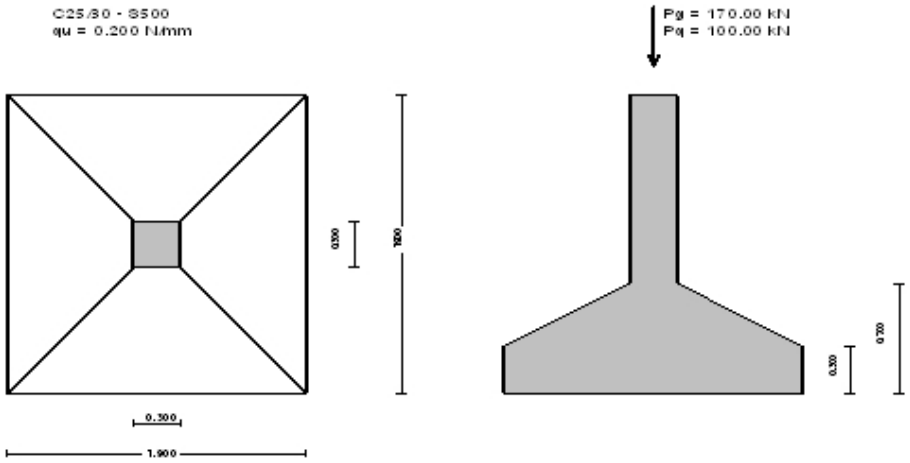
Example of footings

1. FOOTING-001

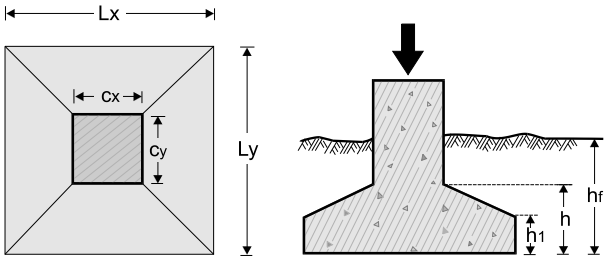
Symmetric footing with centric load

(EC2 EN1992-1-1:2004, EC0 EN1990-1-1:2002, EC7 EN1997-1-1:2004)



Concrete-Steel class: C25/30-S500 (EC2 §3)
Concrete cover : Cnom=75 mm (EC2 §4.4.1)
Concrete weight : 25.0 kN/m³
γc=1.50, γs=1.15 (EC2 Table 2.1N)

1.1. Dimensions, materials, loads



Dimensions

Footing	Lx= 1.900 m	Ly= 1.900 m
Column	cx= 0.300 m	cy= 0.300 m
Heights	h= 0.700 m	h1= 0.300 m
Depth of footing		hf= 1.200 m
Base area of footing		A= 3.61 m²
Volume of footing		V= 1.65 m³

Materials of footing

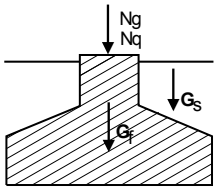
Concrete-Steel class: C25/30-S500 (EN1992-1-1, §3)
Concrete cover: Cnom=75 mm (EC2 §4.4.1)
Effective depth of cross section d=h-d1, d1=Cnomc+(3/2)Ø=75+3x12/2=93mm, d=700-93=607mm

Soil

Soil bearing pressure qu= 0.200 N/mm² (MPa)
Unit weight of soil γ=17.000 kN/m³

Loads

Self weight of footing	[1.65x25.00]	Gf=	41.25 kN
Soil weight on footing	[(3.61x 1.20- 1.65)x17.00]	Gs=	45.59 kN
Vertical permanent load		Ng=	170.00 kN
Vertical variable load		Nq=	100.00 kN



1.2. Eurocode parameters

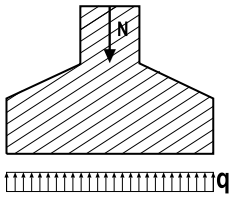
Check of soil bearing capacity (EC7 EN1997-1-1:2004, §6)
Partial factors for actions and soil properties (EC7 Tables A.1-A.4, EC8-5 §3.1)
Equilibrium limit state (EQU), Structural limit state (STR), Geotechnical limit state (GEO)

				(EQU)	(STR)	(GEO)
Actions	Permanent	Unfavourable	γGdst:	1.10	1.35	1.00
	Permanent	Favourable	γGstb:	0.90	1.00	1.00
	Variable	Unfavourable	γQdst:	1.50	1.50	1.30
	Variable	Favourable	γQstb:	0.00	0.00	0.00
Soil parameters	Angle of shearing resistance		γφ:	1.25	1.00	1.25
	Effective cohesion		γc:	1.25	1.00	1.25
	Undrained shear strength		γcu:	1.40	1.00	1.40
	Unconfined strength		γqu:	1.40	1.00	1.40
	Weight density		γw:	1.00	1.00	1.00

Partial safety factors for actions : γG=1.35, γQ=1.50 (EC0 Annex A1)
Combination of accidental actions :(EC7) ψ2 =0.30
Combination of accidental actions :(EC2) ψ2 =0.30

Design of reinforced concrete (EC2 EN1992-1-1:2004)

1.3. Check of soil bearing capacity (EC7 EN1997-1-1:2004, §6)



1.3.1. (EQU), 1.10xPermanent + 1.50xVariable (EC7 §2.4.7.2)

Design Loads
Nsd = 1.10x 256.84+1.50x 100.00= 432.52 kN
Soil pressure q=0.001x432.52/(1.900x1.900)=0.120 N/mm²(Mpa)
Check bearing resistance failure Vd<=Rd (EC7 EN1997-1-1:2004, §6.5.2)
Design effective foundation area A=1.900x1.900=3.61 m² (EC7 Annex D)
Design bearing resistance of footing Rd=1000x3.61x0.200/1.40=515.71 kN > Vd=432.52 kN

1.3.2. (STR), 1.35xPermanent + 1.50xVariable (EC7 §2.4.7.3)

Design Loads
Nsd = 1.35x 256.84+1.50x 100.00= 496.73 kN
Soil pressure q=0.001x496.73/(1.900x1.900)=0.138 N/mm²(Mpa)
Check bearing resistance failure Vd<=Rd (EC7 EN1997-1-1:2004, §6.5.2)
Design effective foundation area A=1.900x1.900=3.61 m² (EC7 Annex D)
Design bearing resistance of footing Rd=1000x3.61x0.200/1.00=722.00 kN > Vd=496.73 kN

1.3.3. (GEO), 1.00xPermanent + 1.30xVariable (EC7 §2.4.7.3)

Design Loads
Nsd = 1.00x 256.84+1.30x 100.00= 386.84 kN
Soil pressure q=0.001x386.84/(1.900x1.900)=0.107 N/mm²(Mpa)
Check bearing resistance failure Vd<=Rd (EC7 EN1997-1-1:2004, §6.5.2)
Design effective foundation area A=1.900x1.900=3.61 m² (EC7 Annex D)
Design bearing resistance of footing Rd=1000x3.61x0.200/1.40=515.71 kN > Vd=386.84 kN

1.4. Internal actions for reinforced concrete design

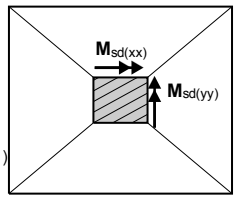
1.4.1. Loading 1.35xPermanent + 1.50xVariable

Design Loads
Nsd = 1.35x 170.00+1.50x 100.00= 379.50 kN

1.5. Design for bending

(EC2 EN1992-1-1:2004, §6.1)

Msd(yy)=0.125x379.50x1.900x(1-0.300/1.900)²= 63.92 kNm
Msd(xx)=0.125x379.50x1.900x(1-0.300/1.900)²= 63.92 kNm



Msd=63.92kNm, b=300mm, d=607mm, Kd=4.16, x/d=0.07
ec/es=1.6/20.0, Ks=2.36, **As= 2.49cm²**
Minimum reinforcement As>=0.26bd·Fctm/fyk (As= 5.74cm²/m) (EC2 §9.3.1)
Minimum reinforcement Ø12/19.5(5.79cm²/m)

Msd=63.92kNm, b=300mm, d=607mm, Kd=4.16, x/d=0.07
ec/es=1.6/20.0, Ks=2.36, **As= 2.49cm²**
Minimum reinforcement As>=0.26bd·Fctm/fyk (As= 5.74cm²/m) (EC2 §9.3.1)
Minimum reinforcement Ø12/19.5(5.79cm²/m)

Reinforcement of footing
Steel reinforcement in x-x direction: Ø12/19.5(5.79cm²/m), **11Ø12**(12.43cm²)
Steel reinforcement in y-y direction: Ø12/19.5(5.79cm²/m), **11Ø12**(12.43cm²)

1.6. Design for shear

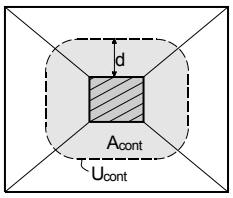
(EC2 EN1992-1-1:2004, §6.2)

The design for shear is covered by the design in punching shear
because the critical rupture surface is considered at angle 45°

1.7. Design for punching shear

(EC2 EN1992-1-1:2004, §6.4)

Footing cantilevers in x-x, L1=0.800>d=0.607m, L2=0.800>d=0.607m
Footing cantilevers in y-y, L1=0.800>d=0.607m, L2=0.800>d=0.607m

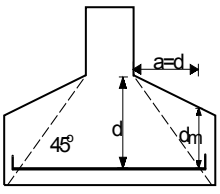


Control perimeter, at 1.0d=0.607m<2.0d (EC2 §6.4.2.2)
we consider rupture surface at angle 45°
Ucont=(0.300+0.300+0.300+0.300)+3.14x(0.607+0.607)=5.012m
Base area within the control perimeter
Acont=0.300x0.300+0.300x1.214+0.300x1.214+3.14x0.607x0.607=1.98m²
Minimum effective height of footing at control section dm= 303mm

Applied shear force at control perimeter Ved=Nsd-σo·Acont, ved=Vedxβ/Ucont
σo=379.50/(1.900x1.900)=105.12 kN/m², β=1.15 (EC2 §6.4.3 Fig.6.21N)
ved=(379.50-105.12x1.98)x1.15/5.012=39.32 kN/m

Tension reinforcement at control section Asxx= 5.79cm²/m, Asyy= 5.79cm²/m
As1²=(Asxx)(Asyy)=5.79x5.79, As1=5.79 cm²

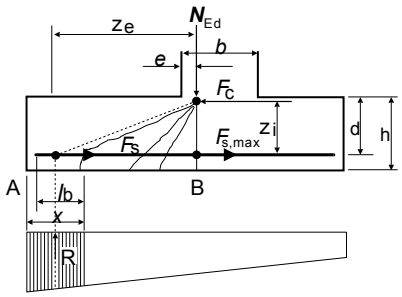
Punching shear capacity without shear reinforcement Vrdc (EC2 §6.4.4)
Vrdc=[Crdc·k·(100ρ1·fck)^(0.333)·(2d/a)]·bw·d (EC2 Eq.6.50)
Vrdc>=[vmin·2d/a]·bw·d, d=dm=303mm, a=607mm
Crdc=0.18/γc=0.18/1.50=0.120, fck=25.00MPa
k=1+(200/d)^½ <=2, k=1.81
ρ1=As1/(bw·d)=579/(1000x303)=0.0019
vmin=0.035·k^(1.50)·fck^½ = 0.43N/mm² (EC2 Eq.6.3N)



Vrd,c(min)=0.001x(0.43x2x303/607)x1000x303=130.08kN/m
Vrdc=0.001x[0.120x1.81x(0.19x25.00)^(0.333)x2x303/607]x1000x303=110.45, Vrdc=Vrcd(min)=130.08kN/m
Vsd=39.32 kN/m <= Vrdc=130.08 kN/m, shear and punching shear OK

1.8. Reinforcement anchorage

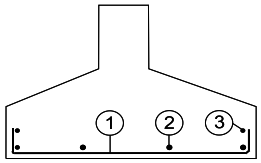
(EC2 EN1992-1-1:2004, §9.8.2.2, §8.4)

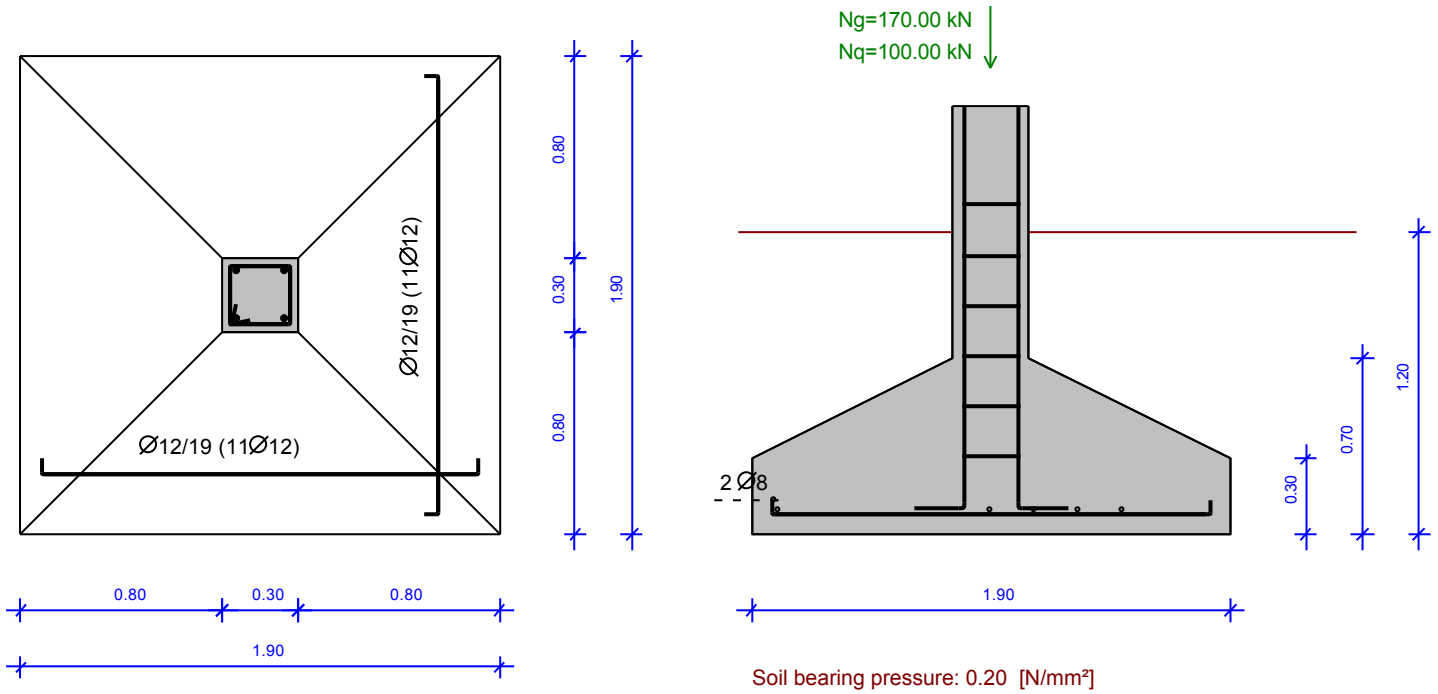


x=h/2=0.150m, R=1000x0.138x0.150x1.900=39.33 kN
e=0.15b=0.045m ze=0.770 m, zi=0.900d=0.546m
Fs=R·ze/zi=39.33x0.770/0.546=55.43 kN
σsd=Fs/As=1000x55.43/1243=45 MPa
Basic required anchorage length (EC2 Eq.8.3)
lb,rqd=(Φ/4)(σsd/fbd)=(12/4)x(45/2.70)=50mm
fbd=2.25x1.00x(fctk0.05/γc)=2.70 MPa (EC2 §8.4.2)
Design anchorage length (EC2 §8.4.4, T.8.2)
lbd=0.70x50=35mm, Cnom=75mm>3Ø=36mm
Minimum anchorage length lb,min=max(0.30lbrqd,10Ø,100mm)=120mm
Necessary anchorage length of longitudinal reinforcement Lbd=120mm =0.120m
lbd=120mm>(x-Cnom)=75.00. Necessary bends 60mm at bar ends for anchorage

1.9. Reinforcing bar schedule

Num	type	reinforcing bar [mm]	items	∅	g/m [kg/m]	length [m]	weight [kg]
1	1	60 — 1450 — 60	7	12	0.888	1.570	9.76
2	2	60 — 1450 — 60	7	12	0.888	1.570	9.76
3	3	1450	2	8	0.395	1.450	1.15
4	3	1450	2	8	0.395	1.450	1.15
		Total weight [kg]					**21.82**





General information

Symmetric footing with centric load

Concrete and steel class: C25/30 - S500

Concrete cover: Cnom=75 mm

Soil bearing pressure: 0.20 [N/mm²]

Design codes

Eurocode 0 EN1991-1-1, Basis of structural design

Eurocode 1 EN1991-1-1, Actions on structures

Eurocode 2 EN1992-1-1, Design of concrete structures

Eurocode 7 EN1997-1-1, Geotechnical design

Eurocode 8 EN1998-5, Earthquaqe design

Loads

Dead load	Ng=170.00 kN
Live load	Nq=100.00 kN

Reinforcing bar schedule

#		reinforcing bar [mm]	items	∅ [mm]	g/m [kg/m]	length [m]	weight [kg]
1	F1	60 — 1750 — 60	11	12	0.888	1.870	18.27
2	F2	60 — 1750 — 60	11	12	0.888	1.870	18.27
3	F3	1750	2	8	0.395	1.750	1.38
4	F3	1750	2	8	0.395	1.750	1.38

Total weight [kg] **39.30**

Concrete volume of footing V= 1.65 [m³]

Reinforcement weight G=39.30 [kg]

Project: Example of fottings

FOOTING-001

Scale : 1:30 **Date:** 12/03/2007

Designer: **Draw.No.:**

Filename: Example of fottings **Sign:**

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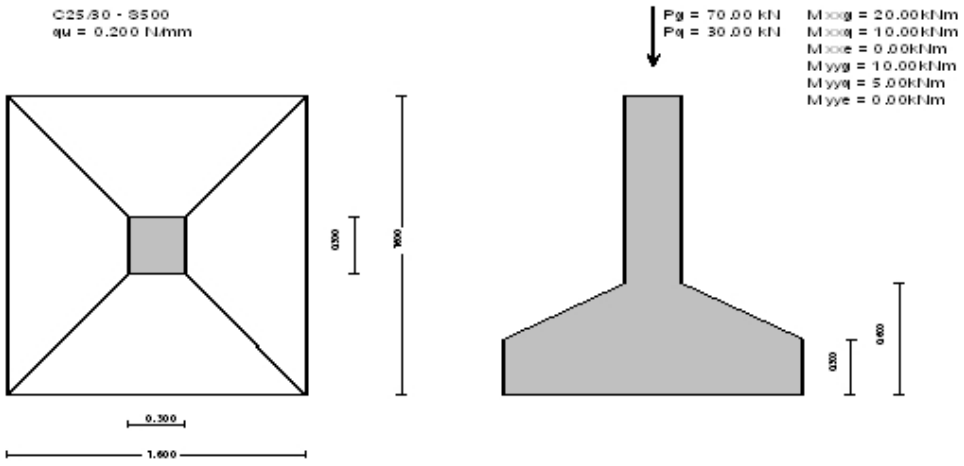
2. FOOTING-003

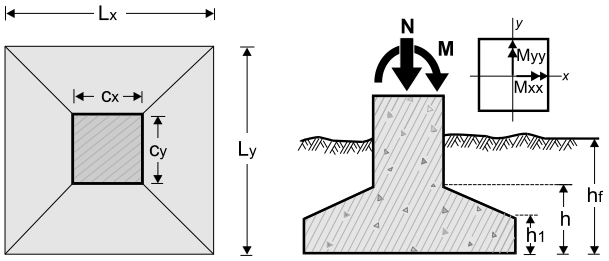
Symmetric footing with eccentric load

(EC2 EN1992-1-1:2004, EC0 EN1990-1-1:2002, EC7 EN1997-1-1:2004)



Concrete-Steel class: C25/30-S500 (EC2 §3)
Concrete cover : Cnom=75 mm (EC2 §4.4.1)
Concrete weight : 25.0 kN/m³
γc=1.50, γs=1.15 (EC2 Table 2.1N)

2.1. Dimensions, materials, loads



Dimensions

Footing	Lx= 1.600 m	Ly= 1.600 m	
Column	cx= 0.300 m	cy= 0.300 m	
Heights	h= 0.600 m	h1= 0.300 m	
Depth of footing		hf= 1.200 m	
Base area of footing		A= 2.56 m²	
Volume of footing		V= 1.08 m³	

Materials of footing

Concrete-Steel class: C25/30-S500 (EN1992-1-1, §3)
Concrete cover: Cnom=75 mm (EC2 §4.4.1)
Effective depth of cross section d=h-d1, d1=Cnomc+(3/2)Ø=75+3x12/2=93mm, d=600-93=507mm

Soil

Soil bearing pressure qu= 0.200 N/mm² (MPa)
Unit weight of soil γ=17.000 kN/m³

Loads

			permanent	variable
Self weight	kN	[1.08x25.00]	27.00	
Soil weight	kN	[(2.56x 1.20- 1.08)x17.00]	33.86	
Vertical load	kN		70.00	30.00
Moment Mxx	kNm		20.00	10.00
Moment Myy	kNm		10.00	5.00

2.2. Eurocode parameters

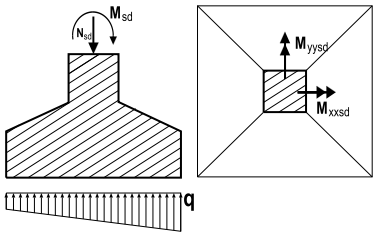
Check of soil bearing capacity (EC7 EN1997-1-1:2004, §6)
Partial factors for actions and soil properties (EC7 Tables A.1-A.4, EC8-5 §3.1)
Equilibrium limit state (EQU), Structural limit state (STR), Geotechnical limit state (GEO)

				(EQU)	(STR)	(GEO)
Actions	Permanent	Unfavourable	γGdst:	1.10	1.35	1.00
	Permanent	Favourable	γGstb:	0.90	1.00	1.00
	Variable	Unfavourable	γQdst:	1.50	1.50	1.30
	Variable	Favourable	γQstb:	0.00	0.00	0.00
Soil parameters	Angle of shearing resistance		γφ:	1.25	1.00	1.25
	Effective cohesion		γc:	1.25	1.00	1.25
	Undrained shear strength		γcu:	1.40	1.00	1.40
	Unconfined strength		γqu:	1.40	1.00	1.40
	Weight density		γw:	1.00	1.00	1.00

Partial safety factors for actions : γG=1.35, γQ=1.50 (EC0 Annex A1)
Combination of accidental actions :(EC7) ψ2 =0.30
Combination of accidental actions :(EC2) ψ2 =0.30

Design of reinforced concrete (EC2 EN1992-1-1:2004)

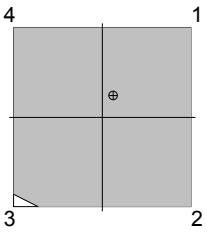
2.3. Check of soil bearing capacity (EC7 EN1997-1-1:2004, §6)

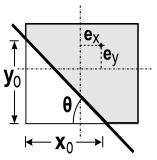


2.3.1. (EQU), 1.10xPermanent + 1.50xVariable (EC7 §2.4.7.2)

Design Loads
Nsd = 1.10x 130.86+1.50x 30.00= 188.95 kN
Mxxsd= 1.10x 20.00+1.50x 10.00= 37.00 kNm
Myysd= 1.10x 10.00+1.50x 5.00= 18.50 kNm

Eccentricities, soil pressures, footing area
relative eccentricity ex/Lx=Myy/(N·Lx)= 0.061
relative eccentricity ey/Ly=Mxx/(N·Ly)= 0.122
soil pressure q1= 0.155 N/mm²
soil pressure q2= 0.047 N/mm²
soil pressure q3= 0.000 N/mm²
soil pressure q4= 0.101 N/mm²
zero pressure line xo=0.22m, yo=0.11m, θ=27°
effective footing area 99.51%



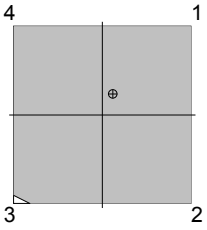


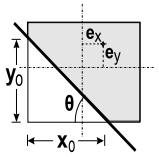
Check bearing resistance failure Vd<=Rd (EC7 EN1997-1-1:2004, §6.5.2)
relative load eccentricities ex/Lx=Myy/(N·Lx)=0.061, ey/Ly=Mxx/(N·Ly)=0.122
relative load eccentricities <=0.333 (EC7 §6.5.4)
effective design length of footing L'=1.600x(1-2x0.061)=1.405 m (EC7 Annex D)
effective design width of footing B'=1.600x(1-2x0.122)=1.210 m
effective design area of footing L'B'=1.405x1.210=1.70 m²
Design bearing resistance of footing Rd=1000x1.70x0.200/1.40=242.86 kN > Vd=188.95 kN
Effective footing area 99.51%>50.00% (EC7 §6.5.4)

2.3.2. (STR), 1.35xPermanent + 1.50xVariable (EC7 §2.4.7.3)

Design Loads
Nsd = 1.35x 130.86+1.50x 30.00= 221.66 kN
Mxxsd= 1.35x 20.00+1.50x 10.00= 42.00 kNm
Myysd= 1.35x 10.00+1.50x 5.00= 21.00 kNm

Eccentricities, soil pressures, footing area





relative eccentricity ex/Lx=Myy/(N·Lx)= 0.059
relative eccentricity ey/Ly=Mxx/(N·Ly)= 0.118
soil pressure q1= 0.179 N/mm²
soil pressure q2= 0.056 N/mm²
soil pressure q3= 0.000 N/mm²
soil pressure q4= 0.117 N/mm²
zero pressure line xo=0.15m, yo=0.07m, θ=27°
effective footing area 99.80%

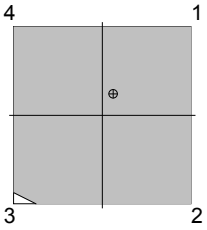
Check bearing resistance failure Vd<=Rd (EC7 EN1997-1-1:2004, §6.5.2)
relative load eccentricities ex/Lx=Myy/(N·Lx)=0.059, ey/Ly=Mxx/(N·Ly)=0.118
relative load eccentricities <=0.333 (EC7 §6.5.4)
effective design length of footing L'=1.600x(1-2x0.059)=1.411 m (EC7 Annex D)
effective design width of footing B'=1.600x(1-2x0.118)=1.222 m
effective design area of footing L'B'=1.411x1.222=1.72 m²
Design bearing resistance of footing Rd=1000x1.72x0.200/1.00=344.00 kN > Vd=221.66 kN
Effective footing area 99.80%>50.00% (EC7 §6.5.4)

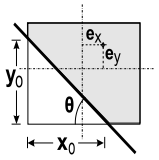
2.3.3. (GEO), 1.00xPermanent + 1.30xVariable (EC7 §2.4.7.3)

Design Loads

Nsd = 1.00x 130.86+1.30x 30.00= 169.86 kN
Mxxsd= 1.00x 20.00+1.30x 10.00= 33.00 kNm
Myysd= 1.00x 10.00+1.30x 5.00= 16.50 kNm

Eccentricities, soil pressures, footing area





relative eccentricity ex/Lx=Myy/(N·Lx)= 0.061
relative eccentricity ey/Ly=Mxx/(N·Ly)= 0.121
soil pressure q1= 0.139 N/mm²
soil pressure q2= 0.042 N/mm²
soil pressure q3= 0.000 N/mm²
soil pressure q4= 0.090 N/mm²
zero pressure line xo=0.21m, yo=0.10m, θ=27°
effective footing area 99.58%

Check bearing resistance failure Vd<=Rd (EC7 EN1997-1-1:2004, §6.5.2)
relative load eccentricities ex/Lx=Myy/(N·Lx)=0.061, ey/Ly=Mxx/(N·Ly)=0.121
relative load eccentricities <=0.333 (EC7 §6.5.4)
effective design length of footing L'=1.600x(1-2x0.061)=1.405 m (EC7 Annex D)
effective design width of footing B'=1.600x(1-2x0.121)=1.213 m
effective design area of footing L'B'=1.405x1.213=1.70 m²
Design bearing resistance of footing Rd=1000x1.70x0.200/1.40=242.86 kN > Vd=169.86 kN
Effective footing area 99.58%>50.00% (EC7 §6.5.4)

2.4. Internal actions for reinforced concrete design

Moments M and shearing forces V, are computed at column faces.
Shearing forces V* are computed at distance d=0.507m from the column face.
They are computed, by numerical integration of the soil pressure under the footing.

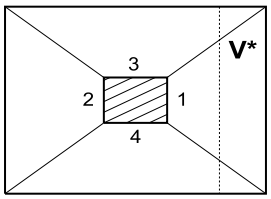
2.4.1. Loading 1.35xPermanent + 1.50xVariable

Design Loads

Nsd = 1.35x 130.86+1.50x 30.00= 221.66 kN
Mxxsd= 1.35x 20.00+1.50x 10.00= 42.00 kNm
Myysd= 1.35x 10.00+1.50x 5.00= 21.00 kNm

Eccentricities, soil pressures, footing area
relative load eccentricities ex/Lx=Myy/(N·Lx)=0.059, ey/Ly=Mxx/(N·Ly)=0.118
soil pressures q1=0.179, q2=0.056, q3=0.000, q4=0.117 N/mm²
zero pressure line xo=0.15m, yo=0.07m, θ=27°
pressure due to self weight+soil weight qg=0.001x1.35x(27.00+33.86)/2.56=0.032 N/mm²
Shear at critical section + (self weight+soil weight) q·Acont+qg·A=165.24 kN

Internal actions (bending moments, shearing forces)

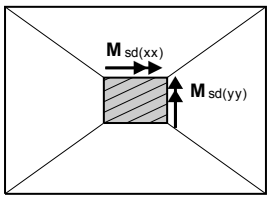


Myy(1)= 25.99 kNm, V(1)= 76.23 kN, V*(1)= 19.00 kN
Myy(2)= 12.07 kNm, V(2)= 41.05 kN, V*(2)= 7.25 kN
Mxx(3)= 33.57 kNm, V(3)= 95.28 kN, V*(3)= 25.45 kN
Mxx(4)= 4.85 kNm, V(4)= 22.12 kN, V*(4)= 1.62 kN

2.5. Design for bending

(EC2 EN1992-1-1:2004, §6.1)

Maximum design moments



Msd(yy)= 25.99 kNm, b= 300 mm, d= 507 mm
Msd(xx)= 33.57 kNm, b= 300 mm, d= 507 mm

Msd=25.99kNm, b=300mm, d=507mm, Kd=5.45, x/d=0.05
ec/es=1.1/20.0, Ks=2.34, **As= 1.20cm²**
Minimum reinforcement As>=0.26bd·Fctm/fyk (As= 4.11cm²/m) (EC2 §9.3.1)
Minimum reinforcement Ø12/27.5(4.11cm²/m)

Msd=33.57kNm, b=300mm, d=507mm, Kd=4.79, x/d=0.06
ec/es=1.3/20.0, Ks=2.35, **As= 1.56cm²**
Minimum reinforcement As>=0.26bd·Fctm/fyk (As= 4.11cm²/m) (EC2 §9.3.1)
Minimum reinforcement Ø12/27.5(4.11cm²/m)

Reinforcement of footing
Steel reinforcement in x-x direction: Ø12/27.5(4.11cm²/m), **7Ø12**(7.91cm²)
Steel reinforcement in y-y direction: Ø12/27.5(4.11cm²/m), **7Ø12**(7.91cm²)

2.6. Design for shear

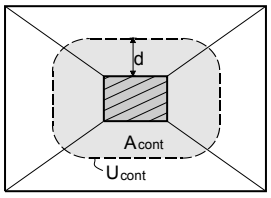
(EC2 EN1992-1-1:2004, §6.2)

The design for shear is covered by the design in punching shear
because the critical rupture surface is considered at angle 45°

2.7. Design for punching shear

(EC2 EN1992-1-1:2004, §6.4)

Footing cantilevers in x-x, L1=0.650>d=0.507m, L2=0.650>d=0.507m
Footing cantilevers in y-y, L1=0.650>d=0.507m, L2=0.650>d=0.507m

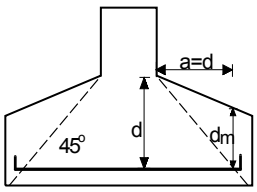


Control perimeter, at 1.0d=0.507m<2.0d (EC2 §6.4.2.2)
we consider rupture surface at angle 45°
Ucont=(0.300+0.300+0.300+0.300)+3.14x(0.507+0.507)=4.384m
Base area within the control perimeter
Acont=0.300x0.300+0.300x1.014+0.300x1.014+3.14x0.507x0.507=1.51m²
Minimum effective height of footing at control section dm= 273mm

Applied shear force at control perimeter Ved=Nsd-σo·Acont, ved=Vedxβ/Ucont
ved=(221.66-165.24)x1.50/4.38=19.31 kN/m, β=1.50 (EC2 §6.4.3 Fig.6.21N)

Tension reinforcement at control section Asxx= 4.11cm²/m, Asyy= 4.11cm²/m
As1²=(Asxx)(Asyy)=4.11x4.11, As1=4.11 cm²

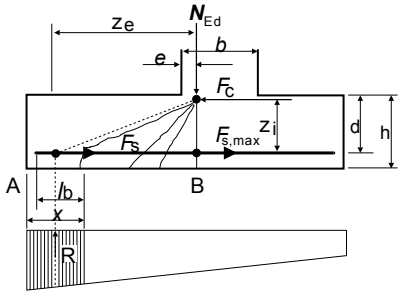
Punching shear capacity without shear reinforcement Vrdc (EC2 §6.4.4)



Vrdc=[Crdc·k·(100ρ1·fck)^(0.333)·(2d/a)]·bw·d (EC2 Eq.6.50)
Vrdc>=[vmin·2d/a]·bw·d, d=dm=273mm, a=507mm
Crdc=0.18/γc=0.18/1.50=0.120, fck=25.00MPa
k=1+(200/d)^½ <=2, k=1.86
ρ1=As1/(bw·d)=411/(1000x273)=0.0015
vmin=0.035·k^(1.50)·fck^½ = 0.44N/mm² (EC2 Eq.6.3N)
Vrd,c(min)=0.001x(0.44x2x273/507)x1000x273=129.36kN/m
Vrdc=0.001x[0.120x1.86x(0.15x25.00)^(0.333)x2x273/507]x1000x273=101.95, Vrdc=Vrcd(min)=129.36kN/m
Vsd=19.31 kN/m <= Vrdc=129.36 kN/m, shear and punching shear OK

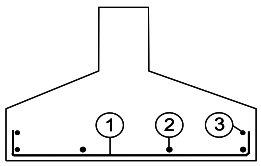
2.8. Reinforcement anchorage

(EC2 EN1992-1-1:2004, §9.8.2.2, §8.4)



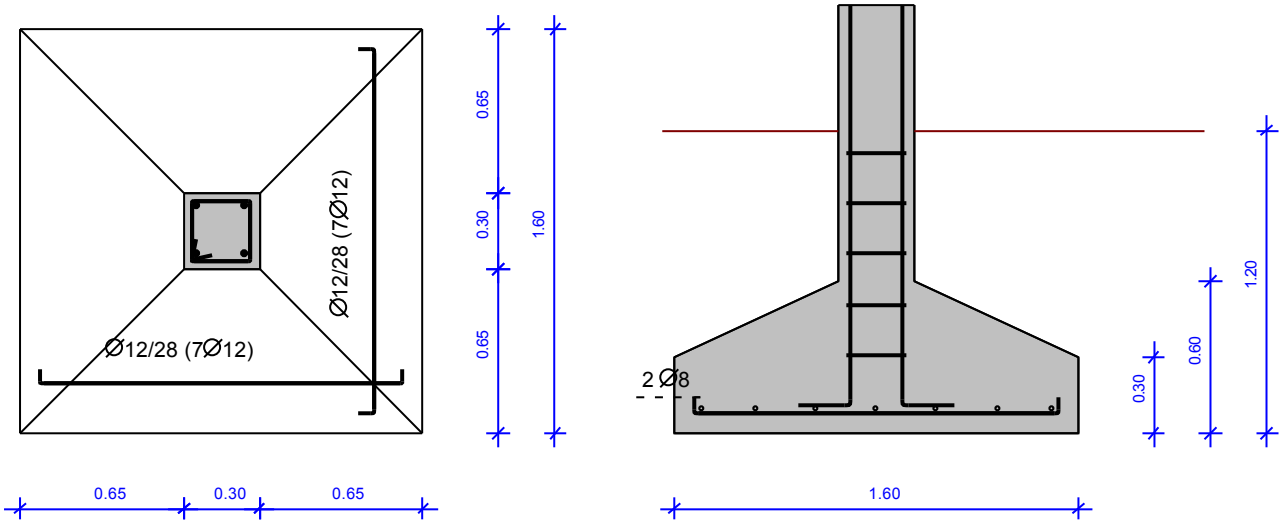
x=h/2=0.150m, R=1000x0.179x0.150x1.600=42.93 kN
e=0.15b=0.045m ze=0.620 m, zi=0.900d=0.456m
Fs=R·ze/zi=42.93x0.620/0.456=58.33 kN
σsd=Fs/As=1000x58.33/791=74 MPa
Basic required anchorage length (EC2 Eq.8.3)
lb,rqd=(Φ/4)(σsd/fbd)=(12/4)x(74/2.70)=82mm
fbd=2.25x1.00x(fctk0.05/γc)=2.70 MPa (EC2 §8.4.2)
Design anchorage length (EC2 §8.4.4, T.8.2)
lbd=0.70x82=58mm, Cnom=75mm>3Ø=36mm
Minimum anchorage length lb,min=max(0.30lbrqd,10Ø,100mm)=120mm
Necessary anchorage length of longitudinal reinforcement Lbd=120mm =0.120m
lbd=120mm>(x-Cnom)=75.00. Necessary bends 60mm at bar ends for anchorage

2.9. Reinforcing bar schedule



Num	type	reinforcing bar [mm]	items	∅	g/m [kg/m]	length [m]	weight [kg]
5	1	60 — 1450 — 60	7	12	0.888	1.570	9.76
6	2	60 — 1450 — 60	7	12	0.888	1.570	9.76
7	3	1450	2	8	0.395	1.450	1.15
8	3	1450	2	8	0.395	1.450	1.15
		Total weight [kg]					**21.82**

	Dead	Live	Seismic
N [kN]	70.00	30.00	0.00
Mxx [kNm]	20.00	10.00	0.00
Myy [kNm]	10.00	5.00	0.00



General information

Symmetric footing with eccentric load

Concrete and steel class: C25/30 - S500

Concrete cover: Cnom=75 mm

Soil bearing pressure: 0.20 [N/mm²]

Design codes

Eurocode 0 EN1991-1-1, Basis of structural design

Eurocode 1 EN1991-1-1, Actions on structures

Eurocode 2 EN1992-1-1, Design of concrete structures

Eurocode 7 EN1997-1-1, Geotechnical design

Eurocode 8 EN1998-5, Earthquaqe design

Loads

	Dead	Live	Seismic
N [kN]	70.00	30.00	0.00
Mxx [kNm]	20.00	10.00	0.00
Myy [kNm]	10.00	5.00	0.00

Reinforcing bar schedule

#		reinforcing bar [mm]	items	∅ [mm]	g/m [kg/m]	length [m]	weight [kg]
1	F1	60 — 1450 — 60	7	12	0.888	1.570	9.76
2	F2	60 — 1450 — 60	7	12	0.888	1.570	9.76
3	F3	1450	2	8	0.395	1.450	1.15
4	F3	1450	2	8	0.395	1.450	1.15

Total weight [kg] **21.82**

Concrete volume of footing V= 1.08 [m³]

Reinforcement weight G=21.82 [kg]

Project: Example of fottings 12/03/2007

FOOTING-003

Scale : 1:30 **Date:** 12/03/2007

Designer: **Draw.No.:**

Filename: Example of fottings **Sign:**

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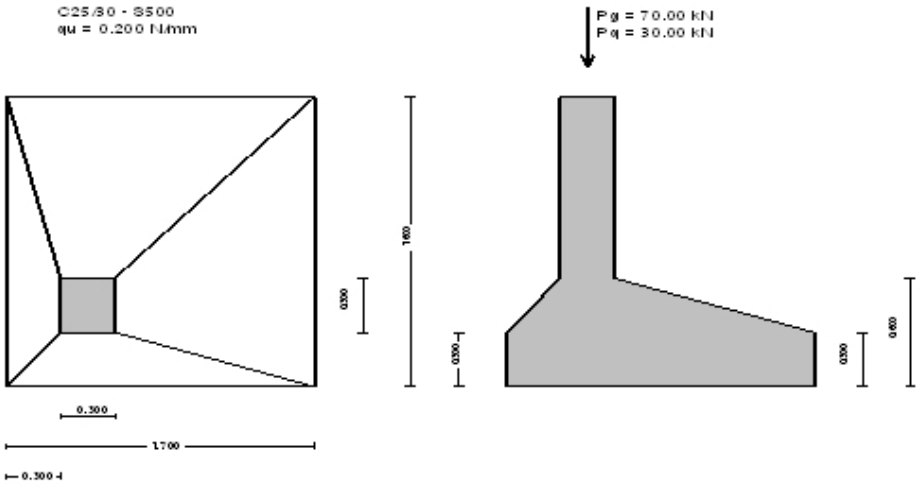
3. FOOTING-005

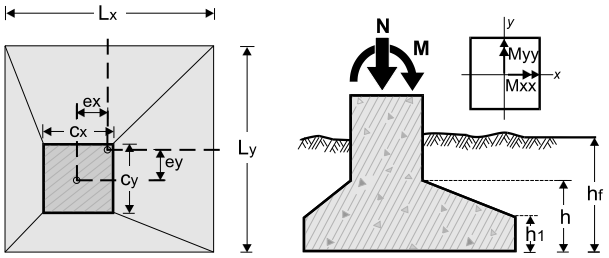
Asymmetric footing with eccentric load

(EC2 EN1992-1-1:2004, EC0 EN1990-1-1:2002, EC7 EN1997-1-1:2004)



Concrete-Steel class: C25/30-S500 (EC2 §3)
Concrete cover : Cnom=75 mm (EC2 §4.4.1)
Concrete weight : 25.0 kN/m³
γc=1.50, γs=1.15 (EC2 Table 2.1N)

3.1. Dimensions, materials, loads



Dimensions

Footing	Lx= 1.700 m	Ly= 1.600 m	
Column	cx= 0.300 m	cy= 0.300 m	
Eccentr.	ex=-0.400 m	ey=-0.350 m	
Heights	h= 0.600 m	h1= 0.300 m	
Depth of footing		hf= 1.200 m	
Base area of footing		A= 2.72 m²	
Volume of footing		V= 1.15 m³	

Materials of footing

Concrete-Steel class: C25/30-S500 (EN1992-1-1, §3)
Concrete cover: Cnom=75 mm (EC2 §4.4.1)
Effective depth of cross section d=h-d1, d1=Cnomc+(3/2)Ø=75+3x12/2=93mm, d=600-93=507mm

Soil

Soil bearing pressure qu= 0.200 N/mm² (MPa)
Unit weight of soil γ=17.000 kN/m³

Loads

			permanent	variable
Self weight	kN	[1.15x25.00]	28.75	
Soil weight	kN	[(2.72x 1.20- 1.15)x17.00]	35.94	
Vertical load	kN		70.00	30.00
Moment Mxx	kNm		0.00	0.00
Moment Myy	kNm		0.00	0.00

3.2. Eurocode parameters

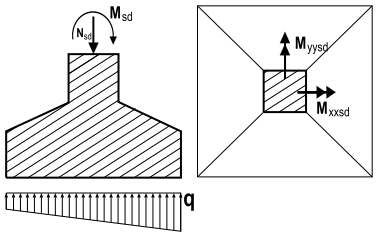
Check of soil bearing capacity (EC7 EN1997-1-1:2004, §6)
Partial factors for actions and soil properties (EC7 Tables A.1-A.4, EC8-5 §3.1)
Equilibrium limit state (EQU), Structural limit state (STR), Geotechnical limit state (GEO)

				(EQU)	(STR)	(GEO)
Actions	Permanent	Unfavourable	γGdst:	1.10	1.35	1.00
	Permanent	Favourable	γGstb:	0.90	1.00	1.00
	Variable	Unfavourable	γQdst:	1.50	1.50	1.30
	Variable	Favourable	γQstb:	0.00	0.00	0.00
Soil parameters	Angle of shearing resistance		γφ:	1.25	1.00	1.25
	Effective cohesion		γc:	1.25	1.00	1.25
	Undrained shear strength		γcu:	1.40	1.00	1.40
	Unconfined strength		γqu:	1.40	1.00	1.40
	Weight density		γw:	1.00	1.00	1.00

Partial safety factors for actions : γG=1.35, γQ=1.50 (EC0 Annex A1)
Combination of accidental actions :(EC7) ψ2 =0.30
Combination of accidental actions :(EC2) ψ2 =0.30

Design of reinforced concrete (EC2 EN1992-1-1:2004)

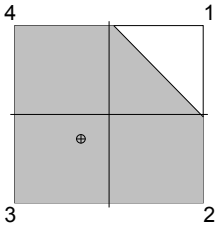
3.3. Check of soil bearing capacity (EC7 EN1997-1-1:2004, §6)

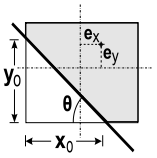


3.3.1. (EQU), 1.10xPermanent + 1.50xVariable (EC7 §2.4.7.2)

Design Loads
Nsd = 1.10x 134.69+1.50x 30.00 = 193.16 kN
Mxxsd= 1.10x 0.00+1.50x 0.00+(-0.35)x 122.00= -42.70 kNm
Myysd= 1.10x 0.00+1.50x 0.00+(-0.40)x 122.00= -48.80 kNm
(1.10x70.00+1.50x30.00=122.00)

Eccentricities, soil pressures, footing area
relative eccentricity ex/Lx=Myy/(N·Lx)=-0.149
relative eccentricity ey/Ly=Mxx/(N·Ly)=-0.138
soil pressure q1= 0.000 N/mm²
soil pressure q2= 0.063 N/mm²
soil pressure q3= 0.204 N/mm²
soil pressure q4= 0.074 N/mm²
zero pressure line xo=2.46m, yo=2.51m, θ=46°
effective footing area 87.52%



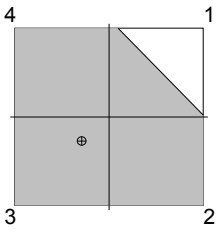


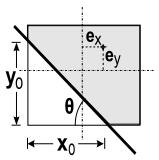
Check bearing resistance failure Vd<=Rd (EC7 EN1997-1-1:2004, §6.5.2)
relative load eccentricities ex/Lx=Myy/(N·Lx)=0.149, ey/Ly=Mxx/(N·Ly)=0.138
relative load eccentricities <=0.333 (EC7 §6.5.4)
effective design length of footing L'=1.700x(1-2x0.149)=1.193 m (EC7 Annex D)
effective design width of footing B'=1.600x(1-2x0.138)=1.158 m
effective design area of footing L'B'=1.193x1.158=1.38 m²
Design bearing resistance of footing Rd=1000x1.38x0.200/1.40=197.14 kN > Vd=193.16 kN
Effective footing area 87.52%>50.00% (EC7 §6.5.4)

3.3.2. (STR), 1.35xPermanent + 1.50xVariable (EC7 §2.4.7.3)

Design Loads
Nsd = 1.35x 134.69+1.50x 30.00 = 226.83 kN
Mxxsd= 1.35x 0.00+1.50x 0.00+(-0.35)x 139.50= -48.82 kNm
Myysd= 1.35x 0.00+1.50x 0.00+(-0.40)x 139.50= -55.80 kNm
(1.35x70.00+1.50x30.00=139.50)

Eccentricities, soil pressures, footing area
relative eccentricity ex/Lx=Myy/(N·Lx)=-0.145
relative eccentricity ey/Ly=Mxx/(N·Ly)=-0.135
soil pressure q1= 0.000 N/mm²
soil pressure q2= 0.075 N/mm²
soil pressure q3= 0.234 N/mm²
soil pressure q4= 0.087 N/mm²
zero pressure line xo=2.50m, yo=2.55m, θ=46°
effective footing area 88.66%





Check bearing resistance failure Vd<=Rd (EC7 EN1997-1-1:2004, §6.5.2)
relative load eccentricities ex/Lx=Myy/(N·Lx)=0.145, ey/Ly=Mxx/(N·Ly)=0.135
relative load eccentricities <=0.333 (EC7 §6.5.4)
effective design length of footing L'=1.700x(1-2x0.145)=1.207 m (EC7 Annex D)
effective design width of footing B'=1.600x(1-2x0.135)=1.168 m
effective design area of footing L'B'=1.207x1.168=1.41 m²
Design bearing resistance of footing Rd=1000x1.41x0.200/1.00=282.00 kN > Vd=226.83 kN
Effective footing area 88.66%>50.00% (EC7 §6.5.4)

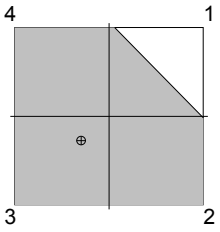
3.3.3. (GEO), 1.00xPermanent + 1.30xVariable (EC7 §2.4.7.3)

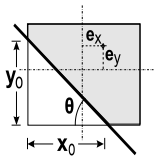
Design Loads

Nsd	= 1.00x	134.69	+1.30x	30.00	=	173.69 kN
Mxxsd	= 1.00x	0.00	+1.30x	0.00+(-0.35)x 109.00	=	-38.15 kNm
Myysd	= 1.00x	0.00	+1.30x	0.00+(-0.40)x 109.00	=	-43.60 kNm

(1.00x70.00+1.30x30.00=109.00)

Eccentricities, soil pressures, footing area
relative eccentricity ex/Lx=Myy/(N·Lx)=-0.148
relative eccentricity ey/Ly=Mxx/(N·Ly)=-0.137
soil pressure q1= 0.000 N/mm²
soil pressure q2= 0.057 N/mm²
soil pressure q3= 0.183 N/mm²
soil pressure q4= 0.067 N/mm²
zero pressure line xo=2.47m, yo=2.52m, θ=46°
effective footing area 87.80%





Check bearing resistance failure Vd<=Rd (EC7 EN1997-1-1:2004, §6.5.2)
relative load eccentricities ex/Lx=Myy/(N·Lx)=0.148, ey/Ly=Mxx/(N·Ly)=0.137
relative load eccentricities <=0.333 (EC7 §6.5.4)
effective design length of footing L'=1.700x(1-2x0.148)=1.197 m (EC7 Annex D)
effective design width of footing B'=1.600x(1-2x0.137)=1.162 m
effective design area of footing L'B'=1.197x1.162=1.39 m²
Design bearing resistance of footing Rd=1000x1.39x0.200/1.40=198.57 kN > Vd=173.69 kN
Effective footing area 87.80%>50.00% (EC7 §6.5.4)

3.4. Internal actions for reinforced concrete design

Moments M and shearing forces V, are computed at column faces.
Shearing forces V* are computed at distance d=0.507m from the column face.
They are computed, by numerical integration of the soil pressure under the footing.

3.4.1. Loading 1.35xPermanent + 1.50xVariable

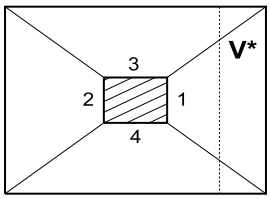
Design Loads

Nsd	= 1.35x	134.69	+1.50x	30.00	=	226.83 kN
Mxxsd	= 1.35x	0.00	+1.50x	0.00+(-0.35)x 139.50	=	-48.82 kNm
Myysd	= 1.35x	0.00	+1.50x	0.00+(-0.40)x 139.50	=	-55.80 kNm

(1.35x70.00+1.50x30.00=139.50)

Eccentricities, soil pressures, footing area
relative load eccentricities ex/Lx=Myy/(N·Lx)=-0.145, ey/Ly=Mxx/(N·Ly)=-0.135
soil pressures q1=0.000, q2=0.075, q3=0.234, q4=0.087 N/mm²
zero pressure line xo=2.50m, yo=2.55m, θ=46°
pressure due to self weight+soil weight qg=0.001x1.35x(28.75+35.94)/2.72=0.032 N/mm²
Shear at critical section + (self weight+soil weight) q·Acont+qg·A=206.05 kN

Internal actions (bending moments, shearing forces)

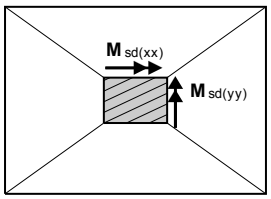


Myy(1)= 21.55 kNm, V(1)= 59.07 kN, V*(1)= 16.85 kN
Myy(2)= 8.34 kNm, V(2)= 55.50 kN, V*(2)= 0.00 kN
Mxx(3)= 20.71 kNm, V(3)= 58.80 kN, V*(3)= 16.38 kN
Mxx(4)= 8.63 kNm, V(4)= 55.87 kN, V*(4)= 0.00 kN

3.5. Design for bending

(EC2 EN1992-1-1:2004, §6.1)

Maximum design moments



Msd(yy)= 21.55 kNm, b= 300 mm, d= 507 mm
Msd(xx)= 20.71 kNm, b= 300 mm, d= 507 mm

Msd=21.55kNm, b=300mm, d=507mm, Kd=5.98, x/d=0.05
ec/es=1.0/20.0, Ks=2.34, **As= 0.99cm²**
Minimum reinforcement As>=0.26bd·Fctm/fyk (As= 4.11cm²/m) (EC2 §9.3.1)
Minimum reinforcement Ø12/27.5(4.11cm²/m)

Msd=20.71kNm, b=300mm, d=507mm, Kd=6.10, x/d=0.05
ec/es=1.0/20.0, Ks=2.34, **As= 0.95cm²**
Minimum reinforcement As>=0.26bd·Fctm/fyk (As= 4.11cm²/m) (EC2 §9.3.1)
Minimum reinforcement Ø12/27.5(4.11cm²/m)

Reinforcement of footing
Steel reinforcement in x-x direction: Ø12/27.5(4.11cm²/m), **7Ø12**(7.91cm²)
Steel reinforcement in y-y direction: Ø12/27.5(4.11cm²/m), **7Ø12**(7.91cm²)

3.6. Design for shear

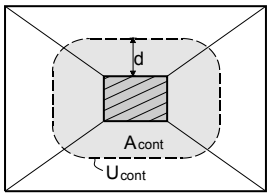
(EC2 EN1992-1-1:2004, §6.2)

The design for shear is covered by the design in punching shear
because the critical rupture surface is considered at angle 45°

3.7. Design for punching shear

(EC2 EN1992-1-1:2004, §6.4)

Footing cantilevers in x-x, L1=1.100>d=0.507m, L2=0.300<d=0.507m
Footing cantilevers in y-y, L1=1.000>d=0.507m, L2=0.300<d=0.507m

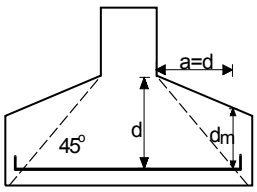


Control perimeter, at 1.0d=0.507m<2.0d (EC2 §6.4.2.2)
we consider rupture surface at angle 45°
Ucont=(0.300+0.000+0.000+0.300)+3.14x(0.254+0.254)=2.192m
Base area within the control perimeter
Acont=0.300x0.300+0.300x0.507+0.300x0.507+3.14x0.254x0.254=0.60m²
Minimum effective height of footing at control section dm= 207mm

Applied shear force at control perimeter Ved=Nsd-σo·Acont, ved=Vedxβ/Ucont
ved=(226.83-206.05)x1.50/2.19=14.22 kN/m, β=1.50 (EC2 §6.4.3 Fig.6.21N)

Tension reinforcement at control section Asxx= 4.11cm²/m, Asyy= 4.11cm²/m
As1²=(Asxx)(Asyy)=4.11x4.11, As1=4.11 cm²

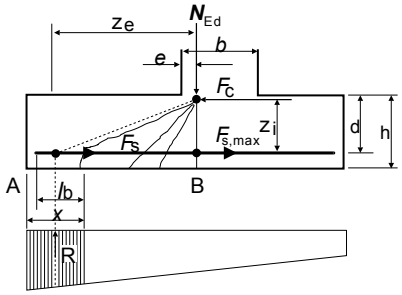
Punching shear capacity without shear reinforcement Vrdc (EC2 §6.4.4)



Vrdc=[Crdc·k·(100ρ1·fck)^(0.333)·(2d/a)]·bw·d (EC2 Eq.6.50)
Vrdc>=[vmin·2d/a]·bw·d, d=dm=207mm, a=507mm
Crdc=0.18/γc=0.18/1.50=0.120, fck=25.00MPa
k=1+(200/d)^½ <=2, k=1.98
ρ1=As1/(bw·d)=411/(1000x207)=0.0020
vmin=0.035·k^(1.50)·fck^½ = 0.49N/mm² (EC2 Eq.6.3N)
Vrd,c(min)=0.001x(0.49x2x207/507)x1000x207=82.82kN/m
Vrdc=0.001x[0.120x1.98x(0.20x25.00)^(0.333)x2x207/507]x1000x207=68.68, Vrdc=Vrcd(min)=82.82kN/m
Vsd=14.22 kN/m <= Vrdc=82.82 kN/m, shear and punching shear OK

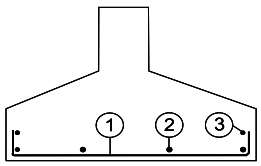
3.8. Reinforcement anchorage

(EC2 EN1992-1-1:2004, §9.8.2.2, §8.4)



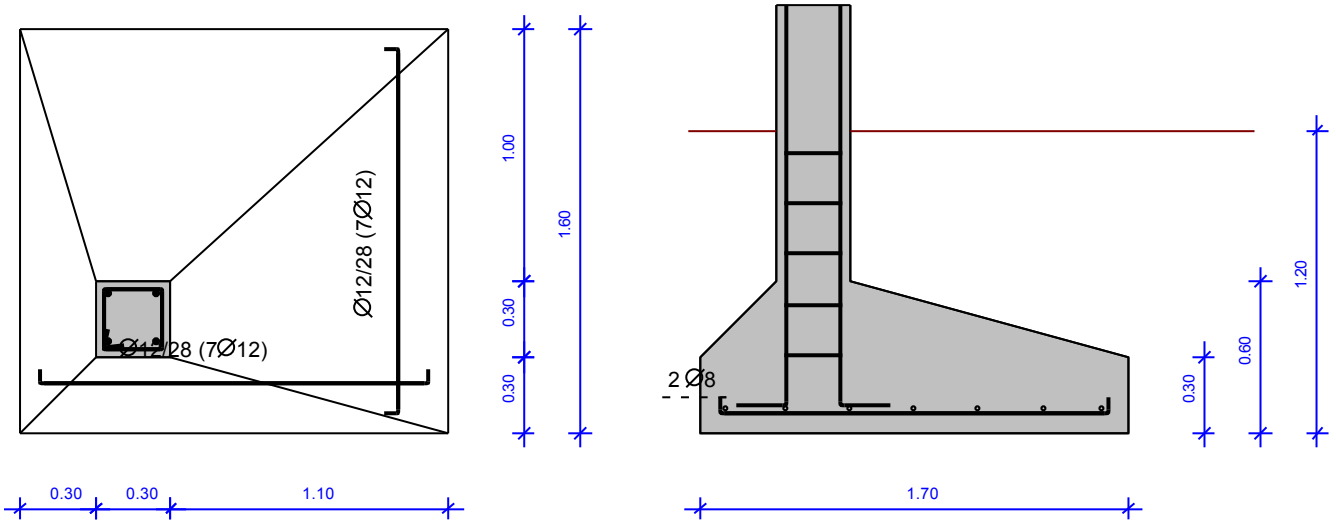
x=h/2=0.150m, R=1000x0.234x0.150x1.600=56.25 kN
e=0.15b=0.045m ze=0.670 m, zi=0.900d=0.456m
Fs=R·ze/zi=56.25x0.670/0.456=82.59 kN
σsd=Fs/As=1000x82.59/791=104 MPa
Basic required anchorage length (EC2 Eq.8.3)
lb,rqd=(Φ/4)(σsd/fbd)=(12/4)x(104/2.70)=116mm
fbd=2.25x1.00x(fctk0.05/γc)=2.70 MPa (EC2 §8.4.2)
Design anchorage length (EC2 §8.4.4, T.8.2)
lbd=0.70x116=81mm, Cnom=75mm>3Ø=36mm
Minimum anchorage length lb,min=max(0.30lbrqd,10Ø,100mm)=120mm
Necessary anchorage length of longitudinal reinforcement Lbd=120mm =0.120m
lbd=120mm>(x-Cnom)=75.00. Necessary bends 60mm at bar ends for anchorage

3.9. Reinforcing bar schedule



Num	type	reinforcing bar [mm]	items	∅	g/m [kg/m]	length [m]	weight [kg]
9	1	60 — 1550 — 60	7	12	0.888	1.670	10.38
10	2	60 — 1450 — 60	7	12	0.888	1.570	9.76
11	3	1550	2	8	0.395	1.550	1.22
12	3	1450	2	8	0.395	1.450	1.15
		Total weight [kg]					**22.51**

	Dead	Live	Seismic
N [kN]	70.00	30.00	0.00
Mxx [kNm]	0.00	0.00	0.00
Myy [kNm]	0.00	0.00	0.00



General information

Asymmetric footing with eccentric load

Concrete and steel class: C25/30 - S500

Concrete cover: Cnom=75 mm

Soil bearing pressure: 0.20 [N/mm²]

Design codes

Eurocode 0 EN1991-1-1, Basis of structural design

Eurocode 1 EN1991-1-1, Actions on structures

Eurocode 2 EN1992-1-1, Design of concrete structures

Eurocode 7 EN1997-1-1, Geotechnical design

Eurocode 8 EN1998-5, Earthquaqe design

Loads

	Dead	Live	Seismic
N [kN]	70.00	30.00	0.00
Mxx [kNm]	0.00	0.00	0.00
Myy [kNm]	0.00	0.00	0.00

Reinforcing bar schedule

#		reinforcing bar [mm]	items	∅ [mm]	g/m [kg/m]	length [m]	weight [kg]
1	F1	60 — 1550 — 60	7	12	0.888	1.670	10.38
2	F2	60 — 1450 — 60	7	12	0.888	1.570	9.76
3	F3	1550	2	8	0.395	1.550	1.22
4	F3	1450	2	8	0.395	1.450	1.15

Total weight [kg] **22.51**

Concrete volume of footing V= 1.15 [m³]

Reinforcement weight G=22.51 [kg]

Project: Example of fottings 12/03/2007

FOOTING-005

Scale : 1:30 **Date:** 12/03/2007

Designer: **Draw.No.:**

Filename: Example of fottings **Sign:**

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