REINFORCED CONCRETE STRUCTURAL DESIGN.

PROJECT TITLE:

PROPOSED OF CONSTRUCTIONOF WORKSHOP ON BEHALF OF ENERGICOTEL Ltd

RUBAVU DISTICT
NYUNDO Sector,

OWNER: ENERGICOTEL LTD

DESIGN CODE: **BS8110-1997**

ROBOT STRUCTURE ANALYSIS PRO.

STRUCTURE DESIGN BUREAU: **.CEGRAPHITEC LTD**

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STRUCTURAL DESIGN ENGINEER: **Eng. HABIMANA AUGUSTIN**
BSc. Civil Eng.

November, 2018

I. GENERAL INTRODUCTION

I.1. INTRODUCTION

The aim of design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during their intended life. With an appropriate degree of safety, they should sustain all the loads and deformations of normal construction and use and have adequate durability and resistance to the effects of misuse and fire.

Once the building form and structural arrangement have been finalized the design problem consists of the following:

1. Idealization of the structure into load bearing frames and elements for analysis and design
2. Estimation of loads
3. Analysis to determine the maximum moments, thrusts and shears for design
4. Design of sections and reinforcement arrangements for slabs, beams, columns, stairs and footings
5. Production of arrangement and detail drawings and bar schedules

This structural design process has been carried out under use of BS 8110 and EUROCODE

design code of practice.

Especially, computations have been made by use of BS 8110 based spreadsheets and Autodesk Robot Structural Analysis Software.

DESIGN INFORMATION

TYPE	DESCRIPTION
BS 8110 :The structural use of Concrete 1997(British Standard)	Relevant Building Regulations and Design Code
Classes building :Residential building)	Intended use of the building
Roof –Imposed :1.5 kN/m2 -Finishes : 1kN/m2 **Floor** –Imposed (3) and partitions(1)3 kN/m2 **Stairs** –Imposed : 4 kN/m2 - Finishes : 1 kN/m2	General loading conditions
Severe (external) and Mild (internal)	Exposure conditions
Reinforced Concrete footing to columns	Foundation type
Concrete: grade C 30 (fck=30MPa) (with 20mm Max. aggregates. Mix ratio : 350 kg/ m3 Reinforcement :-Characteristic strength f_y = 460 N/mm2 for stirrups f_y = 250 N/mm2 Steel Characteristic 275	Material Data
Self weight of Reinforced concrete = 24kN/ m3 Self weight of masonry wall = 18kN/ m3	Other relevant information
For Dead load : 1.4 For Live load : 1.6	Partial safety factor
Sandy-gravel Allowable bearing pressure =250kN/ m2	Subsoil conditions

I.4. SCOPE

1.1 The numerical values of actions on buildings and civil Engineering works to be taken into account in the design are applicable to the various types of construction.

1.2 The purpose of the building: This building will be used as a residential house.

1.3 The materials used are Reinforced Concrete structures of framed type, Solid two way slabs and bricks for walling, and of RC wall for Shear wall elevation, whereas the roof is made up with metal sheets and truss in steel structure.

1.4 The execution of construction of this building is covered by various code of designs to the extent that it is necessary to indicate the quality of construction materials and products which should be used and the standard of workmanship on site needed to be supervised by qualified and experienced Engineer .Some lab test like compressive strength test for concrete should be done as seen as the building structure is important.

1.5 The method of design is Limit state design method accordingly to BS8110-1997; the structural use of Concrete 1992, and the use of Autodesk Robot Structural Analysis Professional software.

I.5. LOAD COMBINATIONS

I.5.1.The Ultimate State (ULS)

Various combinations of the characteristic values of dead load Gk, imposed load Qk, wind load Wk and their partial factors of safety must be considered for the loading of the structure.

The partial factors of safety specified by BS 8110 for ultimate limit state in loading combinations to be considered are as follows;

(1) Dead and imposed load: 1.4Gk+1.6Qk

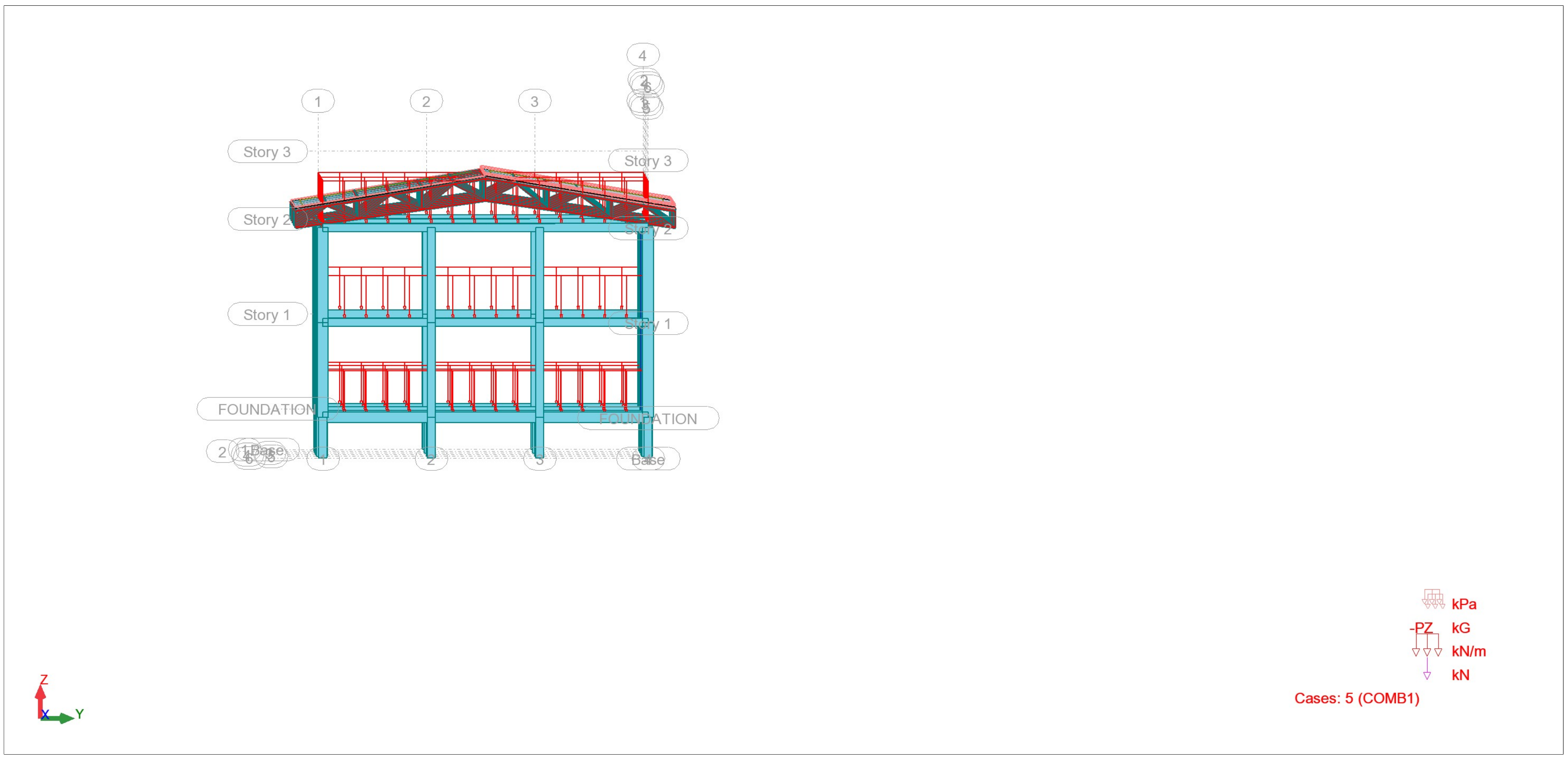
(2) Dead and wind load: 1.0Gk+1.6Qk

(3) Dead imposed and wind load: 1.2Gk+1.2Qk+1.2Wk

I.5.2.The Serviceability Limit State

A partial factor of safety of ɣf=1.0 is usually applied to all load combinations with the serviceability limit state.

View - Cases: 5 (COMB1)



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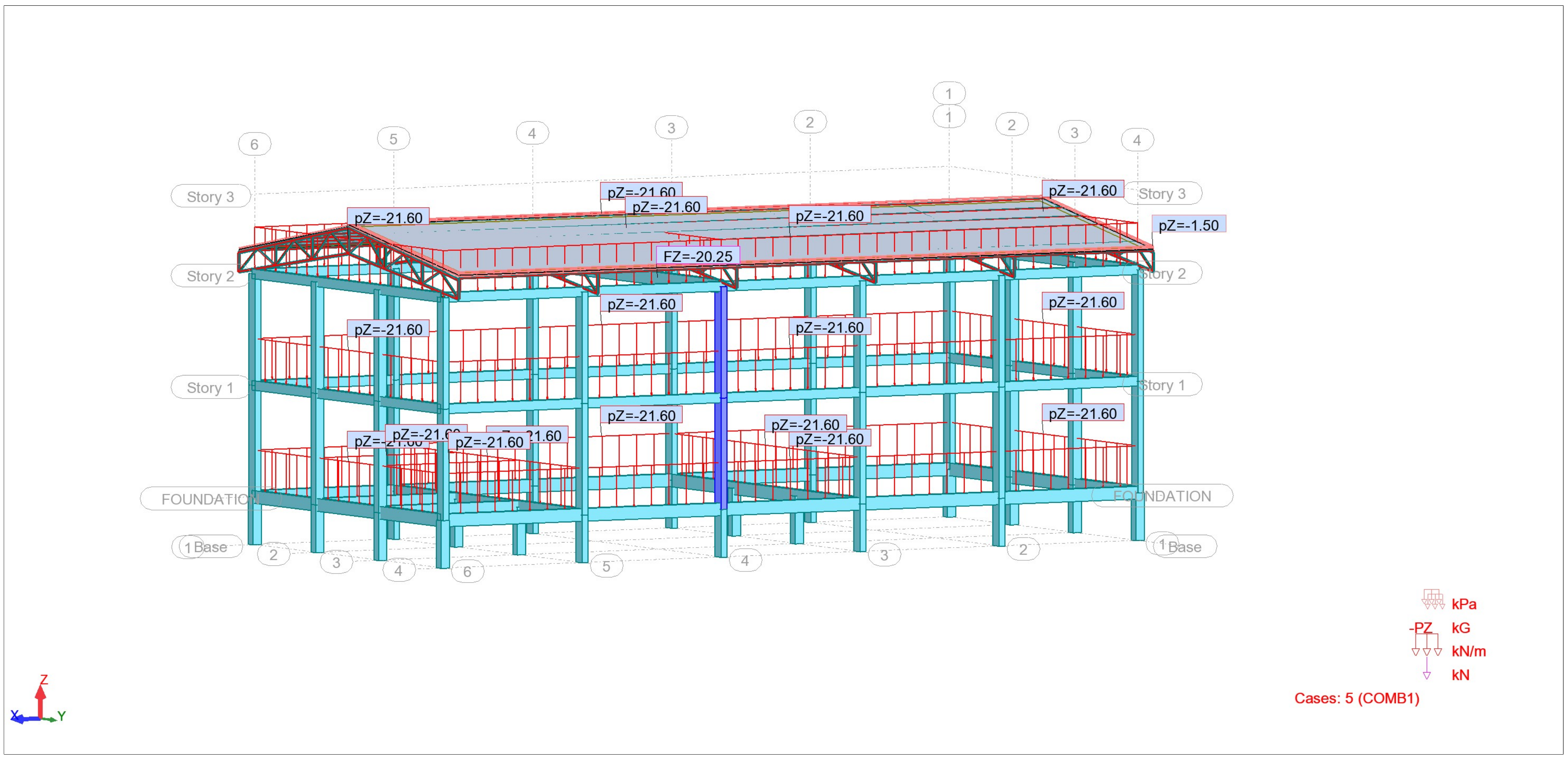
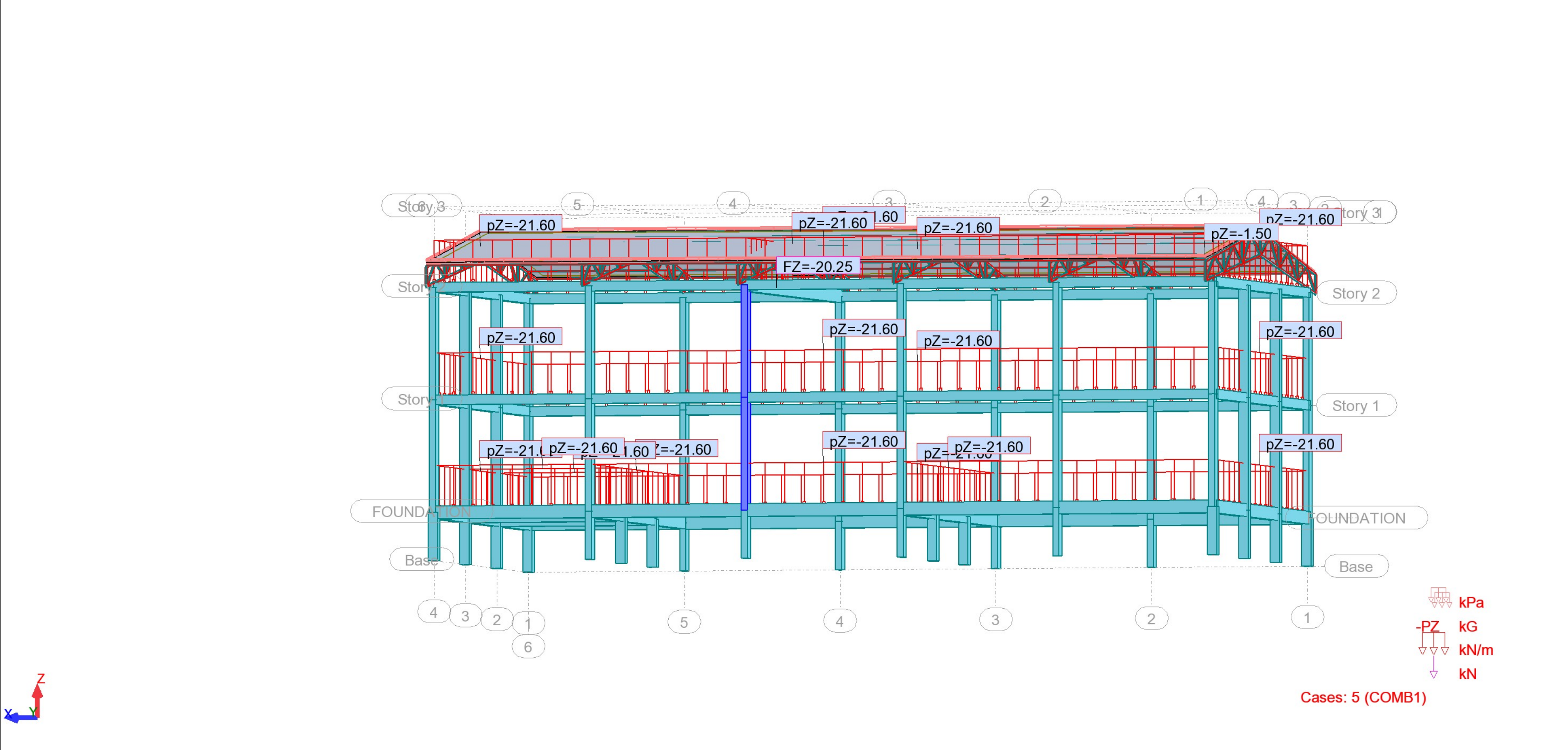


View - Cases: 5 (COMB1) 2



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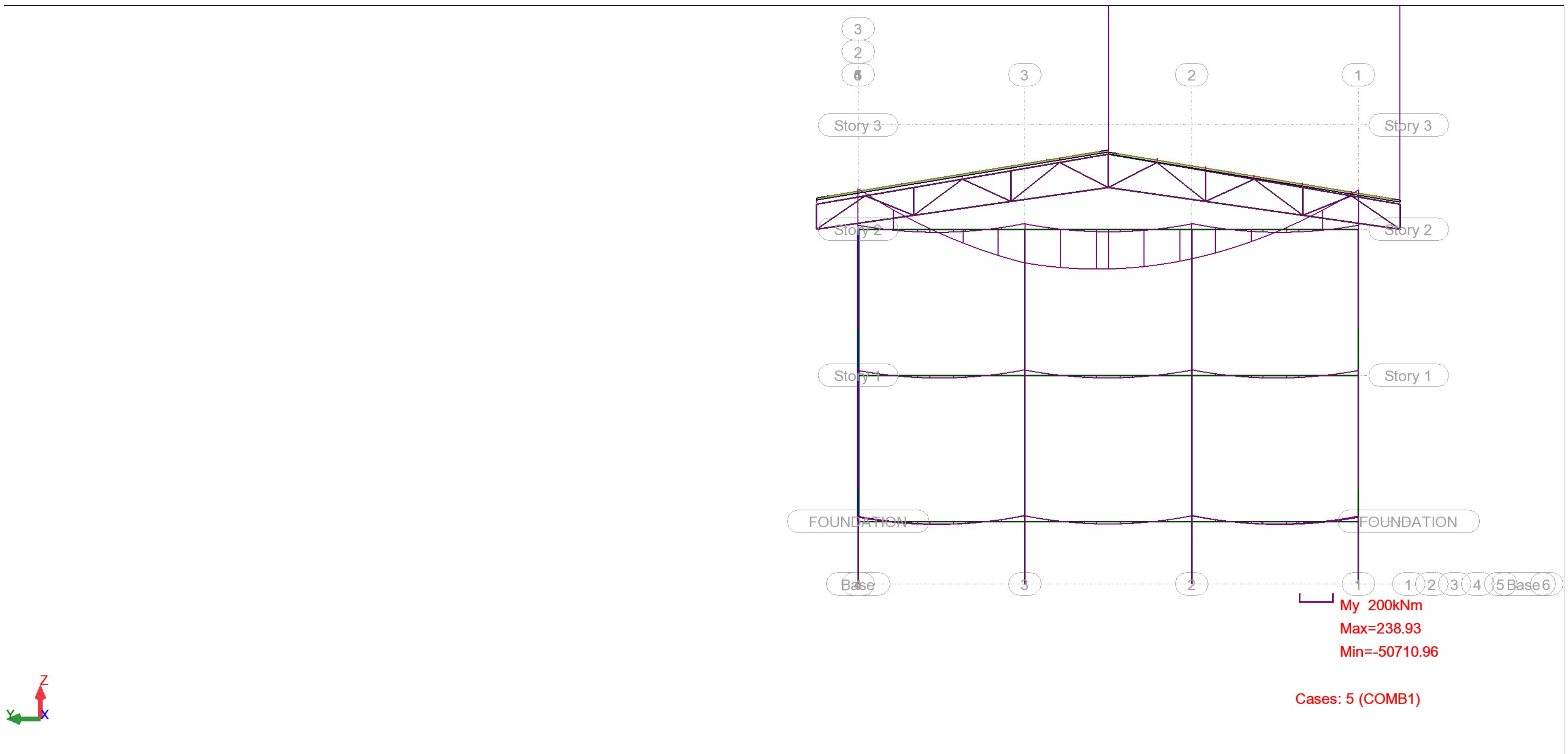


DESIGN CODES: BS 6399- 1: 1996, BS5950-1: 2000.

1. General introduction

The design consists of designing a roof truss of a building with a span of 12m, spaced at 5m C/C. The purlins are spaced at 1.00. The building has a rectangular shape 12x 25 m.

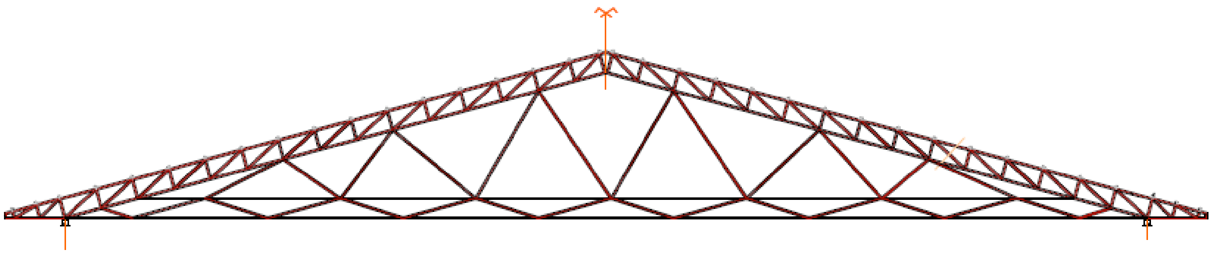
The Design is based to BS 5950-1-2000.

2. Design of trusses

2.1 Architectural design

Depth to span ratio should be ranged from 1:14 to 1:10; means height of apex from centre of span/span should be in range of 1/14 to 1/10 of span.

The roof will be roofed with iron sheet and with a slope of 15^o.



2.2 Structural design

2.2.1 Loads calculation

2.2.1.1. Dead loads (B S 648)

a) Dead load—measured on the slope length

-Sheeting and insulation board = 0.25 kN/m^2,

-Purlins = 0.1 kN/m^2,

-Truss = 0.1 kN/m^2,

-Ceiling and services =0.3kN/m^2

-Total dead load = 0.75 kN/m^2.

2.2.1.2. Live load (B S 6399-3:1988)

(a) Imposed load measured on plan, clause 4.3.1 = 0.6 kN/m^2,

Imposed load measured on slope = 0.6 ×17.242 /16.5= 6.3 kN/m^2.

The design of roof truss will be done by using SHS members and welded joints. The truss is to be fabricated in two parts for transport to site.

2.2.1.3. Wind load (CP 3: Chapter V-2: 1972)

Clause 5.1:

The design wind speed V_s should be calculated from

$V_s = V*S_1*S_2*S_3$

Where V is the basic wind speed (see clause 5.2), and S_1, S_2, S_3 are design wind speed factors (clause 5.3 to 5.6 inclusive).

2.2.1.3.1 Design wind speed V_s Calculation

(A) Basic wind speed

V=20m/s

(B) Topography factor S_1

S_1=1.36; clause 5.4 and appendix D

(C) Factor S_2

S2=0.99; Clause 5.5 and table 3

(D) Factor S_3

S_3=1; Clause 5.6

Then

V_s=20*1.36*0.99*1=27m/s

2.2.1.3.2Dynamic pressure of the wind (q) calculation

$$q = k * V_S^2$$

Values of k are as follows for the various units used in your calculation:

k = 0.613 in SI units (N/m^2 and m/s)

k = 0.062 5 in metric technical units (kgf/m^2 and m/s)

k = 0.002 56 in imperial units (lbf/ft^2 and mile/h).

q=0.613*27^2*10^{-3}kN/m^2

=0.45kN/m^2

2.2.1.3.3 Pressure p exerted at any point of the surface of building

$p=(C_{Pe}-C_{Pi}) * q$ clause 4.3 4)

Cpe -pressure coefficients for external surface

Cpi.- pressure coefficients for internal surface

If the value of p is negative this indicates that *p* is a suction as distinct from a positive pressure.

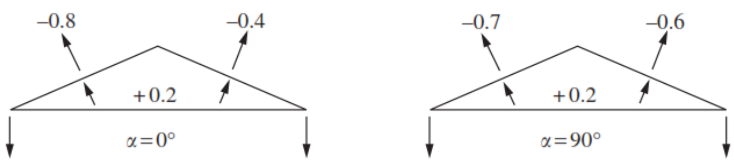
(A) Pressure coefficients, Clause 7

- **Internal pressure coefficient -C_{pi}**

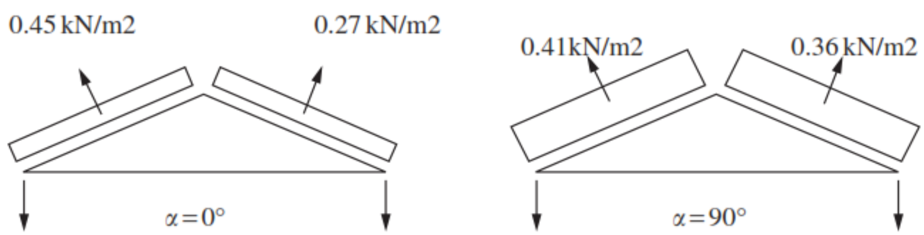
C_{pi} is taken as the more onerous of the values +0.2 or −0.3.Those values are used where there is only a negligible probability of a dominant opening occurring during a severe storm. **Otherwise please consult appendix E of CP3.**

- **External pressure coefficient -C_{pe}**

The external pressure coefficients are shown in Figure below but are calculated from table 8 of CP3.



(B) Pressure calculation



Roof wind loads

The maximum one which is $0.45kN/m^2$ will be used in design.

2.2.2 Roof elements design

2.2.2.1 Loads

- Unfactored load considered are (as calculated above)

  Wind load (WL) = 0.45kN/m^2

  Live load (LL) = 0.63kN/m^2

  Dead load (DL) = 0.75 kN/m^2.

  Note: all of them are at slope length

- **Load combination**

The load combinations are (as per BS 5950-1:2000, clause 2.4.1.2):

COMB1= 1.4DL+1.6LL

COMB2= 1.0DL-1.4WL; if WL is adverse

COMB2=1.4(DL+WL); if WL is beneficial

COMB3= 1.2(DL+LL+WL)

- **Properties and specification of materials**

- Steel grade S275
- Elastic properties of steel (Clause 3.1.3of BS 5950-1:2000):
  1. Modulus of Elasticity E = 205 × 10^3 N/mm2
  2. Poisson's Ratio ν = 0.3
  3. Shear Modulus G = E/[2(1+ν)] = (78.85 × 103 N/mm^2)
  4. Coefficient of Thermal Expansion α = 12 × 10^{-6}/ °C

2.2.2.2 Purlins analysis and design

2.2.2.2.1 Analysis

Span: 2.5m, continuous
Spacing: 1.15m

- **Loads:**

Wind load (WL) = 0.45*1.15=0.52kN/m

Live load (LL) = 0.63*1.15=0.73kN/m

Dead load (DL) = 0.75*1.15=0.87 kN/m

- **Bending moment diagram and shear force**

COMB1:

Summary:

Combination	**Maximum value of**	
	Moment	**Shear force**
COMB1	**1.52**	**3.59**
COMB2	**0.09**	**0.21**
COMB3	**1.63**	**3.83**

The design loads are from COMB3.

2.2.2.2.2 Design of section

I. Selection of section

Assume the section is class 1 and p_y is 275N/mm^2

$$S = \frac{M}{P_y} = \frac{1.63*10^6\,Nmm}{275\,N/mm^2}$$

$$S = 5.93cm^3$$

Select a cold formed RHS 50X50X2 with the following properties:

t=2mm

A=3.74cm^2

d/t=20

Second moment of area; I=14.1cm^2

Radius of gyration; r=1.95cm

Elastic modulus, Z=5.66cm^3

Plastic modulus; S=6.66cm^3

II. Section classification

References	Calculations	Output
Table 9 Table 12 Table 12	t<16; Then p_y=275N/mm^2 $\varepsilon = \left(\frac{275}{p_y}\right)^{1/2} = 1$ **Flange:** d/t =20; ε =1 and $72\varepsilon - d/t = 72 - 20 = 52$ As $d/t \leq 26\varepsilon$ but $\leq 72\varepsilon - d/t$ flange is class one. **Web:** d/t =20; ε =1 and 56 ε =56 As $d/t \leq 56\varepsilon$; web is class1.	**The section is class 1**

III. Section design

(A) Design for shear force

References	Calculations	Output

clause 4.2.3 Clause 4.2.3.	F_v=3.83kN $P_v = 0.6 * P_y * A_V$ $A_V = AD/(D+B)$ Where **A**-is the area of section **D**-is the overall depth **B**-is the overall breadth $A_V = 3.74*100*40/40+40$ =187mm^2 $P_V = 0.6*275\, N/mm^2 *187 mm^2 = 30855N$ =31kN **P_V>F_V** $d/t \leq 70\varepsilon$ therefore no need to check shear buckling	 **The section is adequate in shear force.**

(B) Design for bending moment

References	Calculations	Output
 clause 4.2.5.2 Clause 4.2.5.1 clause 4.2.5.2 clause 4.2.5.2	F_v=0kN 0.6P_v=18.6kN > F_v $M_c \leq 1.5*P_y*Z_x$ 1.5*P_y*Z_x=1.5*275*5.66*10^{-3}=2.335kNm M_c=P_y*S_{xx} =275*6.66*10^{-3}=1.8315kNm Maximum applied moment M_x=1.63kNm < M_c	 **low shear** **The section is adequate in bending moment**

(C) Serviceability check

Allowable deflection= L/200= 1150/200=5.75mm (table 8)

The deflection of the purlins in the outer span is Δ=2.048 mm < 5.75mm →OK

Conclusion: Purlins are cold formed RHS of 60x50x3 S275

2.2.2.3 Roof truss design

2.2.2.3.1 Analysis

Span: 33m centre to centre of bearings.
Spacing: 2.5m

External wind pressure normal to the roof is: $0.45kN/m^2$

Vertical component: $0.45\cos15^0=0.44kN/m^2$

- **Load/Node:**

Wind load (WL) = 0.44*1.15*2.5=1.3kN

Live load (LL) = 0.63*1.15*2.5=1.82kN

Dead load (DL) = 0.75*1.15*2.5=2.2 kN

- **Load arrangement**
- **Analysis results (factored loads)**

	Top chord		**Bottom chord**		**diagonals**	
	Force	Length (mm)	Force	Length (mm)	Force	Length (mm)
Max. Tension (kN)	**93.49**	**4125**	**182.4**	**4125**	**39.61**	**3998**
Max. Compression(kN)	**183.4**	**1150**	**164.6**	**947**	**42.34**	**3283**

2.2.2.3.2 Section design

I. Selection of section

Let's take a **RHS 80x40x3S355** with the following properties:

t=2.5mm

A_g=6.59cm^2

d/t=23

Second moment of area; I=49.4cm^4

Radius of gyration; r=2.74cm

Elastic modulus, Z=14.1cm^3

Plastic modulus; S=16.5cm^3

II. Section classification

References	Calculations	Output
Table 9	t<16; Then p_y=355N/mm^2 $\varepsilon = \left(\frac{275}{p_y}\right)^{1/2} = 0.88$	
Table 12	**Flange:** b/t =23; ε =0.88 and $35\varepsilon = 30.8$ As $d/t \leq 35\varepsilon$ **flange is not class 4.**	
Table 12	**Web:** d/t =23; ε =0.88 $\frac{105\varepsilon}{1+2r_2} \geq 35\varepsilon; r_2 = \frac{F_c}{A_g * P_{yw}} = \frac{183.4*1000N}{781mm^2 * 355 N/mm^2} = 0.66$ $\frac{105\varepsilon}{1+2r_2} = \frac{105*0.88}{1+(2*0.66)} = 39.83$ $\geq 35\varepsilon$ As d/t<39.8; **Web is not class4.**	**The section is not class 4**

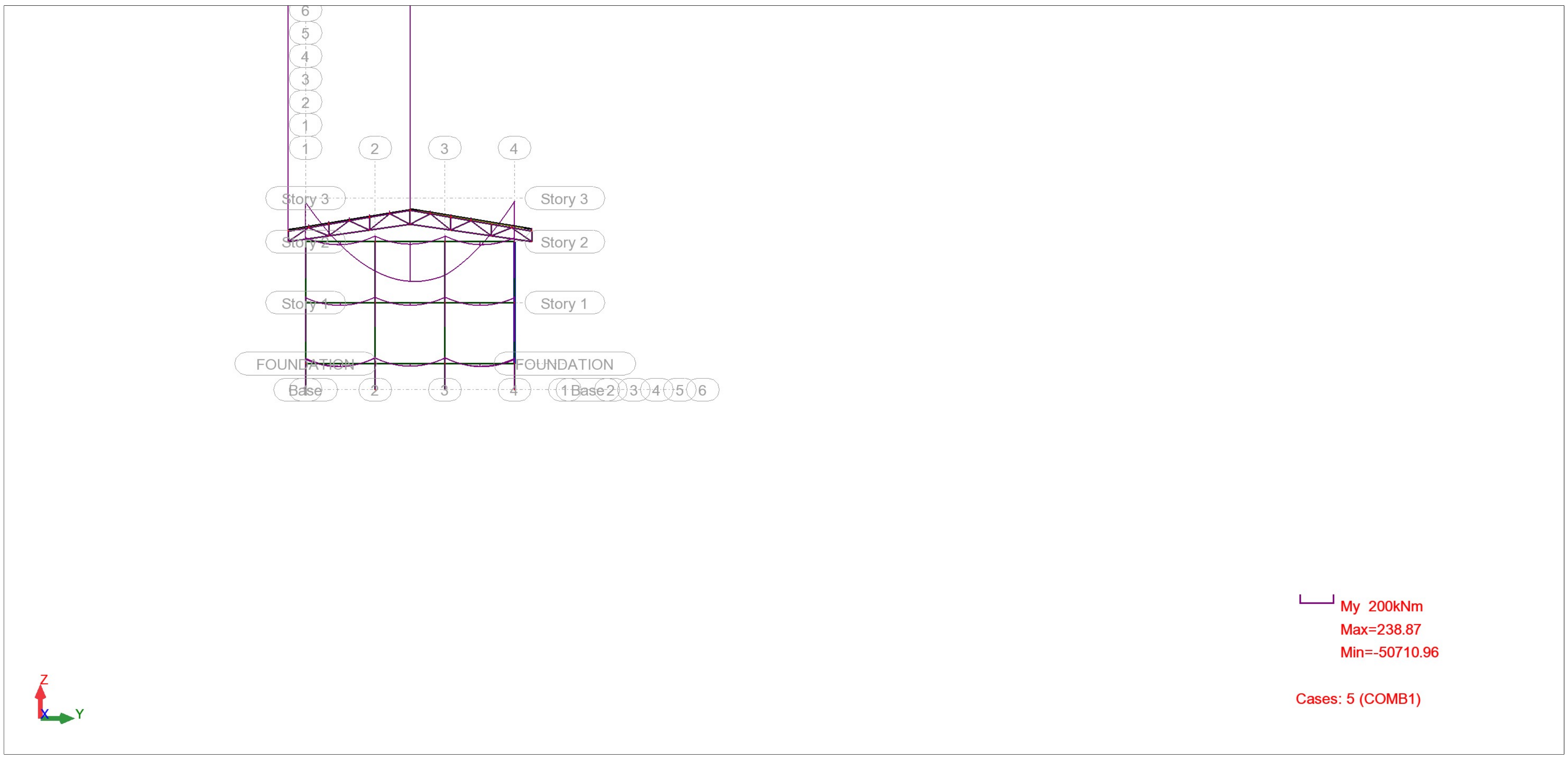
III. Section design

(D) Design for compression force

References	Calculations	Output
clause 4.7.4 Table 23 Table 24-c)	F_c=183.4kN $P_c = A_g * P_c$ strut curve c) $\lambda_y = \frac{l_y}{r_y} = \frac{1150mm}{27.4mm} = 42$ $p_c = 296 \, {}^{N}\!/_{mm^2}$ then $P_c = 296 * 659 * 10^{-3} kN = 195kN$ $P_C > F_C$	**The section is adequate in compression.**

Conclusion: Trusses are cold formed SHS of 80x40x3S355

View - MY, Cases: 5 (COMB1) 1



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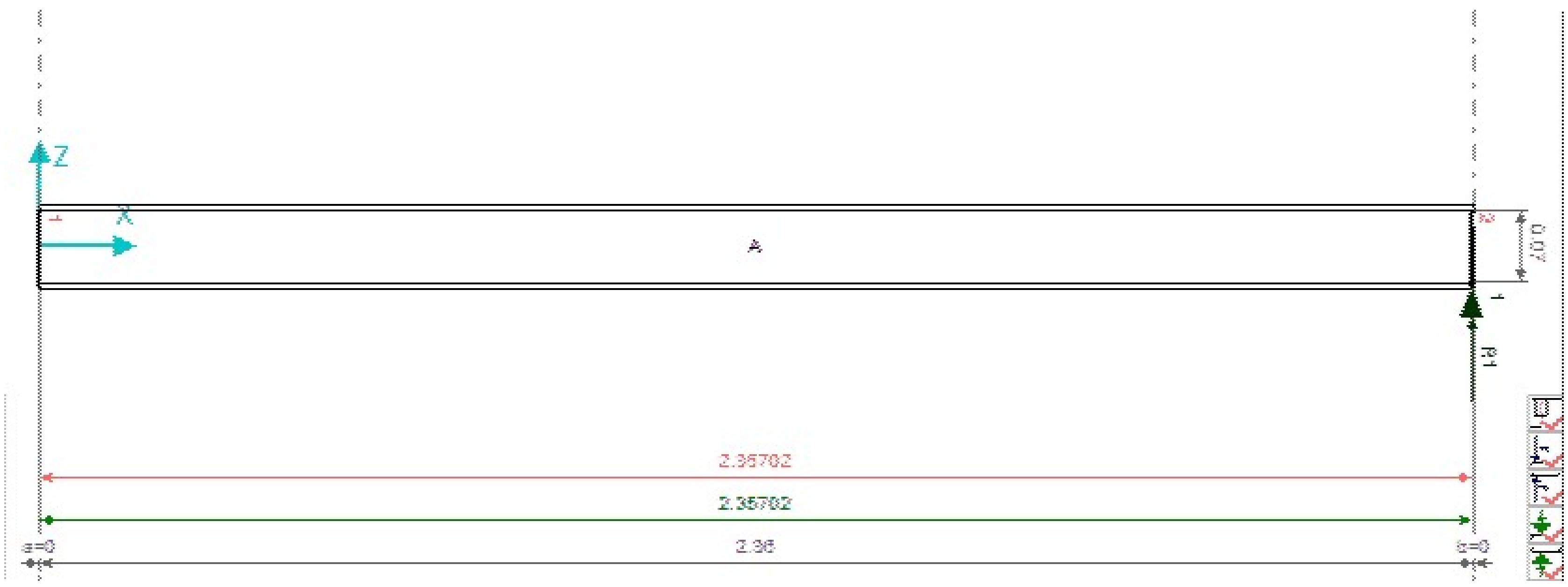
DETAILED ANALYSIS

according to Eurocode 3 (EN 1993-1-5:2005)

for member no. 289

OK



SECTION PARAMETERS: RHSC 80x40x3

ht=80 mm			
bf=40 mm	Ay=220 mm2	Az=441 mm2	Ax=661 mm2
tw=3 mm	Iy=523000 mm4	Iz=176000 mm4	Ix=439000 mm4
tf=3 mm	Wely=13075 mm3	Welz=8800 mm3	

TRANSVERSE STIFFENERS

Stiffener positions: 0.00; 2.36 *real coordinates*

Translation: a = 0.00 m; b = 0.00 m

Stiffener 1	bilateral	ts = 3 mm	hs = 74 mm
Stiffener 2	bilateral	ts = 3 mm	hs = 74 mm

CONCENTRATED FORCES

Force positions: 2.36; *real coordinates*

Force 1 F1 = 0.00 kN ss1 = 0 mm

SHEAR BUCKLING RESISTANCE (EC3 art. 5)

Symbols:

Lam_w	*- relative web slenderness*	*[5.2.(5)]*
kT	*- local buckling coefficient for shear*	*[A.3.(1)]*
Xw	*- Influence factor for shear resistance (web)*	*[5.3.(1)]*

Xf	*- Influence factor for shear resistance (flange)*	*[5.4.(1)]*
Xv	*- Instability factor for shear*	*[5.2.(1)]*
Mf,Rd	*- Design resistance of section flanges*	*[5.4.(1)]*
VEd	*- Maximum shear force in a panel*	*[5.2.(1)]*
Vb,Rd	*- Design shear buckling resistance*	*[5.2.(1)]*

Panel A Panel coordinates A x = (0.00 ; 1.00)
Point x = 0.00 m
According to paragraph 5.1.(2), it is not necessary to check resistance to local shear buckling.

RESISTANCE OF WEBS TO TRANSVERSE FORCES (EC3 art.5.7)

The beam check has not been performed because the concentrated force applied to web without stiffeners was not detected.

INTERACTION SHEAR/BENDING/AXIAL FORCE (EC3 art. 7.1)

Symbols:

My,Ed	*- Design bending moment*	
Mz,Ed	*- Design bending moment*	
NEd	*- Design axial force*	
VEd	*- Design shear force*	
Mf.Rd	*- Design plastic moment resistance of a section consisting of flanges*	*[7.1.(1)]*
My,pl.Rd	*- Design beam resistance at bending*	*[7.1.(1)]*
Vb.Rd	*- Design shear buckling resistance*	*[5.2.(1)]*

Panel A Panel coordinates A x = (0.00 ; 1.00)
Point x = 0.00 m
According to [7.1.(1)] checking of NTM interaction is not necessary (VEd/Vb,Rd < 0.5);

TRANSVERSE STIFFENER RESISTANCE (EC3 art. 9)

Symbols:

bw	*- Effective web width*	*[9.1.(2)]*
Ast	*- Stiffener area*	*[9.1.(2)]*
Ist	*- Moment of inertia of stiffener*	*[9.1.(2)]*
Sig,cr,c	*- Critical Euler stress (column model)*	*[9.1.(5)]*
Sig,cr,p	*- Critical Euler stress (plate model)*	*[9.1.(5)]*
u	*- Coefficient for calculations of Ist,min*	*[9.1.(5)]*
Sigm	*- Stress due to lateral actions*	*[9.1.(5)]*
Ist,min	*- Minimum stiffness due to panel actions*	*[9.1.(5)]*
Ip	*- Polar moment of inertia of a stiffener*	*[9.1.(7)]*
It	*- Torsional moment of inertia of a stiffener*	*[9.1.(7)]*
Nst,Ed	*- Stiffener compressive force*	*[9.3.3.(3)]*
Mst,Ed	*- Additional moment due to lateral actions of panels*	*[9.1.(6)]*
Lam,st	*- Non-dimensional slenderness of stiffener due to buckling*	*[9.4.(2)]*
Xst	*- Stiffener buckling coefficient*	*[9.4.(2)]*
Nst,b,Rd	*- Stiffener buckling capacity*	*[9.1.(3)]*
eN	*- Eccentricity of a compressive force acting on unilateral stiffener*	*[9.4.(3)]*
Mst,Rd	*- Stiffener resistance for bending in the plane perpendicular to web*	*[9.4.(3)]*

Stiffener 1 **Point x = 0.00 m**
ATTENTION! According to the (5.63) formulae it is not necessary to check a stiffener subjected to buckling.

Stiffener 2 **Point x = 2.36 m**
ATTENTION! According to the (5.63) formulae it is not necessary to check a stiffener subjected to buckling.

STABILITY OF COMPRESSIVE FLANGE (EC3 art. 8.1)

Symbols:

k	*- Factor depending on section class*	*[8.(1)]*
Aw	*- Area of stiffener*	*[8.(1)]*
Afc	*- Area of compressive flange*	*[8.(1)]*

k = 0.30 Aw = 222 mm2 Afc = 120 mm2
Check condition: **(8.1)**
D/tw = 24.67 < k(E/fyf)*[Aw/Afc]^0.5 = 315.66 **OK!**

Analyzed beam meets the Eurocode 3 requirements

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1

BEAMS DESIGN

- Name : FOUNDATION
- Reference level : ---
- Maximum cracking : 0.30 (mm)
- Exposure : X0
- Concrete creep coefficient : φ_π = 3.20
- Cement class : N
- Concrete age (loading moment) : 28 (days)
- Concrete age : 50 (years)

- Concrete age after erecting a structure : 365 (years)
- Structure class : S1
- Fire resistance class : no requirements
- FFB Recommendations 7.4.3(7) : 0.00

2 TYPICAL GROUND BEAM DESIGN Number: 1

2.1 Material properties:

- Concrete : CONCR f_{ck} = 20.00 (MPa)
  Rectangular stress distribution [3.1.7(3)]
  Density : 2501.36 (kG/m3)
  Aggregate size : 20.0 (mm)
- Longitudinal reinforcement: : f_{yk} = 500.00 (MPa)
  Horizontal branch of the stress-strain diagram
  Ductility class : C
- Transversal reinforcement: : f_{yk} = 500.00 (MPa)
  Horizontal branch of the stress-strain diagram
  Ductility class : C
- Additional reinforcement: : f_{yk} = 500.00 (MPa)
  Horizontal branch of the stress-strain diagram

2.2 Geometry:

2.2.1

Span	Position	L.supp. (m)	L (m)	R.supp. (m)
P1	**Span**	**0.30**	**4.75**	**0.20**

Span length: L_o = 5.00 (m)
Section from 0.00 to 4.75 (m)
200 x 400 (mm)
without left slab
without right slab

2.2.2

Span	Position	L.supp. (m)	L (m)	R.supp. (m)
P2	**Span**	**0.20**	**4.80**	**0.20**

Span length: L_o = 5.00 (m)
Section from 0.00 to 4.80 (m)
200 x 400 (mm)
without left slab
without right slab

2.2.3

Span	Position	L.supp. (m)	L (m)	R.supp. (m)
P3	**Span**	**0.20**	**4.80**	**0.20**

Span length: L_o = 5.00 (m)
Section from 0.00 to 4.80 (m)
200 x 400 (mm)
without left slab
without right slab

2.2.4

Span	Position	L.supp. (m)	L (m)	R.supp. (m)
P4	**Span**	**0.20**	**4.80**	**0.20**

Span length: L_o = 5.00 (m)
Section from 0.00 to 4.80 (m)
200 x 400 (mm)
without left slab
without right slab

2.2.5

Span	Position	L.supp. (m)	L (m)	R.supp. (m)
P5	**Span**	**0.20**	**4.75**	**0.30**

Span length: L_o = 5.00 (m)
Section from 0.00 to 4.75 (m)
200 x 400 (mm)
without left slab
without right slab

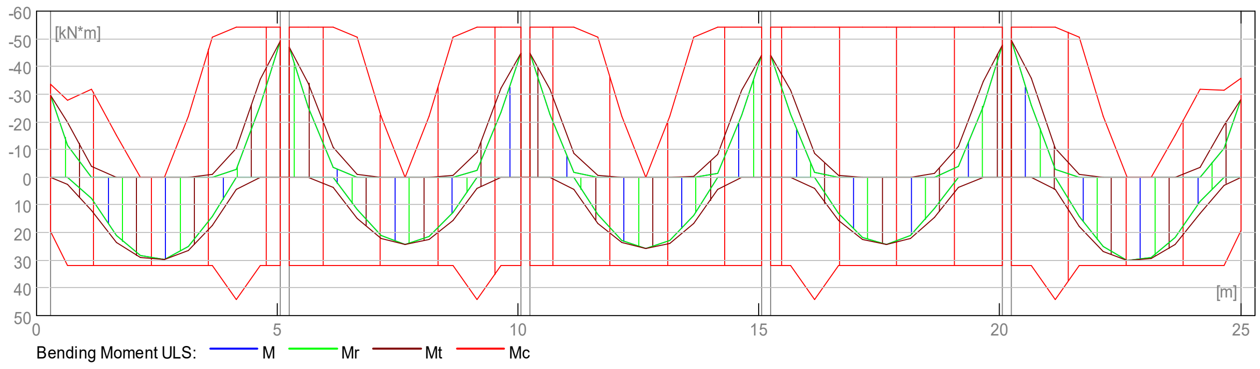
2.3 Calculation options:

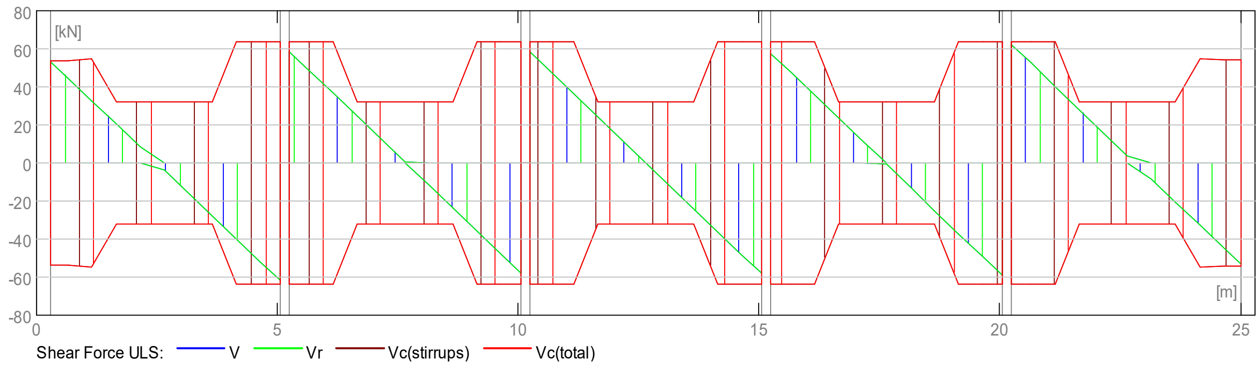
- Regulation of combinations : BS-EN 1990:2002 NA:2004
- Calculations according to : BS EN1992-1-1:2004 NA:2005
- Seismic dispositions : No requirements
- Precast beam : no
- Cover : bottom c = 40 (mm)
  : side c1= 40 (mm)
  : top c2= 40 (mm)
- Cover deviations : Cdev = 10(mm), Cdur = 0(mm)
- Coefficient β_2 =0.50 : long-term or cyclic load
- Method of shear calculations : strut inclination

2.4 Calculation results:

2.4.1 Internal forces in ULS

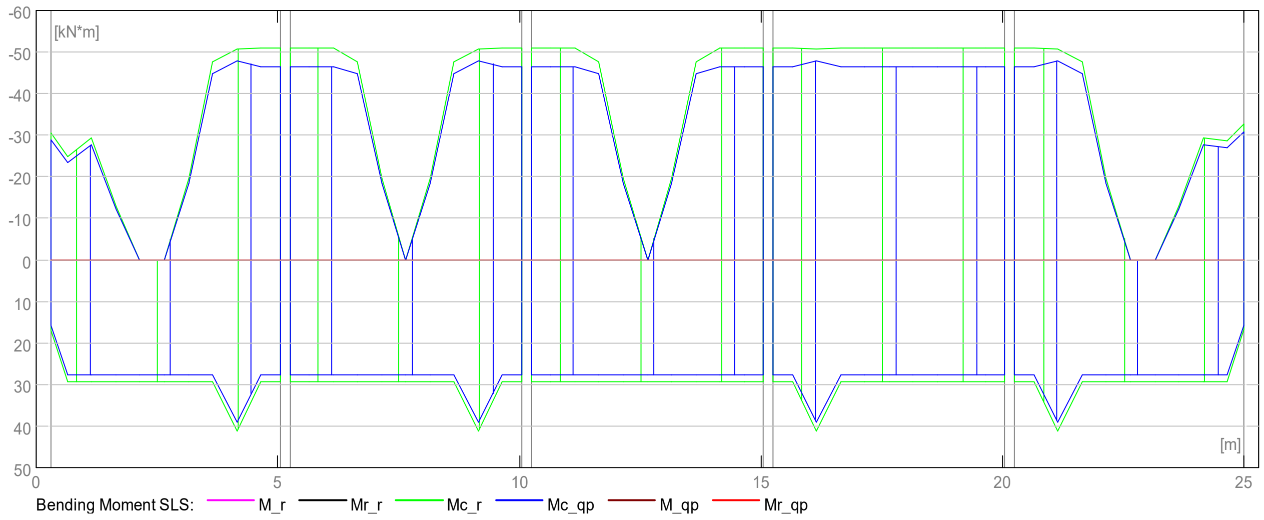
Span	Mt max. (kN*m)	Mt min. (kN*m)	Ml (kN*m)	Mr (kN*m)	Ql (kN)	Qr (kN)
P1	29.70	-0.95	-29.52	-49.18	53.42	-61.76
P2	24.29	-1.19	-47.14	-44.92	58.66	-57.74
P3	25.81	-0.53	-44.77	-44.26	58.31	-58.09
P4	24.32	-1.32	-44.20	-47.81	57.45	-58.95
P5	30.17	-0.95	-49.49	-28.29	62.09	-53.10





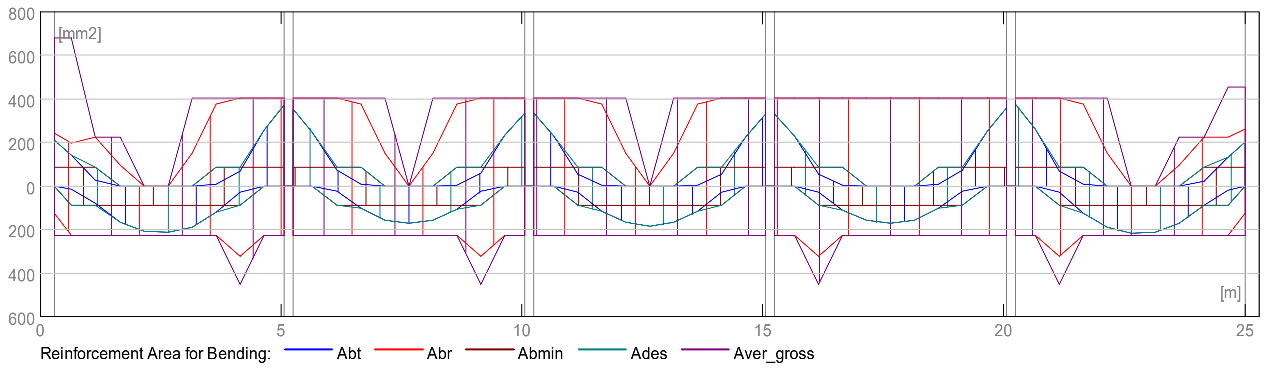
2.4.2 Internal forces in SLS

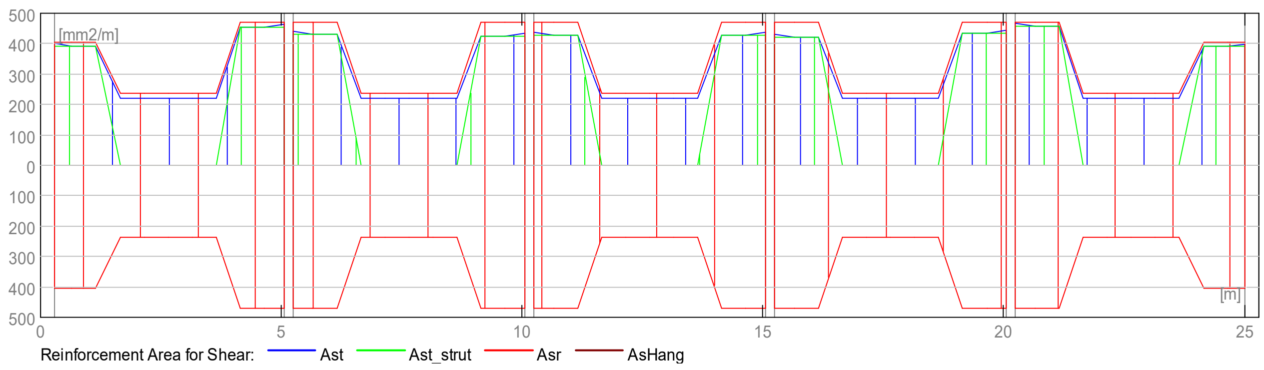
Span	Mt max. (kN*m)	Mt min. (kN*m)	Ml (kN*m)	Mr (kN*m)	Ql (kN)	Qr (kN)
P1	0.00	0.00	0.00	0.00	0.00	0.00
P2	0.00	0.00	0.00	0.00	0.00	0.00
P3	0.00	0.00	0.00	0.00	0.00	0.00
P4	0.00	0.00	0.00	0.00	0.00	0.00
P5	0.00	0.00	0.00	0.00	0.00	0.00



2.4.3 Required reinforcement area

Span	Span (mm2)		Left support (mm2)		Right support (mm2)	
	bottom	top	bottom	top	bottom	top
P1	214	0	0	212	0	372
P2	173	0	0	354	0	336
P3	184	0	0	334	0	330
P4	173	0	0	330	0	360
P5	217	0	0	374	0	203





2.4.4 Deflection and cracking

wt(QP) Total due to quasi-permanent combination
wt(QP)dop Allowable due to quasi-permanent combination
Dwt(QP) Deflection increment from the quasi-permanent load combination after erecting a structure.
Dwt(QP)dop Admissible deflection increment from the quasi-permanent load combination after erecting a structure.

wk - width of perpendicular cracks

Span	wt(QP) (mm)	wt(QP)dop (mm)	Dwt(QP) (mm)	Dwt(QP)dop (mm)	wk (mm)
P1	0	20	0	10	0.0
P2	0	20	0	10	0.0
P3	0	20	0	10	0.0
P4	0	20	0	10	0.0
P5	0	20	0	10	0.0

2.5 Reinforcement:

2.5.1 P1 : Span from 0.30 to 5.05 (m)

Longitudinal reinforcement:

- bottom ()
  2 ϕ12 l = 4.32 from 0.07 to 4.39
- assembling (top) ()
  2 ϕ8 l = 2.60 from 1.10 to 3.70
- support ()
  2 ϕ12 l = 1.86 from 0.04 to 1.90
  2 ϕ16 l = 4.66 from 2.82 to 7.48
  1 ϕ12 l = 1.75 from 0.05 to 0.05

Transversal reinforcement:

- main ()
  stirrups 27 ϕ6 l = 1.05
  e = 1*0.04 + 8*0.14 + 11*0.24 + 7*0.12 (m)

2.5.2 P2 : Span from 5.25 to 10.05 (m)

Longitudinal reinforcement:

- bottom ()
  2 ϕ12 l = 5.57 from 3.81 to 9.38
- assembling (top) ()
  2 ϕ8 l = 2.10 from 6.60 to 8.70
- support ()
  2 ϕ16 l = 4.66 from 7.82 to 12.48

Transversal reinforcement:

- main ()
  stirrups 27 ϕ6 l = 1.05
  e = 8*0.12 + 12*0.24 + 7*0.12 (m)

2.5.3 P3 : Span from 10.25 to 15.05 (m)

Longitudinal reinforcement:

- bottom ()
  2 ϕ12 l = 7.70 from 8.80 to 16.50
- assembling (top) ()
  2 ϕ8 l = 2.10 from 11.60 to 13.70

Transversal reinforcement:

- main ()
  stirrups 27 ϕ6 l = 1.05
  e = 8*0.12 + 12*0.24 + 7*0.12 (m)

2.5.4 P4 : Span from 15.25 to 20.05 (m)

Longitudinal reinforcement:

- bottom ()

2 ϕ12 l = 5.57 from 15.92 to 21.49

- support ()

2 ϕ16 l = 9.66 from 12.82 to 22.48

Transversal reinforcement:

- main ()

stirrups 27 ϕ6 l = 1.05
e = 8*0.12 + 12*0.24 + 7*0.12 (m)

2.5.5 P5 : Span from 20.25 to 25.00 (m)

Longitudinal reinforcement:

- bottom ()

2 ϕ12 l = 4.32 from 20.91 to 25.23

- assembling (top) ()

2 ϕ8 l = 2.60 from 21.60 to 24.20

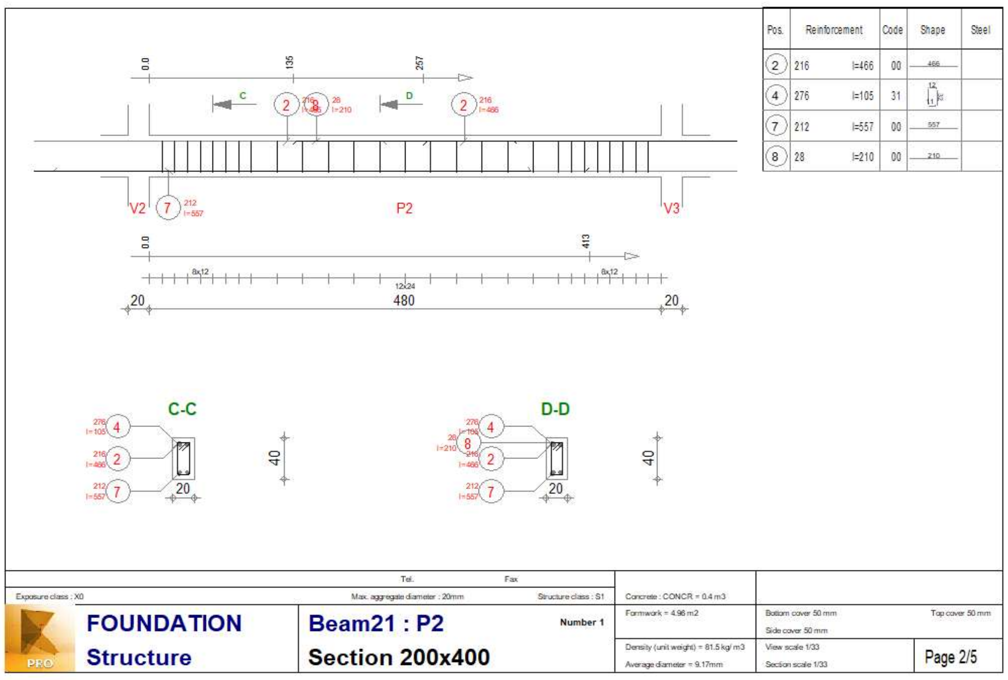
- support ()

2 ϕ12 l = 1.86 from 23.40 to 25.26
1 ϕ12 l = 1.75 from 25.25 to 25.25

Transversal reinforcement:

- main ()

stirrups 27 ϕ6 l = 1.05
e = 1*0.11 + 7*0.12 + 11*0.24 + 8*0.14 (m)



3 Material survey:

- Concrete volume = 2.02 (m3)
- Formwork = 25.18 (m2)

- Steel
  - Total weight = 157.47 (kG)
  - Density = 77.80 (kG/m3)
  - Average diameter = 9.1 (mm)
  - Survey according to diameters:

Diameter	Length (m)	Weight (kG)
6	142.21	31.57
8	18.83	7.43
12	65.88	58.51
16	37.98	59.96

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COLUMNS DESIGN

- Name :
- Reference level : 0.00 (m)
- Concrete creep coefficient : φ_p = 3.16

- Cement class : N
- Environment class : X0
- Structure class : S1

2 TYPICAL COLUMN C1 DESIGN Number: 1

2.1 Material properties:

- Concrete : CONCR f_{ck} = 20.00 (MPa)
  Unit weight : 2501.36 (kG/m3)
  Aggregate size : 20.0 (mm)
- Longitudinal reinforcement: : R f_{yk} = 250.00 (MPa)
  Ductility class : C
- Transversal reinforcement: : R f_{yk} = 250.00 (MPa)

2.2 Geometry:

2.2.1 Rectangular 300 x 300 (mm)
2.2.2 Height: L = 3.45 (m)
2.2.3 Slab thickness = 0.00 (m)
2.2.4 Beam height = 0.30 (m)
2.2.5 Cover = 40 (mm)

2.3 Calculation options:

- Calculations according to : BS EN1992-1-1:2004 NA:2005
- Seismic dispositions : No requirements
- Precast column : no
- Pre-design : no
- Slenderness taken into account : yes
- Compression : with bending
- Ties : to slab
- Fire resistance class : No requirements

2.4 Loads:

Case	Nature	Group	γ_f	N (kN)	My(s) (kN*m)	My(i) (kN*m)	Mz(s) (kN*m)	Mz(i) (kN*m)
COMB1	design(Structural)	46	1.00	213.13	6.40	-0.45	0.66	-0.20

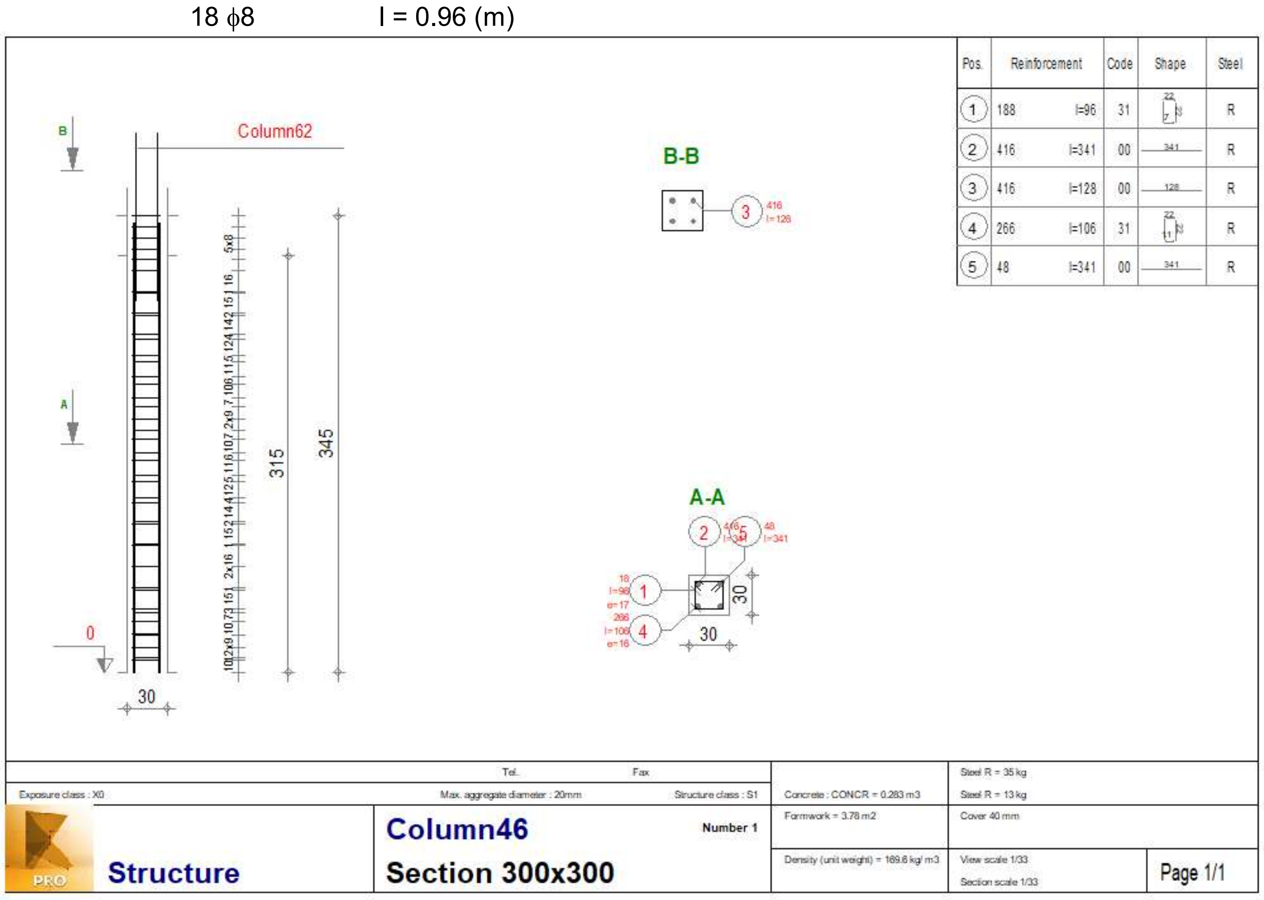
γ_f - load factor

2.5 Reinforcement:

Main bars (R):
- 4 ϕ16 l = 3.41 (m)
- 4 ϕ16 l = 3.41 (m)

Dowel bars (R):
- 4 ϕ16 l = 1.28 (m)

Transversal reinforcement: (R):
stirrups: 26 ϕ6 l = 1.06 (m)
18 ϕ8 l = 0.96 (m)



3 Column: Column33 Number: 1

3.1 Material properties:

- Concrete : CONCR f_{ck} = 20.00 (MPa)
  Unit weight : 2501.36 (kG/m3)
  Aggregate size : 20.0 (mm)
- Longitudinal reinforcement: : T f_{yk} = 460.00 (MPa)
  Ductility class : A
- Transversal reinforcement: : T f_{yk} = 460.00 (MPa)

3.2 Geometry:

3.2.1 Rectangular 400 x 200 (mm)
3.2.2 Height: L = 3.45 (m)
3.2.3 Slab thickness = 0.00 (m)
3.2.4 Beam height = 0.30 (m)
3.2.5 Cover = 40 (mm)

3.3 Calculation options:

- Calculations according to : BS EN1992-1-1:2004 NA:2005
- Seismic dispositions : No requirements
- Precast column : no
- Pre-design : no
- Slenderness taken into account : yes
- Compression : with bending
- Ties : to slab
- Fire resistance class : No requirements

3.4 Loads:

Case	Nature	Group	γ_f	N (kN)	My(s) (kN*m)	My(i) (kN*m)	Mz(s) (kN*m)	Mz(i) (kN*m)
COMB1	design(Structural)	33	1.00	411.12	-0.07	0.17	-2.20	-79.85

γ_f - load factor

3.5 Calculation results:

Safety factors Rd/Ed = 1.82 > 1.0

3.5.1 ULS/ALS Analysis

Design combination: COMB1 (B)
Combination type: ULS
Internal forces:
Nsd = 411.12 (kN) Msdy = 0.17 (kN*m) Msdz = -79.85 (kN*m)
Design forces:
Lower node
N = 411.12 (kN) N*etotz = 8.22 (kN*m) N*etoty= -83.45 (kN*m)

Eccentricity:		ez (My/N)	ey (Mz/N)
Static	eEd:	0 (mm)	-194 (mm)
Imperfection	ei:	0 (mm)	9 (mm)
Initial	e0:	0 (mm)	-185 (mm)
Minimal	emin:	20 (mm)	20 (mm)
Total	etot:	20 (mm)	-203 (mm)

3.5.1.1. Detailed analysis-Direction Y:

3.5.1.1.1 Slenderness analysis

Non-sway structure

L (m)	Lo (m)	λ	λlim	
3.50	3.50	60.62	24.92	Slender column

3.5.1.1.2 Buckling analysis

M2 = 0.17 (kN*m) M1 = -0.07 (kN*m)
Case: Cross-section at the column end (Lower node), Slenderness not taken into account
M0 = 0.17 (kN*m)
ea = 0 (mm)
Ma = N*ea = 0.00 (kN*m)
MEdmin = 8.22 (kN*m)
M0Ed = max(MEdmin,M0 + Ma) = 8.22 (kN*m)

3.5.1.2. Detailed analysis-Direction Z:

M2 = -2.20 (kN*m) M1 = -79.85 (kN*m)
Case: Cross-section at the column end (Lower node), Slenderness not taken into account
M0 = -79.85 (kN*m)
ea = θ1*lo/2 = 9 (mm)

$\theta l = \theta o * \alpha h * \alpha m = 0.01$
$\theta o = 0.01$
$\alpha h = 1.00$
$\alpha m = (0,5(1+1/m))$^0.5 = 1.00
m = 1.00
Ma = N*ea = 3.60 (kN*m)
MEdmin = 8.22 (kN*m)
M0Ed = max(MEdmin,M0 + Ma) = -83.45 (kN*m)

3.5.2 Reinforcement:

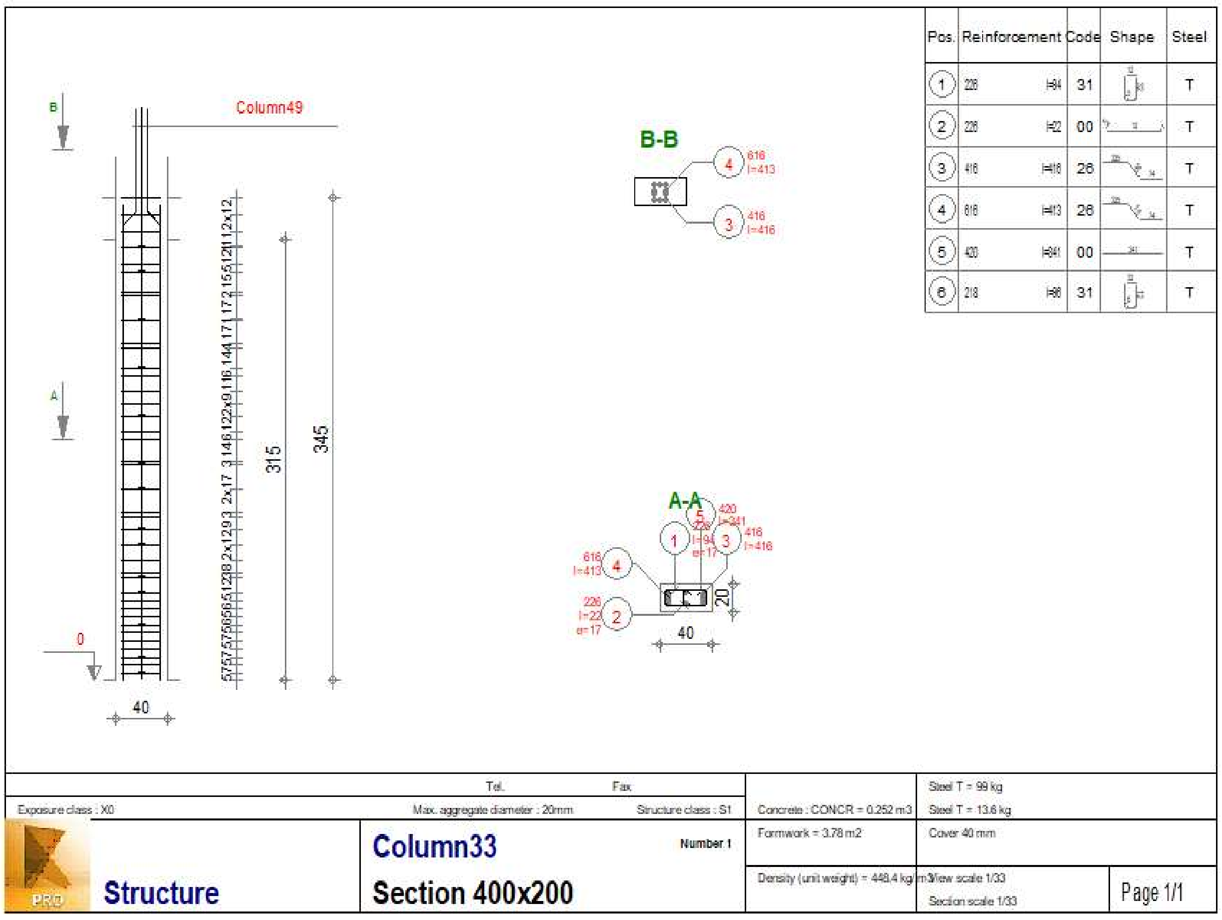
Real (provided) area Asr = 3267 (mm2)
Ratio: ρ = 4.08 %

3.6 Reinforcement:

Main bars (T):

- 4 ϕ20 l = 3.41 (m)
- 6 ϕ16 l = 4.13 (m)

Transversal reinforcement: (T):
stirrups: 21 ϕ8 l = 0.96 (m)



4 Material survey:

- Concrete volume = 0.54 (m3)
- Formwork = 7.56 (m2)

- Steel T
  - Total weight = 47.97 (kG)
  - Density = 89.57 (kG/m3)
  - Average diameter = 9.2 (mm)
  - Reinforcement survey:

Diameter	Length (m)	Weight (kG)
6	27.60	6.13
8	30.96	12.22
16	18.76	29.62

- Steel T
  - Total weight = 112.61 (kG)
  - Density = 210.29 (kG/m3)
  - Average diameter = 12.4 (mm)
  - Reinforcement survey:

Diameter	Length (m)	Weight (kG)
6	25.62	5.69
8	20.09	7.93
16	41.39	65.34
20	13.64	33.65

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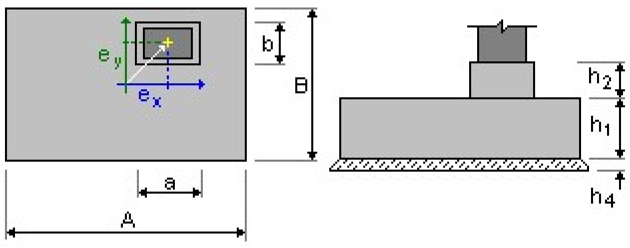
1 TYPICAL COLUMN BASE F1 Number: 1

1.1 Basic data

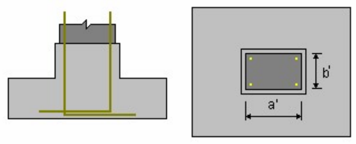
1.1.1 Assumptions

- Geotechnic calculations according to : BS 8004
- Concrete calculations according to : BS EN1992-1-1:2004 NA:2005
- Shape selection : without limits

1.1.2 Geometry:



A	= 1.50 (m)	a	= 0.30 (m)
B	= 1.50 (m)	b	= 0.30 (m)
h1	= 0.25 (m)	e_x	= 0.00 (m)
h2	= 0.20 (m)	e_y	= 0.00 (m)
h4	= 0.05 (m)		



a' = 300 (mm)
b' = 300 (mm)
cnom1 = 60 (mm)
cnom2 = 60 (mm)
Cover deviations: Cdev = 10(mm), Cdur = 0(mm)

1.1.3 Materials

- Concrete : CONCR; Characteristic strength = 20.00 MPa
  Unit weight = 2501.36 (kG/m3)
  Rectangular stress distribution [3.1.7(3)]
- Longitudinal reinforcement : type T Characteristic strength = 460.00 MPa
  Ductility class: A
  Horizontal branch of the stress-strain diagram
- Transversal reinforcement : type T Characteristic strength = 460.00 MPa
- Additional reinforcement: : type T Characteristic strength = 460.00 MPa

1.1.4 Loads:

Foundation loads:

Case	Nature	Group	N (kN)	Fx (kN)	Fy (kN)	Mx (kN*m)	My (kN*m)
COMB1	design	----	213.13	1.96	0.25	-0.20	0.45

Backfill loads:

Case	Nature	Q1 (kN/m2)

1.1.5 Combination list

1/ ULS : COMB1 N=213.13 Mx=-0.20 My=0.45 Fx=1.96 Fy=0.25
2/* ULS : COMB1 N=213.13 Mx=-0.20 My=0.45 Fx=1.96 Fy=0.25

1.2 Geotechnical design

1.2.1 Assumptions

Foundation design for:
• Capacity
• Rotation

1.2.2 Soil:

Soil level:	N_1	= 0.00 (m)
Column pier level:	N_a	= 0.00 (m)
Minimum reference level:	N_f	= -0.50 (m)

well graded gravels

- Soil level: 0.00 (m)
- Unit weight: 2243.38 (kG/m3)
- Unit weight of solid: 2702.25 (kG/m3)
- Internal friction angle: 42.0 (Deg)
- Cohesion: 0.00 (MPa)

1.2.3 Limit states

1.3 RC design

1.3.1 Assumptions

- Exposure : X0
- Structure class : S1

1.3.2 Analysis of punching and shear

Punching

Design combination **ULS : COMB1 N=213.13 Mx=-0.20 My=0.45 Fx=1.96 Fy=0.25**
Load factors: **1.35** * Foundation weight
1.35 * Soil weight
Design load:
Nr = 245.19 (kN) Mx = -0.31 (kN*m) My = 1.33 (kN*m)
Length of critical circumference: 2.78 (m)
Punching force: 157.28 (kN)
Section effective height h_{eff} = 0.18 (m)
Reinforcement ratio: ρ = 0.16 %
Shear stress: 0.32 (MPa)
Admissible shear stress: 0.63 (MPa)
Safety factor: 1.973 > 1

1.3.3 Required reinforcement

Spread footing:

bottom:

ULS : COMB1 N=213.13 Mx=-0.20 My=0.45 Fx=1.96 Fy=0.25
My = 30.10 (kN*m) A_{sx} = 287 (mm2/m)

ULS : COMB1 N=213.13 Mx=-0.20 My=0.45 Fx=1.96 Fy=0.25
Mx = 29.69 (kN*m) A_{sy} = 283 (mm2/m)

$A_{s\ min}$ = 234 (mm2/m)

top:

A'_{sx} = 0 (mm2/m)
A'_{sy} = 0 (mm2/m)

$A_{s\ min}$ = 0 (mm2/m)

Column pier:
Longitudinal reinforcement A = 180 (mm2) A $_{min.}$ = 180 (mm2)
A = 2 * (Asx + Asy)
Asx = 34 (mm2) Asy = 56 (mm2)

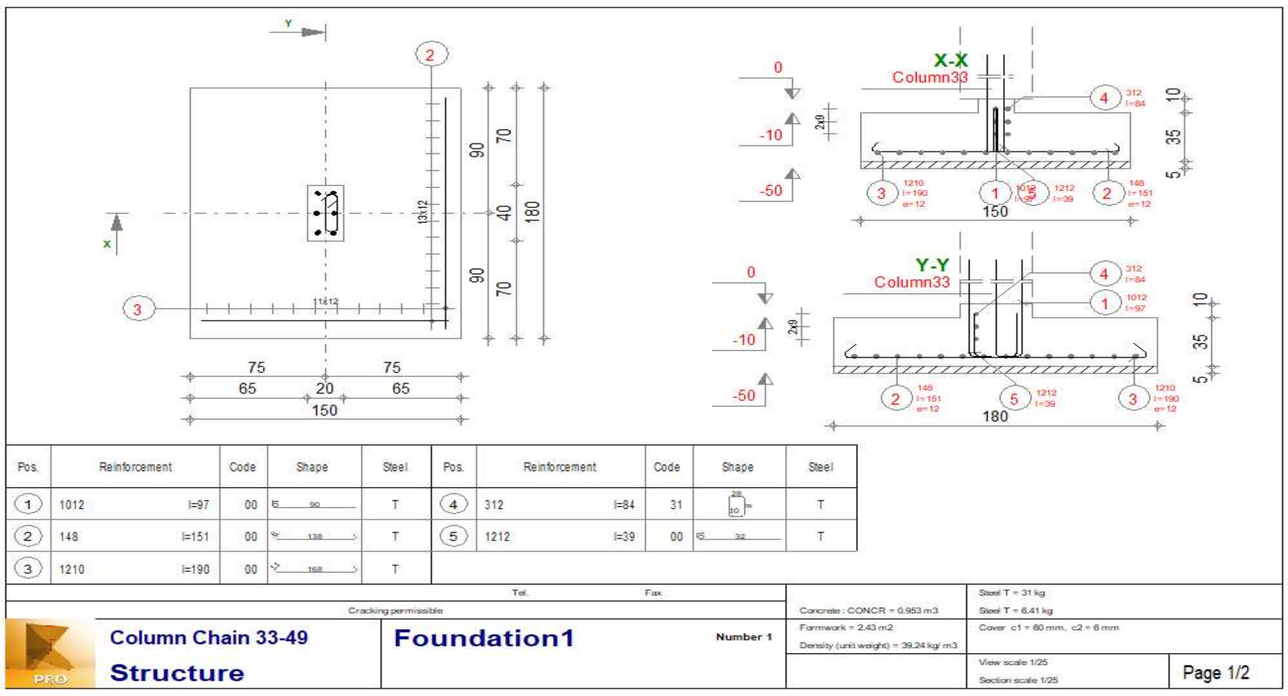
1.3.4 Provided reinforcement

Spread footing:
Bottom:
Along X axis:
6 T 12 l = 1.57 (m) e = 1*-0.62 + 5*0.25
10 T 12 l = 1.38 (m) e = 1*-0.68 + 9*0.15
Along Y axis:
6 T 12 l = 1.57 (m) e = 1*-0.62 + 5*0.25
10 T 12 l = 1.38 (m) e = 1*-0.68 + 9*0.15

Pier
Longitudinal reinforcement

Along Y axis:
4 T 12 l = 0.39 (m) e = 1*-0.07 + 1*0.14
Transversal reinforcement
3 T 12 l = 0.83 (m) e = 1*0.20 + 2*0.09

Dowels
Longitudinal reinforcement
4 T 12 l = 0.97 (m) e = 1*-0.10 + 1*0.21
8 T 6 l = 0.96 (m) e = 1*-0.08 + 1*0.00 + 2*0.08 + 1*0.00



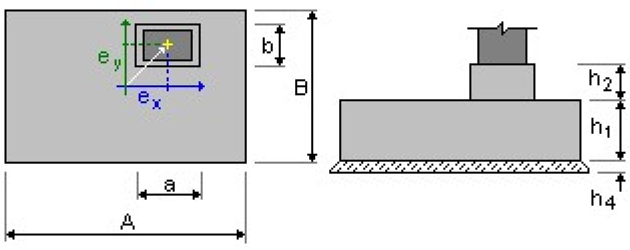
2 TYPICAL COLUMN BASE F1 Number: 1

2.1 Basic data

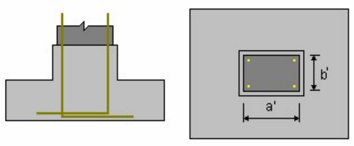
2.1.1 Assumptions

- Geotechnic calculations according to : BS 8004
- Concrete calculations according to : BS EN1992-1-1:2004 NA:2005
- Shape selection : without limits

2.1.2 Geometry:



A	= 1.50 (m)	a	= 0.20 (m)
B	= 1.80 (m)	b	= 0.40 (m)
h1	= 0.35 (m)	e_x	= 0.00 (m)
h2	= 0.10 (m)	e_y	= 0.00 (m)
h4	= 0.05 (m)		



a' = 200 (mm)
b' = 400 (mm)
cnom1 = 60 (mm)
cnom2 = 60 (mm)
Cover deviations: Cdev = 10(mm), Cdur = 0(mm)

2.1.3 Materials

- Concrete : CONCR; Characteristic strength = 20.00 MPa
  Unit weight = 2501.36 (kG/m3)
  Rectangular stress distribution [3.1.7(3)]
- Longitudinal reinforcement : type T Characteristic strength = 460.00 MPa
  Ductility class: A
  Horizontal branch of the stress-strain diagram
- Transversal reinforcement : type T Characteristic strength = 460.00 MPa
- Additional reinforcement: : type T Characteristic strength = 460.00 MPa

2.1.4 Loads:

Foundation loads:

Case	Nature	Group	N (kN)	Fx (kN)	Fy (kN)	Mx (kN*m)	My (kN*m)
COMB1	design	----	411.12	-0.07	22.19	-79.85	-0.17

Backfill loads:

Case	Nature	Q1 (kN/m2)

2.1.5 Combination list

1/ ULS : COMB1 N=411.12 Mx=-79.85 My=-0.17 Fx=-0.07 Fy=22.19
2/* ULS : COMB1 N=411.12 Mx=-79.85 My=-0.17 Fx=-0.07 Fy=22.19

2.2 Geotechnical design

2.2.1 Assumptions

Foundation design for:
• Capacity
• Rotation

2.2.2 Soil:

Soil level:	N_1	= 0.00 (m)
Column pier level:	N_a	= 0.00 (m)
Minimum reference level:	N_f	= -0.50 (m)

well graded gravels
• Soil level: 0.00 (m)
• Unit weight: 2243.38 (kG/m3)
• Unit weight of solid: 2702.25 (kG/m3)
• Internal friction angle: 42.0 (Deg)
• Cohesion: 0.00 (MPa)

2.2.3 Limit states

2.3 RC design

2.3.1 Assumptions

- Exposure : X0
- Structure class : S1

2.3.2 Analysis of punching and shear

Punching

Design combination **ULS : COMB1 N=411.12 Mx=-79.85 My=-0.17 Fx=-0.07 Fy=22.19**
Load factors: **1.35** * Foundation weight
1.35 * Soil weight
Design load:
Nr = 450.46 (kN) Mx = -89.84 (kN*m) My = -0.20 (kN*m)
Length of critical circumference: 2.61 (m)
Punching force: 334.28 (kN)
Section effective height h_{eff} = 0.28 (m)
Reinforcement ratio: ρ = 0.17 %
Shear stress: 0.76 (MPa)
Admissible shear stress: 0.98 (MPa)
Safety factor: 1.299 > 1

2.3.3 Required reinforcement

Spread footing:

bottom:

ULS : COMB1 N=411.12 Mx=-79.85 My=-0.17 Fx=-0.07 Fy=22.19
My = 63.46 (kN*m) A_{sx} = 364 (mm2/m)

ULS : COMB1 N=411.12 Mx=-79.85 My=-0.17 Fx=-0.07 Fy=22.19
Mx = 100.49 (kN*m) A_{sy} = 623 (mm2/m)

$A_{s\ min}$ = 364 (mm2/m)

top:
A'_{sx} = 0 (mm2/m)
A'_{sy} = 0 (mm2/m)

$A_{s\ min}$ = 0 (mm2/m)

Column pier:
Longitudinal reinforcement A = 1063 (mm2) $A_{min.}$ = 160 (mm2)
A = 2 * (Asx + Asy)
Asx = 70 (mm2) Asy = 462 (mm2)

2.3.4 Provided reinforcement

Spread footing:
Bottom:
Along X axis:
14 T 12 l = 1.51 (m) e = 1*-0.78 + 13*0.12
Along Y axis:

12 T 12 l = 1.90 (m) e = 1*-0.65 + 11*0.12

Pier

Longitudinal reinforcement

Along X axis:

8 T 12 l = 0.39 (m) e = 1*-0.01 + 3*0.01

Along Y axis:

4 T 12 l = 0.39 (m) e = 1*-0.12 + 1*0.24

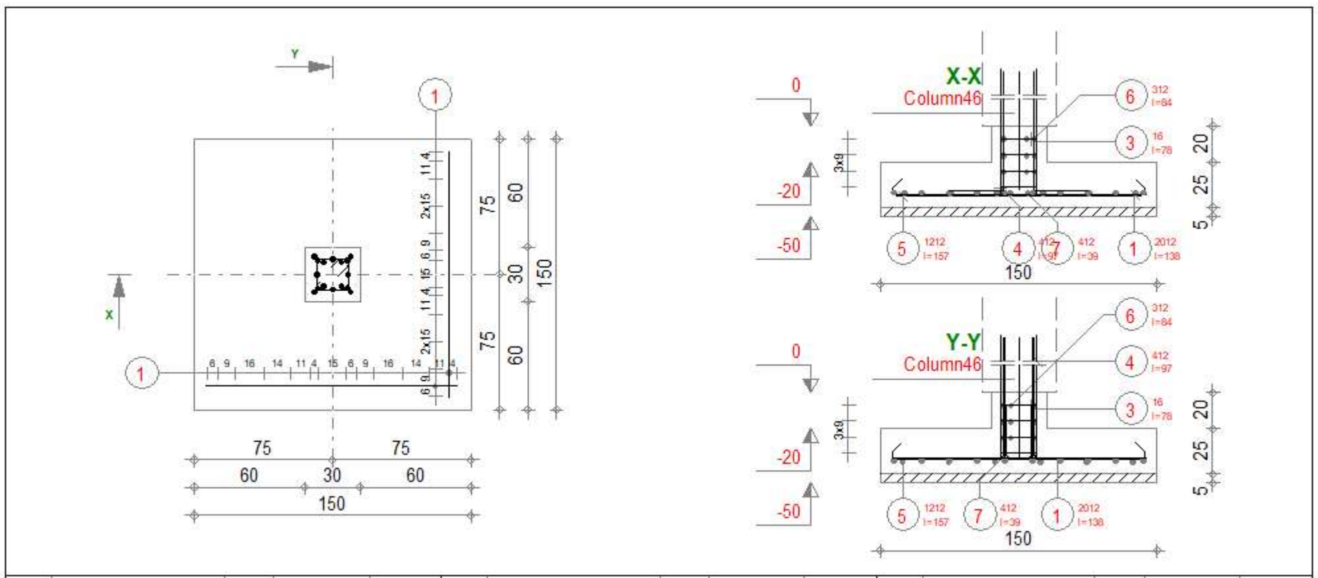
Transversal reinforcement

3 T 12 l = 0.83 (m) e = 1*0.20 + 2*0.09

Dowels

Longitudinal reinforcement

10 T 12 l = 0.97 (m) e = 1*-0.15 + 1*0.01 + 1*0.15 + 1*0.14 + 1*0.01



Pos.	Reinforcement		Code	Shape	Steel	Pos.	Reinforcement		Code	Shape	Steel	Pos.	Reinforcement		Code	Shape	Steel
1	2012	l=138	00	138	T	4	412	l=97	00	90	T	7	412	l=39	00	32	T
2	86	l=96	11	30	T	5	1212	l=157	00	138	T						
3	46	l=78	31	18	T	6	312	l=84	31	18	T						

Tel. Fax

Cracking permissible

Concrete : CONCR = 0.581 m3

Formwork = 1.74 m2

Density (unit weight) = 87.26 kg/ m3

Steel T = 46.4 kg

Steel T = 4.3 kg

Cover c1 = 60 mm, c2 = 6 mm

Column Chain 46-62

Structure

Foundation2

Number 1

View scale 1/25

Section scale 1/25

Page 2/2

3 Material survey:

- Concrete volume = 1.53 (m3)
- Formwork = 4.17 (m2)

- Steel T
  - Total weight = 88.13 (kG)
  - Density = 57.47 (kG/m3)
  - Average diameter = 10.5 (mm)
  - Survey according to diameters:

Diameter	Length (m)	Weight (kG)
8	21.09	8.32
10	22.84	14.09
12	71.31	63.33

C:\Users\AUGUSTIN PC\Documents\Autodesk\Output\RUBAVU\Column62.rtf

COLUMN AT FIRST FLOOR

1 Level:

- Name : Column Chain 46-62
- Reference level : 3.50 (m)
- Concrete creep coefficient : φ_p = 3.16
- Cement class : N
- Environment class : X0
- Structure class : S1

2 TYPICAL COLUMN C2 DESIGN Number: 1

2.1 Material properties:

- Concrete : CONCR f_{ck} = 20.00 (MPa)
  Unit weight : 2501.36 (kG/m3)
  Aggregate size : 20.0 (mm)
- Longitudinal reinforcement: : f_{yk} = 500.00 (MPa)
  Ductility class : C
- Transversal reinforcement: : f_{yk} = 500.00 (MPa)

2.2 Geometry:

2.2.1 Rectangular 300 x 300 (mm)
2.2.2 Height: L = 3.50 (m)
2.2.3 Slab thickness = 0.00 (m)
2.2.4 Beam height = 0.30 (m)
2.2.5 Cover = 40 (mm)

2.3 Calculation options:

- Calculations according to : BS EN1992-1-1:2004 NA:2005
- Seismic dispositions : No requirements
- Precast column : no
- Pre-design : no
- Slenderness taken into account : yes
- Compression : with bending
- Ties : to slab
- Fire resistance class : No requirements

2.4 Loads:

Case	Nature	Group	γ_f	N (kN)	My(s) (kN*m)	My(i) (kN*m)	Mz(s) (kN*m)	Mz(i) (kN*m)
COMB1	design(Structural)	62	1.00	107.41	1.00	-2.66	1.02	-2.18

γ_f - load factor

2.5 Calculation results:

Safety factors Rd/Ed = 4.67 > 1.0

2.5.1 ULS/ALS Analysis

Design combination: COMB1 (C)
Combination type: ULS
Internal forces:
Nsd = 107.41 (kN) Msdy = -1.19 (kN*m) Msdz = -0.90 (kN*m)
Design forces:
Cross-section in the middle of the column
N = 107.41 (kN) N*etotz = -3.12 (kN*m) N*etoty= -2.15 (kN*m)

Eccentricity:		ez (My/N)	ey (Mz/N)
Static	eEd:	-11 (mm)	-8 (mm)
Imperfection	ei:	9 (mm)	0 (mm)
Initial	e0:	-2 (mm)	-8 (mm)
Minimal	emin:	20 (mm)	20 (mm)
Total	etot:	-29 (mm)	-20 (mm)

2.5.1.1. Detailed analysis-Direction Y:

2.5.1.1.1 Slenderness analysis

Non-sway structure

L (m)	Lo (m)	λ	λlim	
3.50	3.50	40.41	32.38	Slender column

2.5.1.1.2 Buckling analysis

M2 = 1.00 (kN*m) M1 = -2.66 (kN*m) Mmid = -1.19 (kN*m)
Case: Cross-section in the middle of the column, Slenderness taken into account
M0e = 0.6*M02+0.4*M01 = -1.19 (kN*m)
M0emin = 0.4*M02
M0 = max(M0e, M0emin)

ea = θ_l*lo/2 = 9 (mm)
$\theta_l = \theta_o * \alpha h * \alpha m$ = 0.01
θ_o = 0.01

αh = 1.00
αm = (0,5(1+1/m))^0.5 = 1.00
m = 1.00

Method based on nominal stiffness

$$\left[1+\frac{\beta}{(N_B/N)-1}\right] = 1.46$$

β = 1.23
Nb = (π^2 * EJ)/ lo^2 = 393.05 (kN)
EJ = Kc*Ecd*Jc+Ks*Es*Js = 487.85 (kN*m2)
φef = 3.16
Jc = 675000000 (mm4)
Js = 1930999 (mm4)
Kc = 0.01 ()
Ks = 1.00 ()
MEdmin = 2.15 (kN*m)

$$M_{Ed} = \max\left\{M_{Ed\,\min};\left[1+\frac{\beta}{(N_B/N)-1}\right]M_{0Ed}\right\} = -3.12 \text{ (kN*m)}$$

2.5.1.2. Detailed analysis-Direction Z:

M2 = 1.02 (kN*m) M1 = -2.18 (kN*m) Mmid = -0.90 (kN*m)
Case: Cross-section in the middle of the column, Slenderness not taken into account
M0e = 0.6*M02+0.4*M01 = -0.90 (kN*m)
M0emin = 0.4*M02
M0 = max(M0e, M0emin)

ea = 0 (mm)
Ma = N*ea = 0.00 (kN*m)
MEdmin = 2.15 (kN*m)
M0Ed = max(MEdmin,M0 + Ma) = -2.15 (kN*m)

2.5.2 Reinforcement:

Real (provided) area Asr = 201 (mm2)
Ratio: ρ = 0.22 %

2.6 Reinforcement:

Main bars ():

- 6 ϕ16 l = 3.46 (m)

Transversal reinforcement: ():
stirrups: 26 ϕ6 l = 1.06 (m)

3 TYPICAL COLUMN C1 DESIGN Number: 1

3.1 Material properties:

- Concrete : CONCR f_{ck} = 20.00 (MPa)
  Unit weight : 2501.36 (kG/m3)
  Aggregate size : 20.0 (mm)
- Longitudinal reinforcement: : f_{yk} = 500.00 (MPa)
  Ductility class : C
- Transversal reinforcement: : f_{yk} = 500.00 (MPa)

3.2 Geometry:

3.2.1 Rectangular 300 x 300 (mm)
3.2.2 Height: L = 3.50 (m)
3.2.3 Slab thickness = 0.00 (m)
3.2.4 Beam height = 0.30 (m)
3.2.5 Cover = 40 (mm)

3.3 Calculation options:

- Calculations according to : BS EN1992-1-1:2004 NA:2005
- Seismic dispositions : No requirements
- Precast column : no
- Pre-design : no
- Slenderness taken into account : yes
- Compression : with bending
- Ties : to slab
- Fire resistance class : No requirements

3.4 Loads:

Case	Nature	Group	γ_f	N (kN)	My(s) (kN*m)	My(i) (kN*m)	Mz(s) (kN*m)	Mz(i) (kN*m)
COMB1	design(Structural)	62	1.00	107.41	1.00	-2.66	1.02	-2.18

γ_f - load factor

3.5 Calculation results:

Safety factors Rd/Ed = 4.67 > 1.0

3.5.3 ULS/ALS Analysis

Design combination: COMB1 (C)
Combination type: ULS
Internal forces:
Nsd = 107.41 (kN) Msdy = -1.19 (kN*m) Msdz = -0.90 (kN*m)
Design forces:
Cross-section in the middle of the column
N = 107.41 (kN) N*etotz = -3.12 (kN*m) N*etoty= -2.15 (kN*m)

Eccentricity:		ez (My/N)	ey (Mz/N)
Static	eEd:	-11 (mm)	-8 (mm)
Imperfection	ei:	9 (mm)	0 (mm)
Initial	e0:	-2 (mm)	-8 (mm)
Minimal	emin:	20 (mm)	20 (mm)
Total	etot:	-29 (mm)	-20 (mm)

3.5.3.3. Detailed analysis-Direction Y:

3.5.3.3.1 Slenderness analysis

Non-sway structure

L (m)	Lo (m)	λ	λlim	
3.50	3.50	40.41	32.38	Slender column

3.5.3.3.2 Buckling analysis

M2 = 1.00 (kN*m) M1 = -2.66 (kN*m) Mmid = -1.19 (kN*m)
Case: Cross-section in the middle of the column, Slenderness taken into account
M0e = 0.6*M02+0.4*M01 = -1.19 (kN*m)
M0emin = 0.4*M02
M0 = max(M0e, M0emin)

ea = θ1*lo/2 = 9 (mm)
θ1 = θo * αh * αm = 0.01
θo = 0.01
αh = 1.00
αm = (0,5(1+1/m))^0.5 = 1.00
m = 1.00
Method based on nominal stiffness

$$\left[1+\frac{\beta}{(N_B/N)-1}\right] = 1.46$$

β = 1.23
Nb = (π^2 * EJ)/ lo^2 = 393.05 (kN)
EJ = Kc*Ecd*Jc+Ks*Es*Js = 487.85 (kN*m2)
φef = 3.16
Jc = 675000000 (mm4)
Js = 1930999 (mm4)
Kc = 0.01 ()
Ks = 1.00 ()
MEdmin = 2.15 (kN*m)

$$M_{Ed} = \max\left\{M_{Ed\min};\left[1+\frac{\beta}{(N_B/N)-1}\right]M_{0Ed}\right\} = -3.12 \text{ (kN*m)}$$

3.5.3.4. Detailed analysis-Direction Z:

M2 = 1.02 (kN*m) M1 = -2.18 (kN*m) Mmid = -0.90 (kN*m)
Case: Cross-section in the middle of the column, Slenderness not taken into account
M0e = 0.6*M02+0.4*M01 = -0.90 (kN*m)
M0emin = 0.4*M02
M0 = max(M0e, M0emin)

ea = 0 (mm)
Ma = N*ea = 0.00 (kN*m)
MEdmin = 2.15 (kN*m)
M0Ed = max(MEdmin,M0 + Ma) = -2.15 (kN*m)

3.5.4 Reinforcement:

Real (provided) area Asr = 201 (mm2)
Ratio: ρ = 0.22 %

3.6 Reinforcement:

Main bars ():
- 8 ϕ16 l = 3.46 (m)

Transversal reinforcement: ():
stirrups: 26 ϕ6 l = 1.06 (m)

4 Material survey:

- Concrete volume = 0.58 (m3)
- Formwork = 7.68 (m2)

- Steel
  - Total weight = 23.18 (kG)
  - Density = 40.24 (kG/m3)
  - Average diameter = 6.7 (mm)
  - Reinforcement survey:

Diameter	Length (m)	Weight (kG)
6	55.19	12.25
8	27.68	10.93