

pi DESIGN

User Guide



ATHENS
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1.1 Hardware Requirements

1.1.1 Minimum configuration

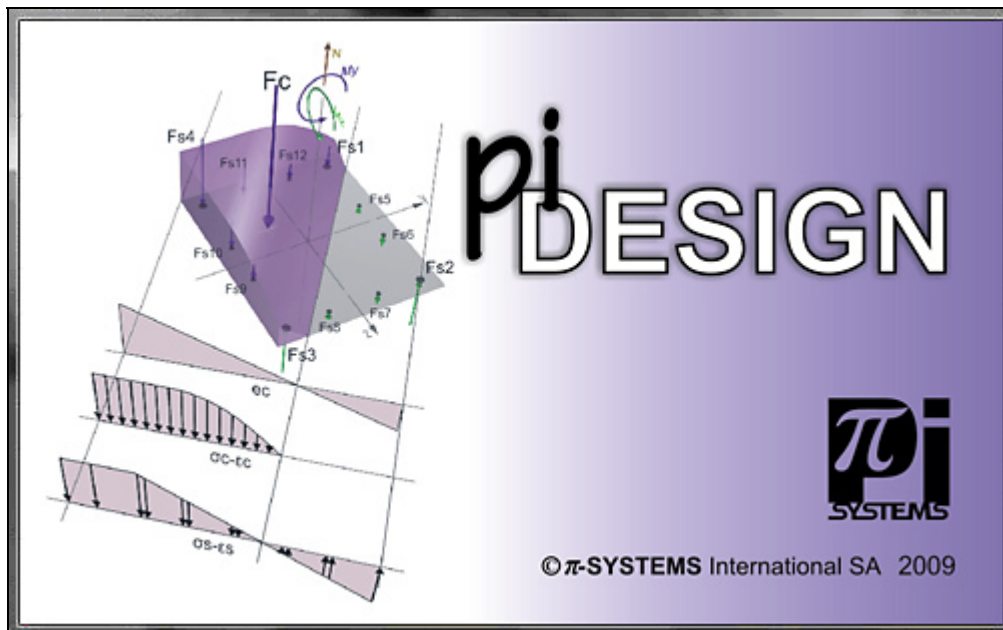
1. Operating system (O/S):
 - Windows 2000 Service Pack 3 (SP3) or better
 - Windows XP Service Pack 2 (SP2) or better
 - Windows Vista
 - Windows 7
2. System memory: 256MB RAM (1024MB RAM προτεινόμενη)
3. CPU: Pentium IV 1800MHz or better.
4. Graphics card:
 - NVIDIA GFORCE 4 (64MB RAM) or better
 - ATI 9000 (64MB RAM) or better
5. Screen resolution 1024 x 768 (χρώματα: 16 bit). suggested resolution: 1280 x 1024 (32 bit)
6. 1GB Minimum free space (4GB suggested free space)

1.2 Introduction

Pi – Design is a software package for advanced analysis and design of reinforced concrete elements (columns, beams, slabs) subjected to axial forces (N) and axial or **biaxial** (Mx and My) bending moments.

The application can analyze:

- **Columns** of the following sections : Rectangular, L-shaped, Z-shaped, T-shaped, Circular, Quadrilateral, Π -shaped (elevator). The analysis refers to concentrated or distributed reinforcement
- **Beams** of the following sections: Rectangular, Slab beam , Z-shaped beam. The analysis refers to both compressive and tensile reinforcement.
- **Slabs** with both single or double reinforcement.



The application calculates the necessary areas of the reinforcing bars ($A_{s,req}$), the R/C cross-sections strains, stresses, curvatures and stiffnesses and automatically generates the appropriate stress – deformation diagrams in both 2D and 3D environment.

It supports a user friendly graphical input of required data and an impressive graphical output of calculated data.

Specifications:

Design codes

- EC2 (Eurocodes)
- EKOS 2000 (Greek regulations)
- German DIN 1045 (nominal B_n και B_{St})
- Maximum stresses (strength B and St)

Materials

- Concrete from C12 to C90
- All steel qualities

All calculated data are adequately organized in table format, ready to be printed. All diagrams are visualized both in 2D and 3D for a better clarification and presentation.

Connectivity:

The application can exchange data with similar type software packages through the use of generated XML-type files.

The application is also integrated in our Software, StereoSTATIKA.

1.3 The Interface of Pi-DESIGN

The working layout is divided into two major parts. The left part, contains the tools for the description of the section and the input of required data. The rest of the working space is used for the presentation of the calculated results, both in the form of numerical data and in the form of the produced diagrams.

The screenshot displays the Pi-DESIGN software interface, which is divided into three main functional areas:

- Graphical Input:** Located on the left side, this panel contains controls for defining the section properties. It includes a 'Section Properties' section with a visual representation of a square section (400x400 mm) and input fields for dimensions (d1 = 0.05 m, dis = 0.50). Below this is a 'Location' section with a dropdown menu set to 'Top' and buttons for 'Add', 'Edit', and 'Delete'. At the bottom is a table for 'Bending Moment Capacity' with columns for 'Comp.', 'My', 'Mz', and 'N'.
- Graphical Output:** The central workspace displays a graphical representation of the section and its properties. It shows a square section with a central reinforcement layout, a cross-section diagram, and a longitudinal section diagram. A label 'Graphical Output' is overlaid on this area.
- Numerical Data:** The bottom right section, titled 'Report of Data and Design Results', provides detailed numerical data. It includes material properties for concrete (C25/30) and steel (B500C), section properties, and a table of design results for 'Combination A'.

Report of Data and Design Results

Column Ctest (400/400) Metacenter section $x' = 0.200$, $y' = 0.200$.
Concrete C25/30: $f_{ck} = 25.0 \text{ MPa}$, $\gamma_c = 1.50$, $\alpha_{cc} = 1.00$, $f_{cd} = 16.7 \text{ MPa}$, $\epsilon_{c2} = -2.0\text{‰}$, $\epsilon_{c0.2} = -3.5\text{‰}$, $n = 2.0$
Steel B500C: $f_{yk} = 500.0 \text{ MPa}$, $\gamma_s = 1.15$, $f_{yd} = 434.8 \text{ MPa}$, $E_s = 200.0 \text{ GPa}$, $f_{yd}/E_s = 2.17\text{‰}$, $\epsilon_{sd} = 67.5\text{‰}$, $d1 = 0.05 \text{ m}$, $f_t/f_y = 1.15$, $dis = 0.500$

Location : Top
Combination A : $N = -800.00 \text{ kN}$, $M_y = 170.00 \text{ kNm}$, $M_z = 60.00 \text{ kNm}$

$A_{s,tot}$ (mm ²)	$A_{s,dis} / A_{s,cor}$ (mm ² / mm ²)	a_s (mm ² /m)	ρ_t x100	ϵ_c x1000	ϵ_s x1000	θ degrees	x m	d m	x/d
1518.31	759.16 / 759.16	632.63	0.949	-3.500	3.139	22.962	0.242	0.459	0.527

1.4 The input of Data

The left section of the working space contains the tools used to simplify the input procedure of the required data. The application offers a user friendly graphical environment for the selection of the desired section and the specification of its dimensions.

Element	Dimensions
Ctest	400/400

Comp.	My	Mz	N
A	170.00	60.00	-800.00

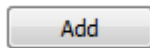
Depending on the structural element (column, beam, slab) that we select to calculate the necessary areas of the reinforcing bars, the screen will be modified accordingly to the specified data that we must put in order for the calculation to execute.

The selection of the section and the specification of its dimension is described graphically in order to minimize the possibility of errors.

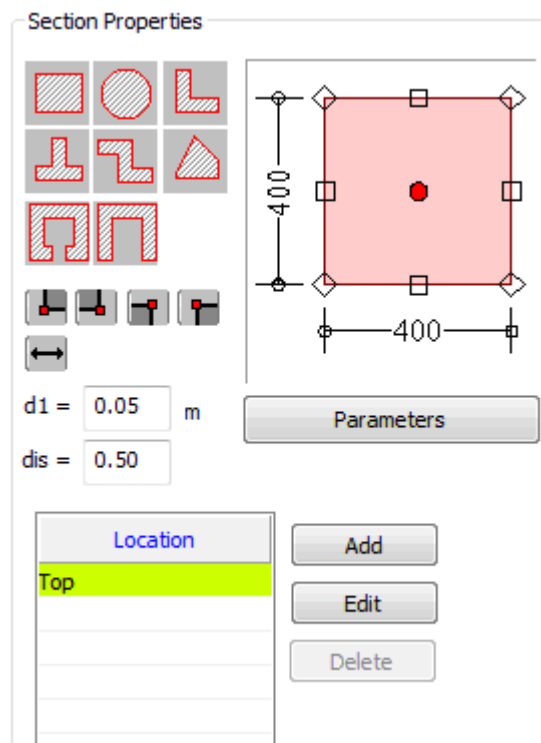
All described structural elements are simultaneously available from the list on the left of the screen. When an element is

selected or an input variable is altered, all calculation result (tables and diagrams) are automatically refreshed.

1.4.1 Columns

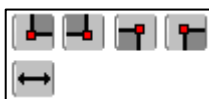


The option **Add** will create a new column for calculation. The section of the column is determined by the user by selecting one of the available types by clicking on the appropriate icon. The column is created with pre defined dimensions which the user can then alter accordingly, from the column's sketch.

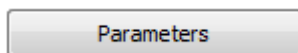


The application supports a variety of different column sections (Rectangular, L-shaped, Z-shaped, T-shaped, Circular, Quadrilateral, Π -shaped (elevator))

Depending on the section that the user selects, the sketch of the column will change in order to represent the different data that should be input. The dimensions of the column are directly altered by just clicking on them and typing in the desired value.



With the appropriate icons we can change the orientation of the section.



The option **Parameters** is used in order to modify the initial values of the calculation parameters. All changes made will only apply to the particular structural element. In order to alter the

parameters of all structural elements calculated with this application, we should use the menu **General Parameters**.

d1 – The distance of the reinforcement bar from the outer edge of the section.

dis – Distribution percentage of reinforcement on the corners and the sides of the section. (e.g. for $dis=0.5$ 50% of the reinforcement will be put in the corners and 50% in the sides).

The user can specify the area thought the body of the column that all forces and moments will be applied. The option **Add** will create new areas of application. Each area can have its own unique combination of axials and

Location
Top

Add Edit Delete

moments.

Comp.	My	Mz	N
A	170.00	60.00	-800.00

Add Edit Delete

The input of all required forces and moments is easily performed by using the **Add** button in the combination dialogue box. There are no limitations in the number of user-created combinations.

The option **Edit** will enable the alternation of combinations that are already described.

When we select the Add option, a new dialogue box will open in order to specify the values of the axial force (N) and the moments My and Mx in the corresponding axis. The more combination we use, the more accurate the solution will be. The mean combination can be easily displayed by selecting the option **Calculate Mean Combination**

Όνομα

My = 0.00

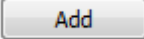
Mz = 0.00

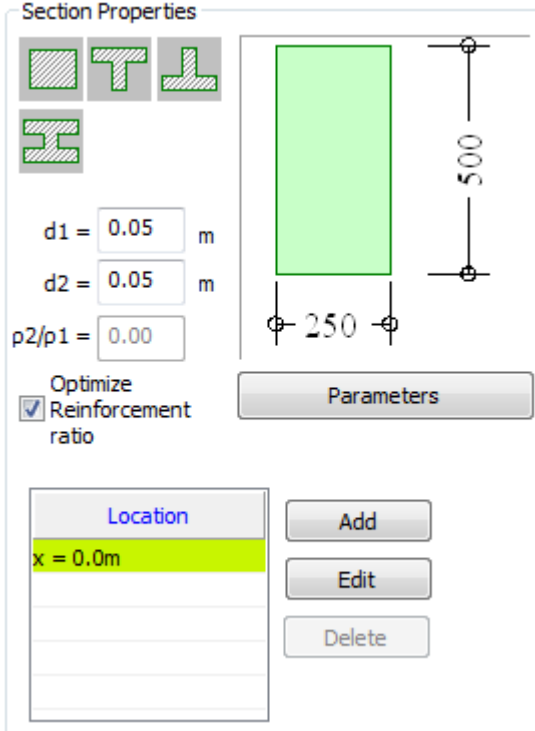
N = 0.00

OK Ακύρωση

The working procedure is the same if we know the $A_{s,req}$ and the axial force N and we want to calculate the corresponding Moment M_{rd} .

1.4.2 Beams

 The option **Add** will create a new beam for calculation. The section of the beam is determined by the user by selecting one of the available types by clicking on the appropriate icon. The beam is created with pre defined dimensions which the user can then alter accordingly, from the beam's sketch.



The dialog box titled "Section Properties" contains the following elements:

- Section Type Selection:** Four icons representing different beam cross-sections: Rectangular, T-shaped, L-shaped, and I-shaped.
- Dimensions:**
 - $d1 = 0.05$ m
 - $d2 = 0.05$ m
 - $p2/p1 = 0.00$
- Optimization:** A checkbox labeled "Optimize Reinforcement ratio" which is currently checked.
- Parameters:** A button to open the parameters dialog.
- Location Table:**

Location
x = 0.0m
- Actions:** Three buttons labeled "Add", "Edit", and "Delete" are positioned to the right of the location table.
- Sketch:** A central area showing a green rectangular beam cross-section with dimensions 250 (width) and 500 (height) indicated.

The application supports a variety of different beam sections (Rectangular, Z-shaped, slab beam)

Depending on the section that the user selects, the sketch of the beam will change in order to represent the different data that should be input. The dimensions of the beam are directly altered by just clicking on them and typing in the desired value.

The user can specify the area through the body of the beam that all forces and moments will be applied. The option **Add** will create new areas of application. Each area can

have its own unique combination of axials and moments.

Parameters

The option **Parameters** is used in order to modify the initial values of the calculation parameters. All changes made will only apply to the particular structural element. In order to alter the parameters of all structural elements calculated with this application, we should use the menu **General Parameters**.

d1 – The distance of the reinforcement bars from the lower edge of the section.

d2 – The distance of the reinforcement bars from the upper edge of the section.

ρ'/ρ – the ratio of the compressing reinforcement to the tensile reinforcement.

Optimum reinforcement percentage ρ'/ρ – It is calculated automatically when checked.

Calculate As,cal Calculate Bending Moment

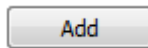
Comp.	My	N
min	200.00	0.00

When we select **Add**, a new dialogue box will open in order to specify the axial force and moments needed for the calculation of the required reinforcement.

The option **Edit** is used to edit an already described load combination.

The working procedure is the same if we know the $A_{s,req}$ and the axial force N and we want to calculate the corresponding Moment M_{rd} .

1.4.3 Slabs



The option **Add** will create a new slab for calculation. The slab is created with pre defined dimensions which the user can then alter accordingly, from the slab's sketch.

Section Properties

d1 = 0.03 m

d2 = 0.03 m

ρ_2/ρ_1 = 0.00

☒ Optimize Reinforcement ratio

Parameters

Location

Span x

Add

Edit

Delete

Depending on the section that the user selects, the sketch of the slab will change in order to represent the different data that should be input. The dimensions of the slab are directly altered by just clicking on them and typing in the desired value.

The user can specify the area thought the body of the beam that all forces and moments will be applied. The option **Add** will create new areas of application. Each area can have its own unique combination of axials and moments.

When we select **Add**, a new dialogue box will open in order to specify the axial force and moments needed for the calculation of the required reinforcement. The option **Edit** is used to edit an already described load combination.

Calculate As,cal Calculate Bending Moment

Comp.	My	N
min	200.00	0.00

Parameters

The option **Parameters** is used in order to modify the initial values of the calculation parameters. All changes made will only apply to the particular structural element. In order to alter the parameters of all structural elements calculated with this application, we should use the menu **General Parameters**.

d1 – The distance of the reinforcement bars from the lower edge of the section.

d2 – The distance of the reinforcement bars from the upper edge of the section.

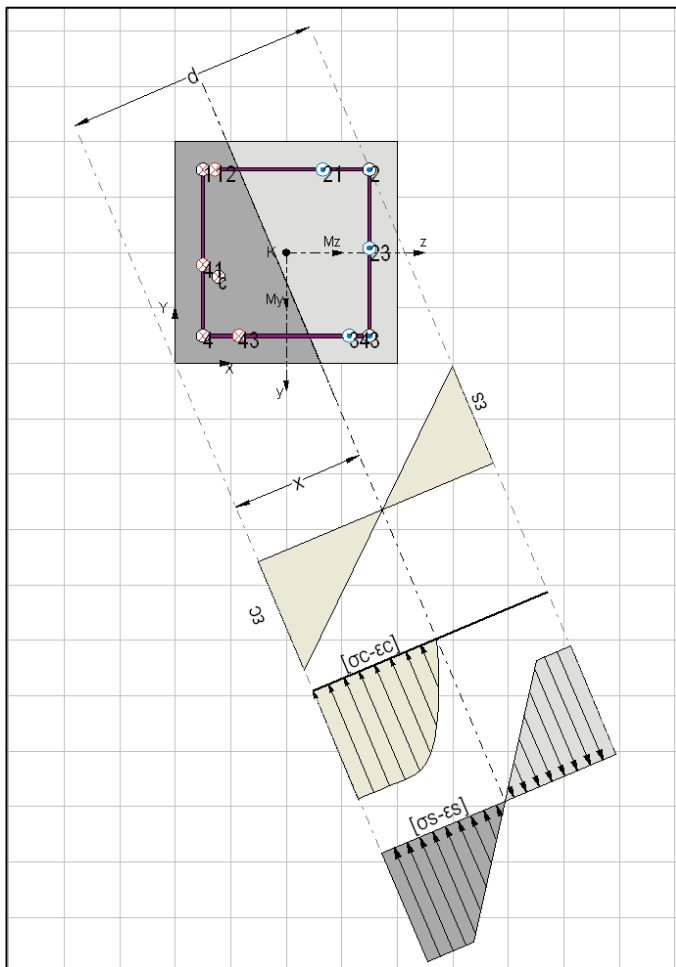
ρ'/ρ – the ratio of the compressing reinforcement to the tensile reinforcement.

Optimum reinforcement percentage ρ'/ρ – It is calculated automatically when checked.

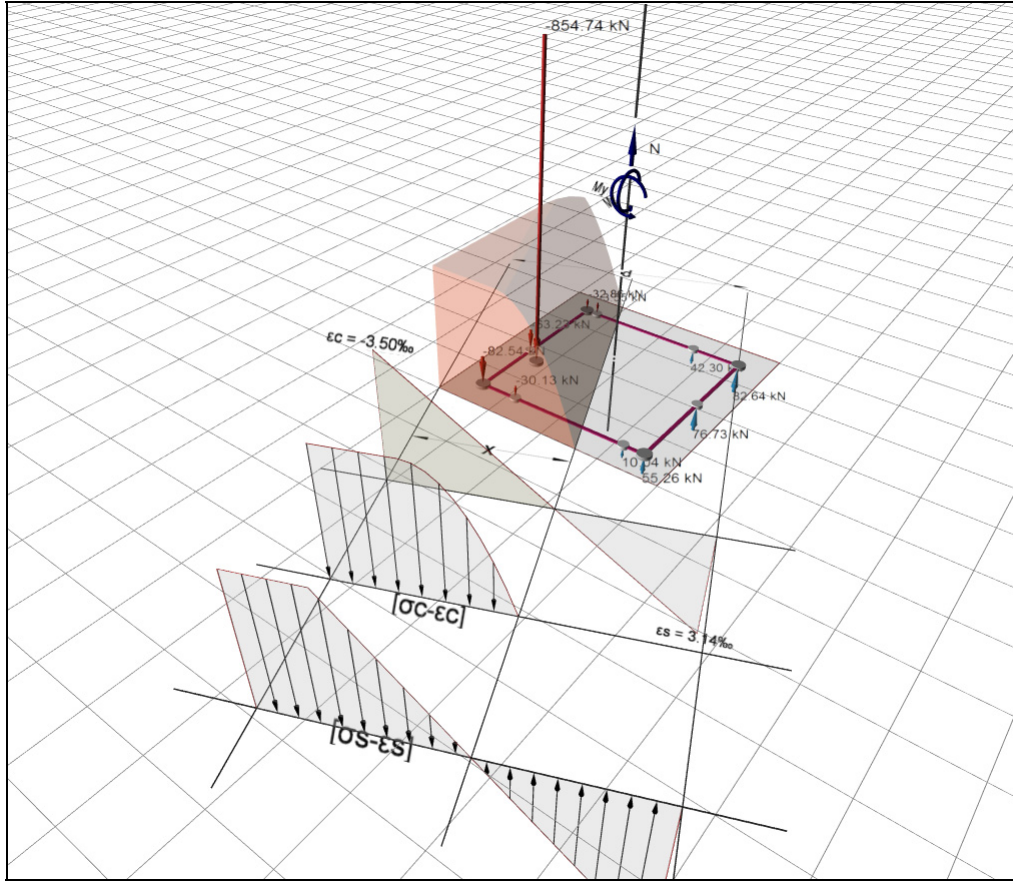
The working procedure is the same if we know the $A_{s,req}$ and the axial force N and we want to calculate the corresponding Moment M_{rd} .

1.5 Displaying the results

The right area of the working environment is dedicated in displaying the results of the calculations. The software will automatically create the corresponding diagrams as well as the printout tables. The upper part of the screen will display the analytical stress-deformation diagram of the selected structural element.



We can modify the zoom level by using the appropriate icons next to the diagram. We can also display it in full screen or print it. All tools required for the proper visualization of the diagram are located in the right part of the working environment.



It is also possible to display an accurate 3D presentation of the calculated diagram by using the appropriate icon. This will help the user to better understand the produced result. The movement inside the 3D environment is performed with the keyboard arrows or the mouse wheel button.

The use of *Shift + up arrow or down arrow* will allow the vertical movement of the camera, the same action can be performed by pressing and holding the mouse wheel and then moving the mouse forward or backwards. The use of *Ctrl + up arrow or down arrow* will change the viewing angle in relevance to the diagram. The same action can be performed by holding the left mouse button and then moving the mouse forward or backwards.

1.6 Parameters

Regulations - materials

Concrete - Eurocodes

Type - the quality of concrete

Safety factor γ_c – The safety factor for concrete (typically is equal to 1.5)

Ultimate Strain ϵ_{cu2} – Ultimate compressive strain limit in concrete which is not fully in pure axial compression assuming use of the parabolic-rectangular stress-strain relationship (numerically $\epsilon_{cu2} = \epsilon_{cu3}$)

Maximum Strain Strength ϵ_{c2} - Compressive strain limit in concrete for concrete in pure axial compression or strain in concrete at reaching maximum strength assuming use of the bilinear stress-strain Relationship.

f_{ck} – Characteristic compressive cylinder strength of concrete at 28 days

f_{cd} - Design value of concrete compressive strength

α_{cc} - A coefficient taking into account long term effects of compressive (tensile) load and the way load is applied

Steel - Eurocodes

Type - the quality of steel

Safety factor γ_s - The safety factor for steel (typically is equal to 1.15)

Ultimate Strain ϵ_{ud} - Design limit for strain for reinforcing steel in tension

Elasticity modulus E_s – the elasticity modulus for steel

f_{yk} – characteristic yield strength of reinforcement

f_{yd} - Design yield strength of longitudinal reinforcement

f_t/f_y – strength limit/elasticity limit for steel

ϵ_{uk} – Characteristic strain of reinforcement (or prestressing steel) at maximum load

Calculation

Precise calculation of the neutral axis - The calculation that determines the direction of the neutral axis by using the balance condition of forces and moments. The simplified calculation assumes that the neutral axis direction is perpendicular to the direction of the resultant of the moments.

Maximum Tolerance – The precision of calculations is increased from 10^{-5} to 10^{-6} .

Maximum number of attempts for neutral axis calculation – This option is only active when the precise calculation method is selected.

Precision in reinforcement allocation (0 to 100) – A value lower than 100 should only be used in cases of indefiniteness phenomena due to the formation of opposite forces.

Number of particles for circular sections – The number of sides used to simulate the circular section.

1.7 Printout symbols explanation

Report of Data and Design Results

Column Ctest (40/40). Metacenter section $x' = 0.200$, $y' = 0.200$.

Concrete C25/30: $f_{ck} = 25.0\text{MPa}$, $\gamma_c = 1.50$, $a_{cc} = 1.00$, $f_{cd} = 16.7\text{MPa}$, $\epsilon_{c2} = -2.0\text{‰}$, $\epsilon_{cu2} = -3.5\text{‰}$, $n = 2.0$

Steel B500C: $f_{yk} = 500.0\text{MPa}$, $\gamma_s = 1.15$, $f_{yd} = 434.8\text{MPa}$, $E_s = 200.0\text{GPa}$, $f_{yd}/E_s = 2.17\text{‰}$, $\epsilon_{ud} = 67.5\text{‰}$, $d1 = 0.050\text{m}$, $f_t/f_y = 1.15$, $dis = 0.500$

Location : Top

Combination A : $N = -800.00\text{kN}$, $M_y = 170.00\text{kNm}$, $M_z = 60.00\text{kNm}$.

$A_{s,tot}$ (cm^2)	$A_{s,dis} / A_{s,cor}$ ($\text{cm}^2 / \text{cm}^2$)	a_s (cm^2/m)	ρ_l $\times 100$	ϵ_c $\times 1000$	ϵ_s $\times 1000$	ϕ degrees	x m	d m	x/d
15.18	7.59 / 7.59	6.33	0.949	-3.500	3.139	22.962	0.2419	0.4588	0.527

Point	l (m)	A_s (cm^2)	ϵ_{s1} (‰)	ϵ_{s2} (‰)	σ_{s1} (MPa)	σ_{s2} (MPa)	F kN	c (m)	x' (m)	y' (m)	M_y kNm	M_z kNm
c	-	-	-	-	-	-	-854.42	-	0.078	0.156	104.19	37.40
1	-	1.898	-0.858	-	-171.65	-	-32.58	-	0.050	0.350	4.89	-4.89
2	-	1.898	3.139	-	435.65	-	82.68	-	0.350	0.350	12.40	12.40
3	-	1.898	1.445	-	289.03	-	54.85	-	0.350	0.050	8.23	-8.23
4	-	1.898	-2.552	-	-435.12	-	-82.58	-	0.050	0.050	12.39	12.39
41	0.300	1.898	-0.858	-2.552	-171.65	-435.12	-63.12	0.128	0.050	0.178	9.47	1.40
21	0.236	1.490	3.139	0.000	435.65	0.00	42.38	0.084	0.266	0.350	2.79	6.36
12	0.064	0.408	0.000	-0.858	0.00	-171.65	-3.50	0.021	0.071	0.350	0.45	-0.52
23	0.300	1.898	1.445	3.139	289.03	435.65	76.61	0.142	0.350	0.208	11.49	0.64
34	0.108	0.686	0.000	1.445	0.00	289.03	9.92	0.036	0.314	0.050	1.13	-1.49
43	0.192	1.212	-2.552	0.000	-435.12	0.00	-30.24	0.065	0.115	0.050	2.57	4.54
Sum	1.20	15.183					-800.00				169.99	60.00

$A_{s,tot}$ – The total calculated reinforcement

$A_{s,cor}$ - The reinforcement in the corners of the column

$A_{s,dir}$ - The distributed reinforcement in the sides of the column

ρ_l – Reinforcement percentage

ϵ_c – The deformation in the outer compressive fiber of concrete

ϵ_s - The deformation in the outer tensile fiber of steel

ϕ – The corner created by the neutral axis and the y axis measured from right to left

x – The length of the compression zone calculated from the outer compressive fiber vertically to the neutral axis

d – The outer length of the section measured vertically to the neutral axis

x/d – The ratio of the length of the compression zone and the outer length of the section

y, z - The coordinates of the point of application of tensile or compressive forces, on point or distributed reinforcement

ϵ_{s1} , ϵ_{s2} - The calculated deformations

σ_{s1} , σ_{s2} - The calculated stresses

F - The force imposed as it calculated in the solution

M_y , M_z - The moments developed as it calculated in the solution