 50 kN which will act at a distance of 0.4 m from the centre-line. Take the weight density of concrete, γ_{concrete} as 24 kN/m^3.

Check the Eurocode 7 GEO limit state using Design Approach 1.

Example 6.2: GEO, DA1

Example 9.7 from Elements of soil mechanics, 9th Edition

Bearing resistance: Undrained and drained (i.e. short- and long- term)

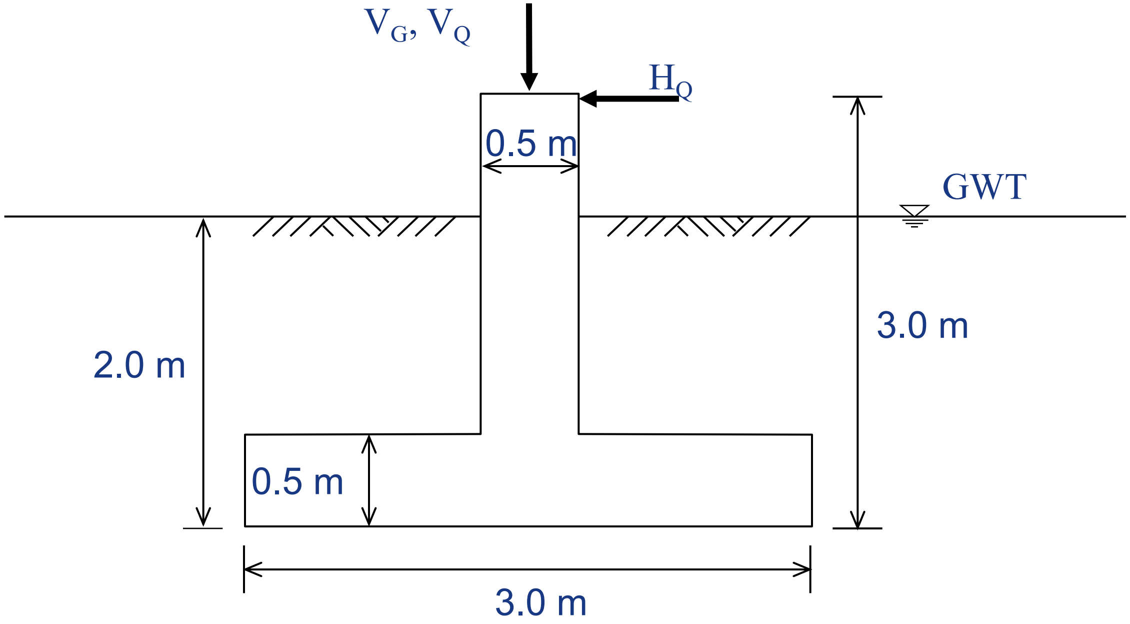


c_u = 200 kPa
c' = 0
ϕ' = 28°
γ = 20 kN/m^3
γ_{conc} = 25 kN/m^3

Example 6.3

Example 9.8 from Elements of soil mechanics, 9th Edition

Bearing resistance: vertical and horizontal loading



$V_{G;k} = 800$ kN
$V_{Q;k} = 400$ kN
$H_{Q;k} = 100$ kN

$c' = 0$
$\phi' = 30°$
$\gamma = 19$ kN/m^3
$\gamma_{conc} = 24$ kN/m^3

Sliding resistance

The principles we used when we looked at the sliding resistance of gravity retaining walls apply here and EN 1997-1:2004 § 6.5.3 gives guidance:

(2)P The following inequality shall be satisfied:

$$H_d \leq R_d + R_{p;d}$$

EN 1997-1:2004 § 6.5.3(2)P

(8)P For drained conditions, the design shear resistance, *R*d, shall be calculated either by factoring the ground properties or the ground resistance as follows;

$$R_d = V'_d \tan \delta_d$$

or

$$R_d = (V'_d \tan \delta_k) / \gamma_{R;h}$$

EN 1997-1:2004 § 6.5.3(8)P

Serviceability limit state

All partial factors on actions and material properties in a serviceability limit state analysis have value of unity.

i.e. $\gamma_F = \gamma_M = 1.0$

— s_0: immediate settlement; for fully-saturated soil due to shear deformation at constant volume, and for partially-saturated soil due to both shear deformation and volume reduction;

— s_1: settlement caused by consolidation;

— s_2: settlement caused by creep.

Serviceability limit state

(16) For conventional structures founded on clays, the ratio of the bearing capacity of the ground, at its initial undrained shear strength, to the applied serviceability loading should be calculated (see 2.4.8(4)). If this ratio is less than 3, calculations of settlements should always be undertaken. If the ratio is less than 2, the calculations should take account of non-linear stiffness effects in the ground.

EN 1997-1:2004 §6.6.2

Clause 6.6.2(16) above shows that a settlement analysis need not be carried out if the following inequality is satisfied:

$$V_k \leq \frac{R_k}{3}$$

Example 6.4: SLS check

Example 11.8 from Elements of soil mechanics, 9th Edition

Perform the serviceability limit state check for the footing of Example 6.3 by checking the total settlement against the allowable settlement of 25mm.

Assume the design modulus of elasticity, E_m = 60 MPa and coefficient of volume compressibility, m_v = 0.04 m^2/MN and the soil to be homogenous to a depth beyond 6m.