Spread footing verification

Input data

Project
Date : 28.10.2015

Settings
(input for current task)

Materials and standards
Concrete structures : EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1 : standard

Settlement
Analysis method : Analysis using oedometric modulus
Restriction of influence zone : based on structural strength

Spread Footing
Analysis for drained conditions : Standard approach
Analysis of uplift : Standard
Allowable eccentricity : 0,333
Verification methodology : Safety factors (ASD)

<table>
<thead>
<tr>
<th>Safety factors</th>
<th>Permanent design situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety factor for vertical bearing capacity :</td>
<td>SF_v = 1,50 [-]</td>
</tr>
<tr>
<td>Safety factor for sliding resistance :</td>
<td>SF_h = 1,50 [-]</td>
</tr>
</tbody>
</table>

Basic soil parameters

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Pattern</th>
<th>$\varphi_{ef}$ [°]</th>
<th>$c_{ef}$ [kPa]</th>
<th>$\gamma$ [kN/m$^3$]</th>
<th>$\gamma_{su}$ [kN/m$^3$]</th>
<th>$\delta$ [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soil No. 1</td>
<td></td>
<td>31,50</td>
<td>0,00</td>
<td>17,50</td>
<td>7,50</td>
<td>0,00</td>
</tr>
<tr>
<td>2</td>
<td>Soil No. 2</td>
<td></td>
<td>45,00</td>
<td>100,00</td>
<td>22,00</td>
<td>12,00</td>
<td>0,00</td>
</tr>
</tbody>
</table>

Soil parameters to compute pressure at rest

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type calculation</th>
<th>$\varphi_{ef}$ [°]</th>
<th>$\nu$ [-]</th>
<th>OCR [-]</th>
<th>$K_r$ [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soil No. 1</td>
<td>cohesive</td>
<td>-</td>
<td>0,30</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Soil No. 2</td>
<td>cohesive</td>
<td>-</td>
<td>0,20</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Soil parameters

**Soil No. 1**
Unit weight : $\gamma = 17,50$ kN/m$^3$
Angle of internal friction : $\varphi_{ef} = 31,50$ °
Cohesion of soil : $c_{ef} = 0,00$ kPa
Deformation modulus : $E_{def} = 21,00$ MPa
Poisson's ratio : $\nu = 0,30$
Coeff. of structural strength : $m = 0,30$
Saturated unit weight : $\gamma_{sat} = 17,50$ kN/m$^3$

**Soil No. 2**
Unit weight : $\gamma = 22,00$ kN/m$^3$
Angle of internal friction: \( \varphi_{ef} = 45,00 \, ^\circ \)
Cohesion of soil: \( c_{ef} = 100,00 \) kPa
Deformation modulus: \( E_{def} = 1000,00 \) MPa
Poisson's ratio: \( \nu = 0,20 \)
Coeff. of structural strength: \( m = 0,30 \)
Saturated unit weight: \( \gamma_{sat} = 22,00 \) kN/m\(^3\)

Foundation

**Foundation type: centric spread footing**

Depth from original ground surface \( h_z = 2,00 \) m
Depth of footing bottom \( d = 1,20 \) m
Foundation thickness \( t = 0,40 \) m
Incl. of finished grade \( s_1 = 0,00 \) \(^\circ\)
Incl. of footing bottom \( s_2 = 0,00 \) \(^\circ\)

Unit weight of soil above foundation = 20,00 kN/m\(^3\)

Geometry of structure

**Foundation type: centric spread footing**

Spread footing length \( x = 1,50 \) m
Spread footing width \( y = 1,50 \) m
Column width in the direction of \( x \) \( c_x = 0,40 \) m
Column width in the direction of \( y \) \( c_y = 0,40 \) m
Spread footing volume \( = 0,90 \) m\(^3\)
Material of structure

Unit weight $\gamma = 23.00$ kN/m$^3$
Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

Concrete: C20/25
Cylinder compressive strength $f_{ck} = 20.00$ MPa
Tensile strength $f_{ctm} = 2.20$ MPa
Elasticity modulus $E_{cm} = 30000.00$ MPa

Longitudinal steel: B500
Yield strength $f_{yk} = 500.00$ MPa

Transverse steel: B500
Yield strength $f_{yk} = 500.00$ MPa
Geological profile and assigned soils

<table>
<thead>
<tr>
<th>No.</th>
<th>Layer [m]</th>
<th>Assigned soil</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,00</td>
<td>Soil No. 1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>Soil No. 2</td>
<td></td>
</tr>
</tbody>
</table>

Name: Profile and assignment

Stage - analysis : 1 - 0

Load

<table>
<thead>
<tr>
<th>No.</th>
<th>Load new</th>
<th>Load change</th>
<th>Name</th>
<th>Type</th>
<th>N [kN]</th>
<th>Mx [kNm]</th>
<th>My [kNm]</th>
<th>Hx [kN]</th>
<th>Hy [kN]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td></td>
<td>Load No. 1</td>
<td>Design</td>
<td>910,00</td>
<td>-2,00</td>
<td>70,00</td>
<td>14,00</td>
<td>5,00</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td></td>
<td>Load No. 2</td>
<td>Design</td>
<td>820,00</td>
<td>0,00</td>
<td>-100,00</td>
<td>0,00</td>
<td>0,00</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td></td>
<td>Load No. 3</td>
<td>Service</td>
<td>700,00</td>
<td>0,00</td>
<td>0,00</td>
<td>100,00</td>
<td>0,00</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td></td>
<td>Load No. 4</td>
<td>Service</td>
<td>700,00</td>
<td>100,00</td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
</tr>
</tbody>
</table>

Surface surcharges in the vicinity of footing

<table>
<thead>
<tr>
<th>No.</th>
<th>Surcharge new</th>
<th>Surcharge change</th>
<th>Name</th>
<th>x [m]</th>
<th>y [m]</th>
<th>q [kPa]</th>
<th>α [°]</th>
<th>h [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td></td>
<td>Surcharge No. 1</td>
<td>3,00</td>
<td>0,00</td>
<td>2,00</td>
<td>2,00</td>
<td>15,00</td>
</tr>
</tbody>
</table>

Ground water table

The ground water table is at a depth of 4,00 m from the original terrain.

Global settings

Type of analysis : analysis for drained conditions
Settings of the stage of construction
Design situation: permanent

Verification No. 1
Load case verification

<table>
<thead>
<tr>
<th>Name</th>
<th>$e_x$ [m]</th>
<th>$e_y$ [m]</th>
<th>$\sigma$ [kPa]</th>
<th>$R_d$ [kPa]</th>
<th>Utilization [%]</th>
<th>Is satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load No. 1</td>
<td>-0.07</td>
<td>0.00</td>
<td>470.40</td>
<td>11233.98</td>
<td>6.28</td>
<td>Yes</td>
</tr>
<tr>
<td>Load No. 2</td>
<td>0.11</td>
<td>0.00</td>
<td>458.43</td>
<td>11423.46</td>
<td>6.02</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Analysis carried out with automatic selection of the most unfavourable load cases.

Computed weight of spread footing $G = 20.70$ kN
Computed weight of overburden $Z = 33.44$ kN

Vertical bearing capacity check
Shape of contact stress: rectangle
Most severe load case No. 1. (Load No. 1)

Parameters of slip surface below foundation:
Depth of slip surface $z_{sp} = 2.85$ m
Length of slip surface $l_{sp} = 9.39$ m

Design bearing capacity of found. soil $R_d = 11233.98$ kPa
Extreme contact stress $\sigma = 470.40$ kPa

Factor of safety $= 23.88 > 1.50$

**Bearing capacity in the vertical direction is SATISFACTORY**

Verification of load eccentricity
Max. eccentricity in direction of base length $e_x = 0.076 < 0.333$
Max. eccentricity in direction of base width $e_y = 0.000 < 0.333$
Max. overall eccentricity $e_t = 0.076 < 0.333$

**Eccentricity of load is SATISFACTORY**

Horizontal bearing capacity check
Most severe load case No. 1. (Load No. 1)
Earth resistance: at rest
Design magnitude of earth resistance $S_{pd} = 5.01$ kN
Horizontal bearing capacity $R_{dh} = 595.84$ kN
Extreme horizontal force $H = 14.87$ kN

Factor of safety $= 40.08 > 1.50$

**Bearing capacity in the horizontal direction is SATISFACTORY**

**Bearing capacity of foundation is SATISFACTORY**
**Verification No. 2**

**Load case verification**

<table>
<thead>
<tr>
<th>Name</th>
<th>$e_x$ [m]</th>
<th>$e_y$ [m]</th>
<th>$\sigma$ [kPa]</th>
<th>$R_d$ [kPa]</th>
<th>Utilization [%]</th>
<th>Is satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load No. 1</td>
<td>-0,07</td>
<td>0,00</td>
<td>470,40</td>
<td>11233,98</td>
<td>6,28</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Analysis carried out for the load case No. 1. (Load No. 1)

Computed weight of spread footing $G = 20,70$ kN
Computed weight of overburden $Z = 33,44$ kN

**Vertical bearing capacity check**

Shape of contact stress: rectangle

Parameters of slip surface below foundation:
Depth of slip surface $z_{sp} = 2,85$ m
Length of slip surface $l_{sp} = 9,39$ m

Design bearing capacity of found.soil $R_d = 11233,98$ kPa

Factor of safety $= 23,88 > 1,50$

**Bearing capacity in the vertical direction is SATISFACTORY**

**Verification of load eccentricity**

Max. eccentricity in direction of base length $e_x = 0,045 < 0,333$
Max. eccentricity in direction of base width $e_y = 0,000 < 0,333$
Max. overall eccentricity $e_t = 0,045 < 0,333$

**Eccentricity of load is SATISFACTORY**
**Horizontal bearing capacity check**

Earth resistance: at rest  
Design magnitude of earth resistance \( S_{pd} = 5,01 \text{ kN} \)

Horizontal bearing capacity \( R_{dh} = 595,84 \text{ kN} \)  
Extreme horizontal force \( H = 14,87 \text{ kN} \)

Factor of safety = 40,08 > 1,50  
**Bearing capacity in the horizontal direction is SATISFACTORY**

**Bearing capacity of foundation is SATISFACTORY**

**Verification No. 1**

**Settlement and rotation of foundation - input data**

Analysis carried out with automatic selection of the most unfavourable load cases.  
Analysis carried out with accounting for coefficient \( k_1 \) (influence of foundation depth).  
Stress at the footing bottom considered from the finished grade.

Computed weight of spread footing \( G = 20,70 \text{ kN} \)  
Computed weight of overburden \( Z = 33,44 \text{ kN} \)

Settlement of mid point of edge \( x - 1 = 5,5 \text{ mm} \)  
Settlement of mid point of edge \( x - 2 = 2,5 \text{ mm} \)  
Settlement of mid point of edge \( y - 1 = 4,0 \text{ mm} \)  
Settlement of mid point of edge \( y - 2 = 4,0 \text{ mm} \)  
Settlement of foundation center point = 7,5 mm  
Settlement of characteristic point = 5,1 mm

(1-max.compressed edge; 2-min.compressed edge)

**Settlement and rotation of foundation - results**

**Foundation stiffness:**  
Computed weighted average modulus of deformation \( E_{def} = 336,54 \text{ MPa} \)

Foundation in the longitudinal direction is rigid \( (k=1,69) \)  
Foundation in the direction of width is rigid \( (k=1,69) \)

**Verification of load eccentricity**

Max. eccentricity in direction of base length \( e_x = 0,035<0,333 \)  
Max. eccentricity in direction of base width \( e_y = 0,088<0,333 \)  
Max. overall eccentricity \( e_t = 0,088<0,333 \)

**Eccentricity of load is SATISFACTORY**

**Overall settlement and rotation of foundation:**

Foundation settlement = 5,1 mm  
Depth of influence zone = 2,80 m

Rotation in direction of \( x = 0,799 \text{ (tan*1000); } (3,9E-02 °) \)  
Rotation in direction of \( y = 1,998 \text{ (tan*1000); } (6,3E-02 °) \)
Dimensioning No. 1

Analysis carried out with automatic selection of the most unfavourable load cases.

Verification of longitudinal reinforcement of foundation in the direction of x

Bar diameter = 22.0 mm
Number of bars = 10
Reinforcement cover = 35.0 mm
Cross-section width = 1.50 m
Cross-section depth = 0.40 m
Reinforcement ratio $\rho = 0.72 \% > 0.13 \% = \rho_{\text{min}}$
Position of neutral axis $x = 0.10 \text{ m} < 0.22 \text{ m} = x_{\max}$
Ultimate moment $M_{Rd} = 516.78 \text{ kNm} > 115.81 \text{ kNm} = M_{Ed}$

Cross-section is SATISFACTORY.

Verification of longitudinal reinforcement of foundation in the direction of y

Bar diameter = 22.0 mm
Number of bars = 8
Reinforcement cover = 35.0 mm
Cross-section width = 1.50 m
Cross-section depth = 0.40 m
Reinforcement ratio $\rho = 0.57 \% > 0.13 \% = \rho_{\text{min}}$
Position of neutral axis $x = 0.08 \text{ m} < 0.22 \text{ m} = x_{\max}$
Ultimate moment $M_{Rd} = 424.35 \text{ kNm} > 103.59 \text{ kNm} = M_{Ed}$

Cross-section is SATISFACTORY.

Spread footing for punching shear failure check

Column normal force = 820.00 kN
**Maximum resistance at the column perimeter**

- Force transmitted into found. soil $F_0 = 58,31$ kN
- Force transmitted by shear strength of SRC $F_{SR} = 761,69$ kN
- Considered column perimeter $u_0 = 1,60$ m
- Shear resistance at the column perimeter $v_{Ed,max} = 2,05$ MPa
- Resistance at the column perimeter $v_{Rd,max} = 2,94$ MPa

**Critical section without shear reinforcement**

- Force transmitted into found. soil $F_0 = 293,80$ kN
- Force transmitted by shear strength of SRC $F_{SR} = 526,20$ kN
- Distance of section from the column $u = 0,27$ m
- Section perimeter $u = 3,27$ m
- Shear stress at section $v_{Ed} = 0,61$ MPa
- Shear resistance of section without shear reinforcement $v_{Rd,c} = 1,31$ MPa

$v_{Ed} < v_{Rd,c} \Rightarrow$ Reinforcement is not required

**Spread footing for punching shear is SATISFACTORY**

<table>
<thead>
<tr>
<th>Name: Dimensioning</th>
<th>Stage - analysis : 1 - 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan:</td>
<td>Punching shear - critical section:</td>
</tr>
<tr>
<td><img src="image" alt="Plan" /></td>
<td><img src="image" alt="Punching shear" /></td>
</tr>
<tr>
<td>Section A-A:</td>
<td>Section B-B:</td>
</tr>
<tr>
<td>10 pc prof. 22,0mm length 1430mm, concrete cover 35mm</td>
<td>8 pc prof. 22,0mm length 1430mm, concrete cover 35mm</td>
</tr>
</tbody>
</table>