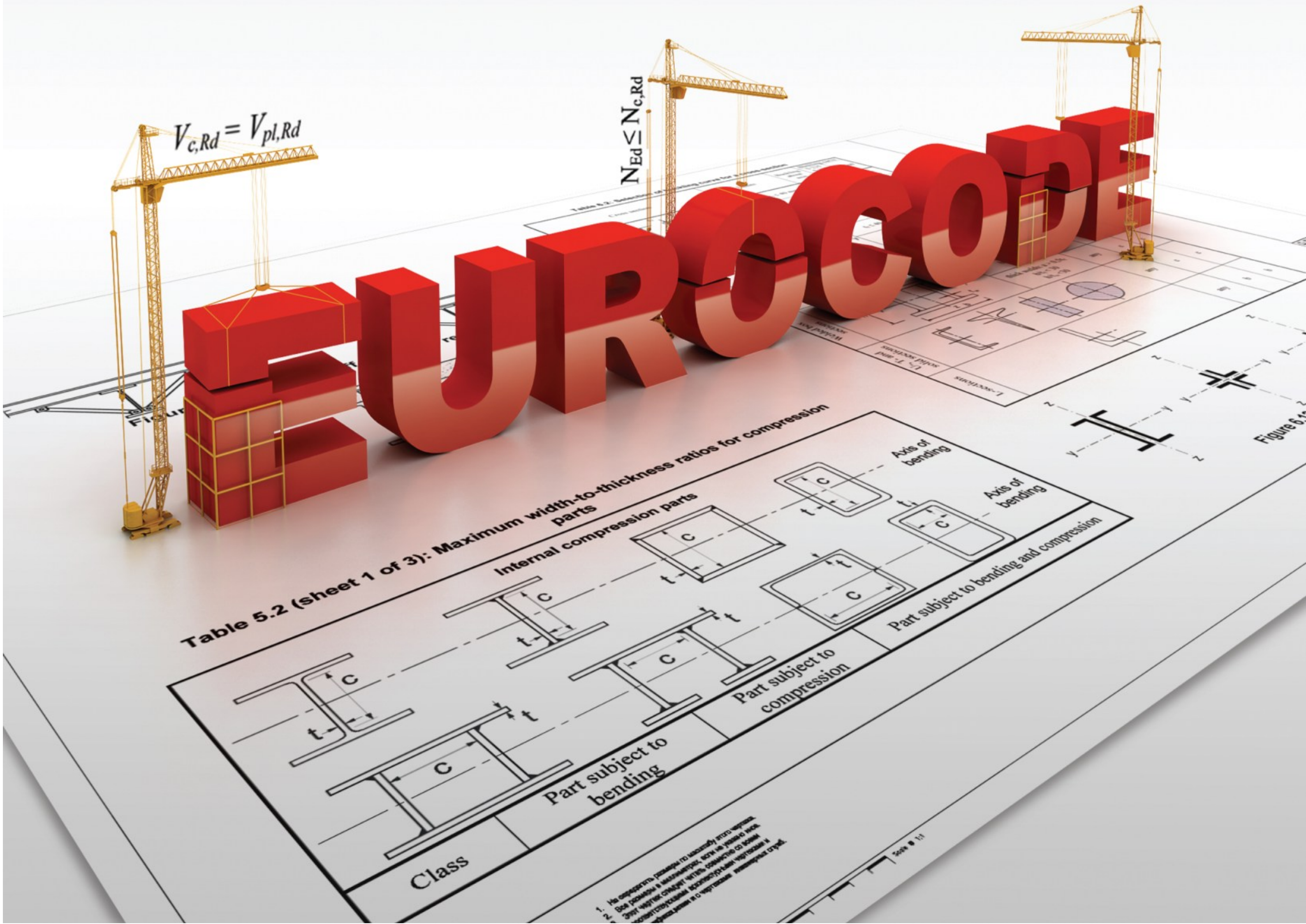
Eurocode2 Design Guide

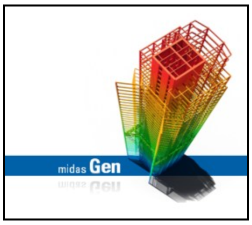
for midas Gen

Integrated Design System for Building and General Structures



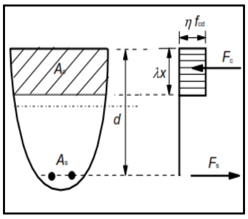
Introduction

This design example book provides a comprehensive guide for RC design as per Eurocode2-1-1:2002. Specifically, this guide will review the design algorithms implemented in midas Gen, and go through design tutorials. This book is helpful in understanding the Eurocode design concept and verifying design results using midas Gen.



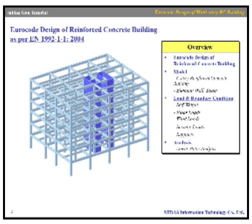
CHAPTER 1 Why midas Gen

This chapter describes the main features and advantages of midas Gen and showcases prominent project applications.



CHAPTER 2 RC Design Algorithms

This chapter discusses the general design concept of EN1992-1-1 and how it has been implemented in midas Gen. This enables the user to understand the equations, formulas, program limitations and development scope of the midas Gen design features.



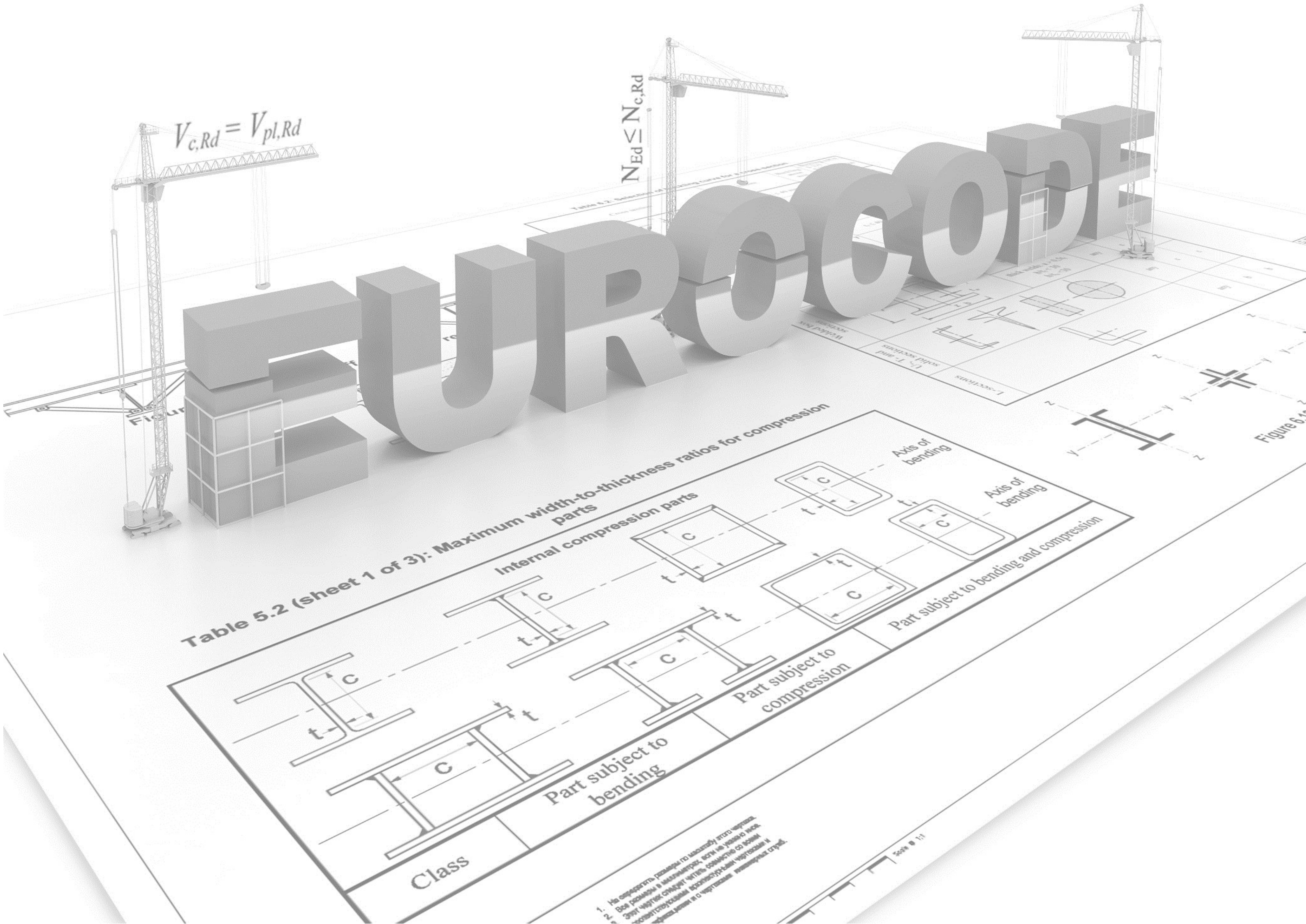
CHAPTER 3 RC Design Tutorial

This chapter enables the user to get acquainted with the RC design procedure in midas Gen as per EN1992-1-1: 2004. It encompasses the overall design procedure, from generating load combinations to checking design results with updated sections.

CHAPTER 1

Why midas Gen

Eurocode2 Design Guide for midas Gen



CHAPTER 1

Why midas Gen

01 Intuitive User Interface

The intuitive User Interface, contemporary Computer Graphics and substantially fast Solver Speed are some of the highlights of midas Gen. The user-oriented input/output features and significant analysis capabilities enable the practicing engineers and re-searchers to readily undertake structural analyses and designs for all types of buildings and even complex and long-span structures.

02 Advanced Analysis Features

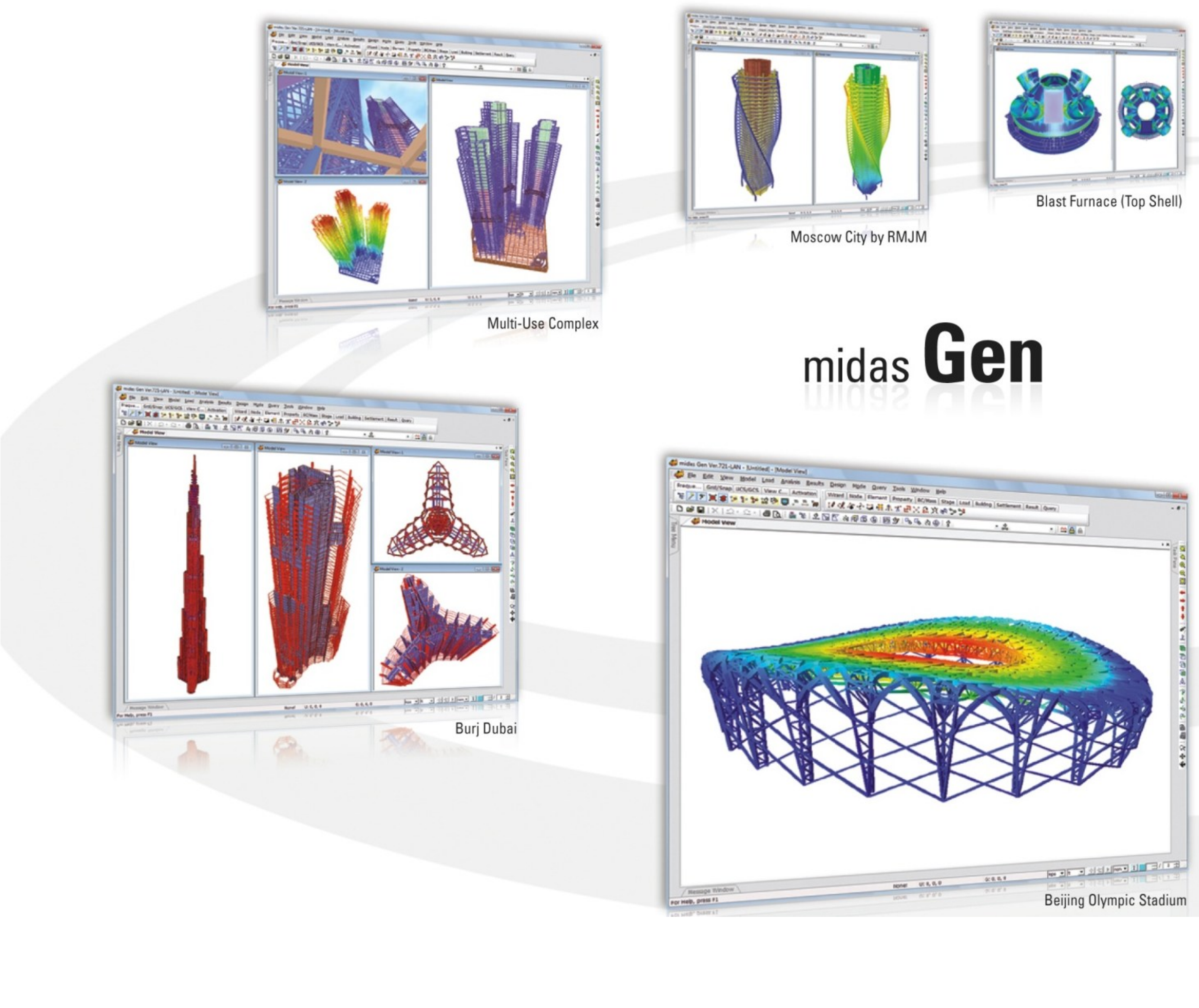
midas Gen offers conventional analysis capabilities as well as other analyses such as Geometric Nonlinear Analysis reflecting Large Displacement, Boundary Nonlinear Analysis, Pushover Analysis, Construction Simulated Analysis reflecting time dependent material properties, Heat of Hydration Analysis, etc.

03 Accurate and Practical Results

Diverse ranges of specialty finite elements in conjunction with the latest theories of structural analyses render accurate and practical results. It is prominent for providing convenience, efficiency, versatility and productivity.

04 Design Capabilities

midas Gen provides design capabilities using various standards of different countries reflecting conventional as well as unusual design conditions, leading to Optimal Design. midas Gen has been used for over 20 years and applied to over an uncountable number of projects successfully, thereby, demonstrating its credibility and stability.



Features

Design Features

- **RC Design:**
  ACI318, Eurocode 2 & 8, BS8110, IS:456 & 13920, CSA-A23.3, GB50010, AIJ-WSD, TWN-USD, AIK-USD & WDS, KSCE-USD, KCI-USD
- **Steel Design:**
  AISC-ASD & LRFD, AISI-CFSD, Eurocode 3, BS5950, IS:800, CSA-S16, GBJ17 & GB50017, AIJ-ASD, TWN-ASD & LSD, AIK-ASD & LSD & CFSD, KSCE-ADS, KSSC-ASD
- **SRC Design:**
  SSRC, JGJ138, CECS28, AIJ-SRC, TWN-SRC, AIK-SRC2K, AIK-SRC, KSSC-CFT
- **Footing Design:** ACI381, BS8110
- **Slab & Wall Design:** Eurocode 2
- **Capacity Design:** Eurocode 8, NTC2008
- **General Section Designer:** P-M & M-M Interaction Surface, Moment Curvature Curve, Stress Contour

Wind & Seismic Loads auto-generation

- **Wind Load:**
  IBC2000, UBC, ANSI, Eurocode 1, BS6399, IS875, NBC, GB, Japan, Taiwan & Korea
- **Seismic Load:**
  IBC2000, UBC, ATC 3-06, Eurocode 8, IS1893, NBC, GB, Japan, Taiwan & Korea

High-rise Specific Functionality

- **3-D Column Shortening** reflecting change in modulus, creep and shrinkage
- **Construction Stage Analysis** accounting for change in geometry, supports and loadings
- **Building model generation wizard**
- Automatic mass conversion
- Material stiffness changes for **cracked sections**

High-end Analysis Capabilities

- **P-Delta** & Large Displacement Analysis
- Dynamic Analysis (**Time History, Response Spectrum**, etc.)
- Base Isolators & Dampers
- **Pushover** Analysis
- Inelastic Time History Analysis
- Staged **post-tensioning**
- Catenary Cable Structure
- Heat of Hydration Analysis

Intuitive User Interface

- Works Tree (Input summary with powerful modeling capabilities)
- Models created and changed with ease
- Floor Loads defined by areas and on inclined plane
- Built-in **Section Property Calculator**
- **Tekla Structures, Revit Structure & STAAD** interfaces

Why midas Gen?

midas Gen is a Windows-based, **general-purpose** structural analysis and optimal design system.

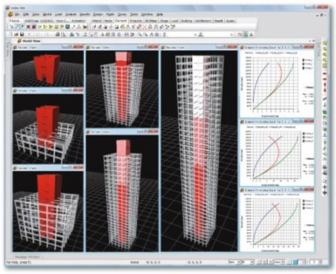
The **intuitive user interface**, contemporary computer graphics and substantially fast **solver speed** are some of the highlights of midas Gen.

The user-oriented input/output features and significant analysis capabilities enable the **practicing engineers** and researchers to readily undertake structural **analysis and design** for even complex and large structures.

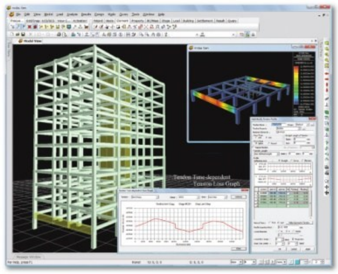
The fastest Multi-Frontal Solver and the latest analysis algorithms instantly bring accurate and practical analysis results.

In addition, midas Gen provides design capabilities using various standards of different countries leading to an **optimal design solution**.

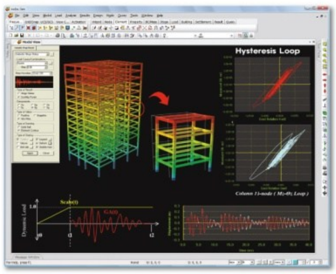
High-end Analysis Features



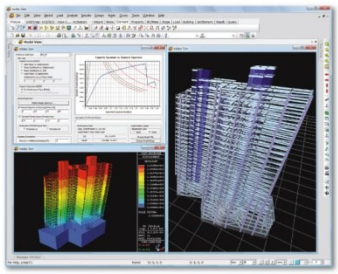
[Construction Stage Analysis]



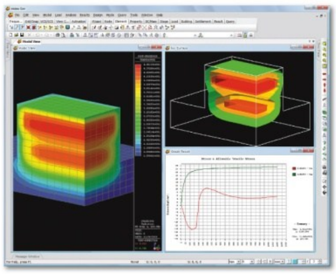
[Post-tension Analysis]



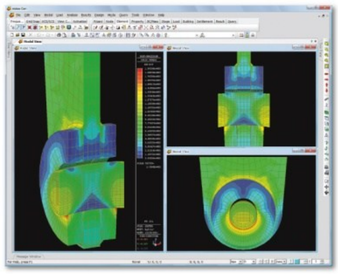
[Inelastic Time History Analysis]



[Pushover Analysis]



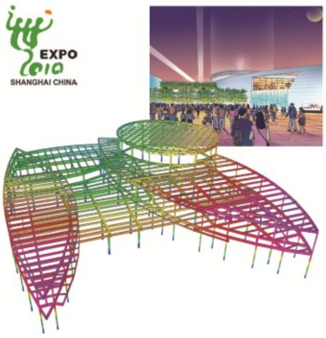
[Heat of Hydration Analysis]



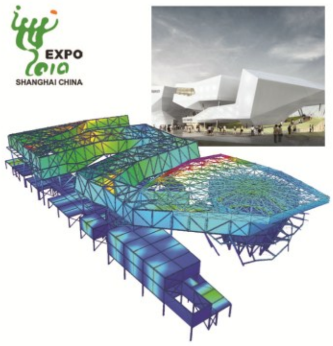
[Detail Analysis]

Project Applications

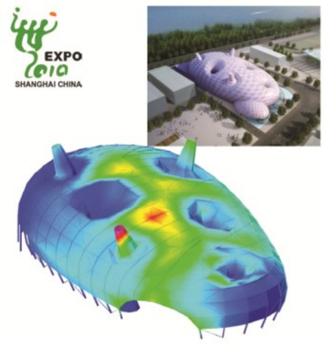
Specialty Structures



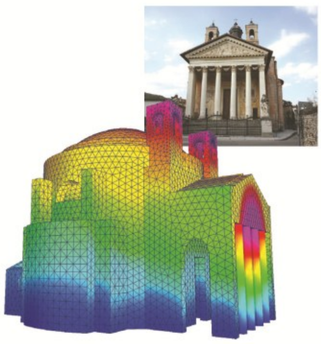
USA Pavilion (Shanghai EXPO)



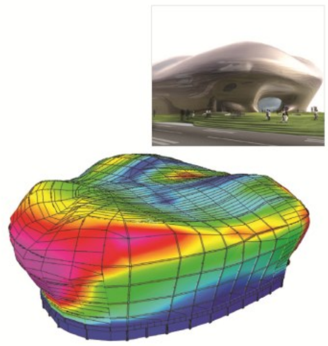
German Pavilion (Shanghai EXPO)



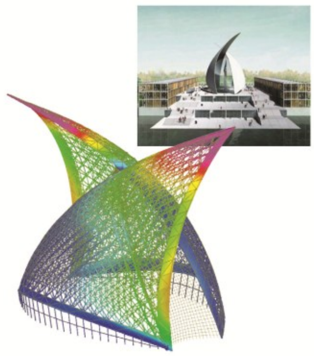
Japan Pavilion (Shanghai EXPO)



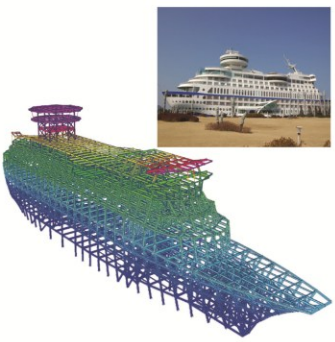
Tempietto di Villa Barbaro (Italy)



Erdos Museum (Mongolia)

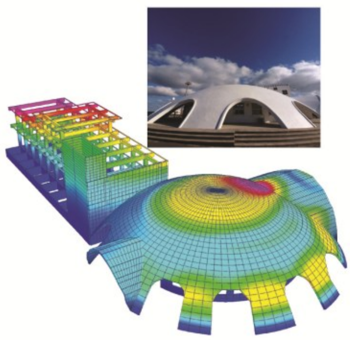


Maritime Museum (China)



Jeongdongjin Resort Facilities (Korea)

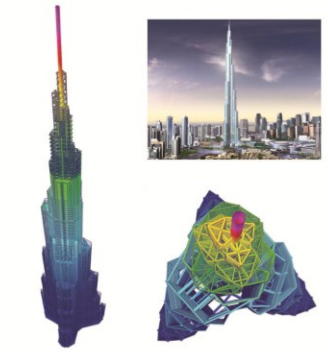
Saint Ignatius High School (Taiwan)



Sungsanpo Marine Terminal (Korea)

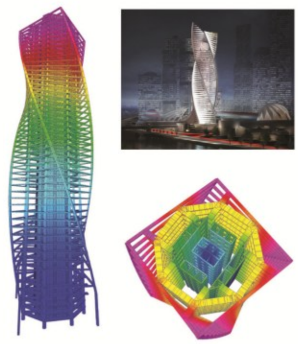
Project Applications

Buildings

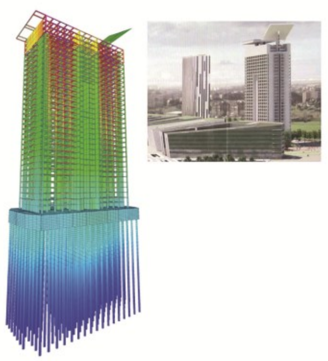


Burj Khalifa (UAE)

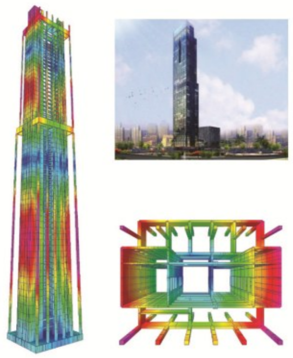
Guangzhou Twin Tower (China)



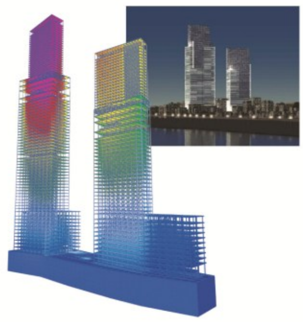
Moscow City Palace (Russia)



Torre Eurosky (Italy)

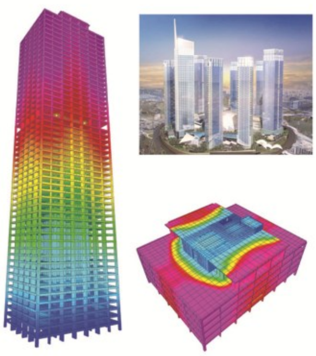


Rolex Tower (UAE)

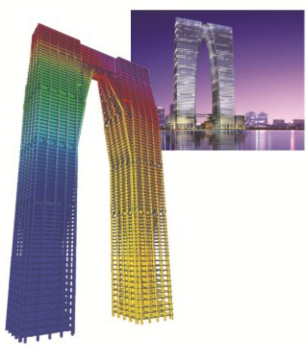


Taipei Twin Tower (Taiwan)

Hanoi Landmark (Vietnam)



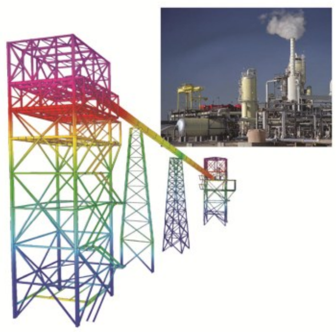
Omnix Tower (UAE)



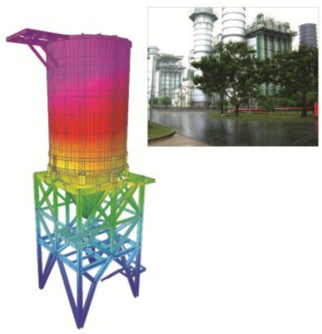
Gate of the Orient (China)

Project Applications

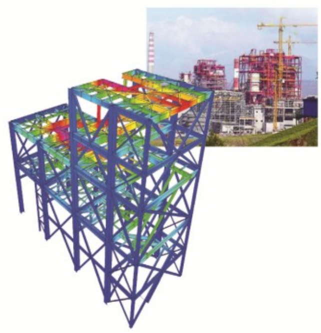
Plant Structures



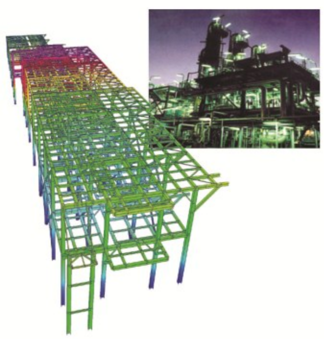
Campiche Power Plant (Chile)



Nghi Power Plant (Vietnam)



Angamos Power Plant (Chile)

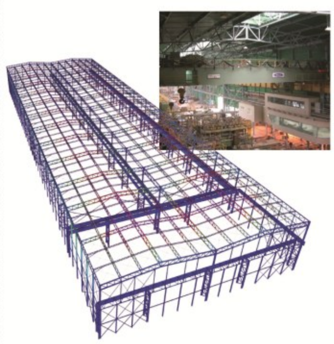


Hadeed CCL Steel Plant (Saudi Arabia)

TAVAZON Steel Plant (Iran)

India IISCO Steel Plant (India)

Pohang Steel Plant (Korea)

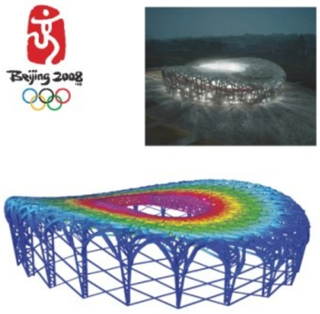


Zhangjiagang STS Steel Plant (China)

Gwangyang Steel Plant (Korea)

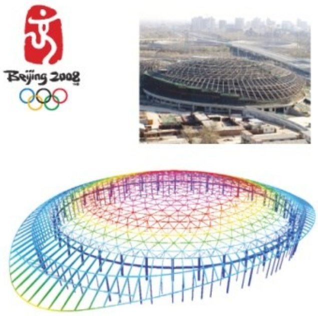
Project Applications

Spatial Structures

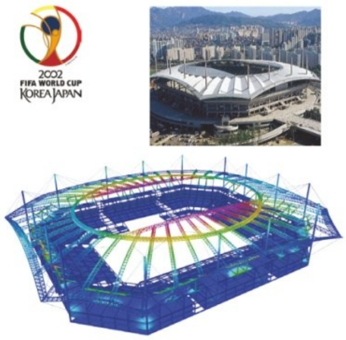


2008 Beijing Olympic Main Stadium (China)

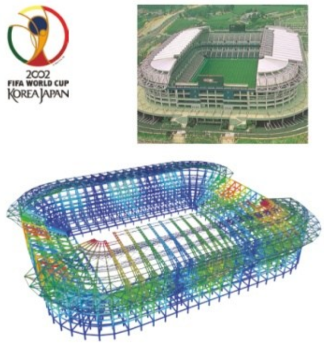
2008 Beijing Olympic Basketball Arena (China)



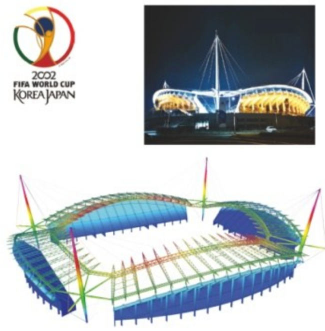
2008 Beijing Olympic Badminton Arena (China)



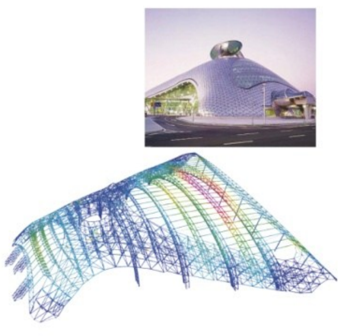
FIFA World Cup Main Stadium (Korea)



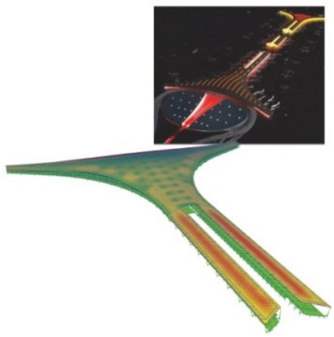
FIFA World Cup Daejeon Stadium (Korea)



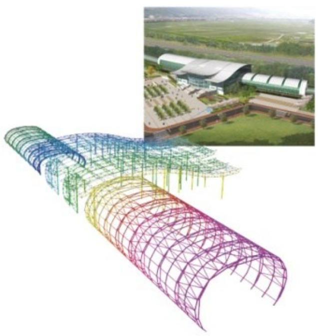
FIFA World Cup Jeonju Stadium (Korea)



Inchoen International Airport (Korea)



Beijing International Airport (China)

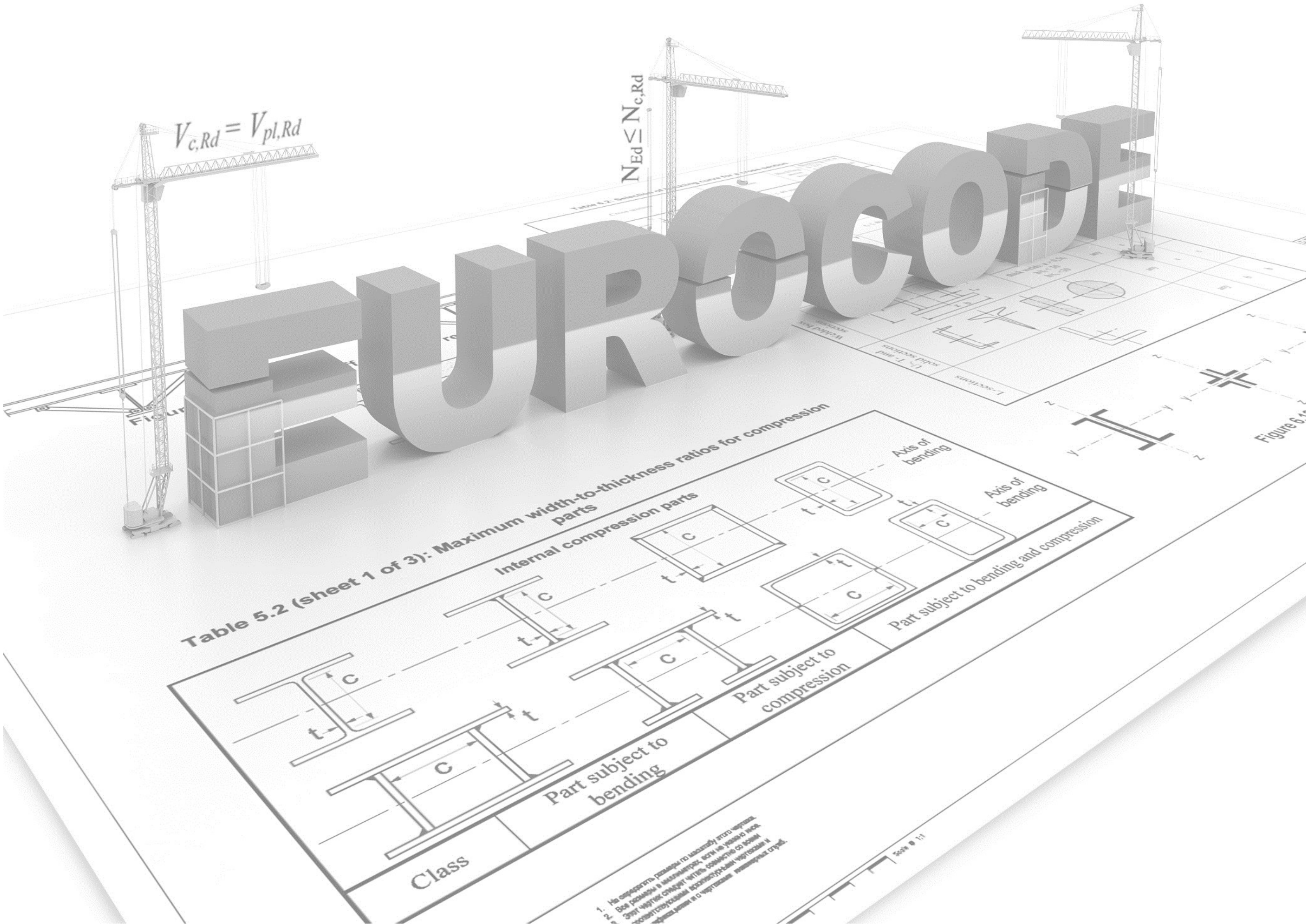


Seoksan Subway Station (Korea)

CHAPTER 2

RC Design Algorithm

Eurocode2 Design Guide for midas Gen



Overview

Ultimate Limit State

Overview

1.1 Design Scope

midas Gen provides automatic design of concrete beam, column, shear wall, meshed slab and meshed wall. The program also supports section checking when relevant data is specified. With respect to Eurocode, the major capabilities of the program can be summarized as below:

- Ultimate Limit State and Serviceability Limit State design and checking
- Auto generation of load combinations as per Eurocode 1990:2002
- Auto generation of Static Wind Loads as per Eurocode 1991-1-4:2005
- Auto generation of Static Seismic Loads & Response Spectrum Functions as per Eurocode 1998-1:2004
- Capacity design as per Eurocode 1998-1:2004
- Available Section shapes for design:
  - Beam: Rectangle, T-shape
  - Column: Rectangle, Circular, Hollow circular
  - Wall: Rectangle
- Design and checking of meshed slab and meshed wall
- Cracked section analysis of slabs for serviceability checks

The following should be taken care of by the user:

- Torsion check is not provided by midas Gen.
- Irregular wall such as L or H shape cannot be designed.
- Isolated footing design is not supported as per EN 1992-1-1:2004.

This design guide covers the design of frame elements as per EN 1992-1-1:2004 for non-seismic situations. Aspects of column design, beam design and wall design are discussed in this guide.

For the purpose of component design, midas Gen interacts with midas Design+. midas Design+ is a collection of handy structural component design and detailing tools, which are easy to use and speed up the day-to-day design process. midas Design+ is developed to be simple, fast and accurate. It enables engineers to systematically and consistently manage design reports. midas Design+ supports Column design, Wall Design and Strip Footing Design as per Eurocode.

[Table 1.1] Capabilities of midas Gen with respect to Eurocode

	Ultimate Limit State				Serviceability Limit State		
	Flexure	**Shear**	**Axial**	**Torsion**	**Stress**	**Deflection**	**Crack Control**
Beam	✓	✓			✓	✓	✓
Column	✓	✓	✓		✓		
Wall	✓	✓	✓				
Meshed Slab	✓	✓			✓	✓	✓
Meshed Wall	✓	✓	✓				

1.2 Materials

1.2.1 Concrete

EN 1992-1-1:2004 (Table 3.1) provides specifications about strength and deformation characteristics of concrete. midas Gen supports a material database as per the specifications. Any of the materials can be easily chosen for analysis as well as design. The following are the strength classes of concrete as identified by the code:

- C12/15
- C16/20
- C20/25
- C30/37
- C35/45
- C40/50
- C45/55
- C50/60
- C55/67
- C60/75
- C70/85
- C80/95
- C90/105

Material name C40/50 implies that the cylinder characteristic strength (f_{ck}) at 28 days is 40 MPa and cube characteristic strength ($f_{ck,cube}$) at 28 days is 50 MPa.

The material can be chosen in **Material Data** dialog Box as shown below. In dialog box, choose **Type of Design** as "**Concrete**". **Standard** as "**EN04(RC)**". Then from DB drop down list any of the above materials can be chosen.

1.2.1.1 Modulus of Elasticity (E_c)

For materials selected from EN 1992-1-1:2004, the modulus of elasticity is obtained using the formula as specified by the code:

$$E_{cm} = 22\left(\frac{f_{cm}}{10}\right)^{0.3} \qquad (1.1)$$

EN1992-1-1:2004 Table 3.1

$$f_{cm} = f_{ck} + 8\ \text{(MPa)} \qquad (1.2)$$

<u>Note for Italian users</u>

For Italian user, the program supports the UNI material database. The database includes the following materials:

- *Rck 10*
- *Rck 15*
- *Rck 20*
- *Rck 25*
- *Rck 30*
- *Rck 35*
- *Rck 40*
- *Rck 45*
- *Rck 50.*

For these materials, the user needs to choose the Standard as "UNI(RC)" and then select the desired material.

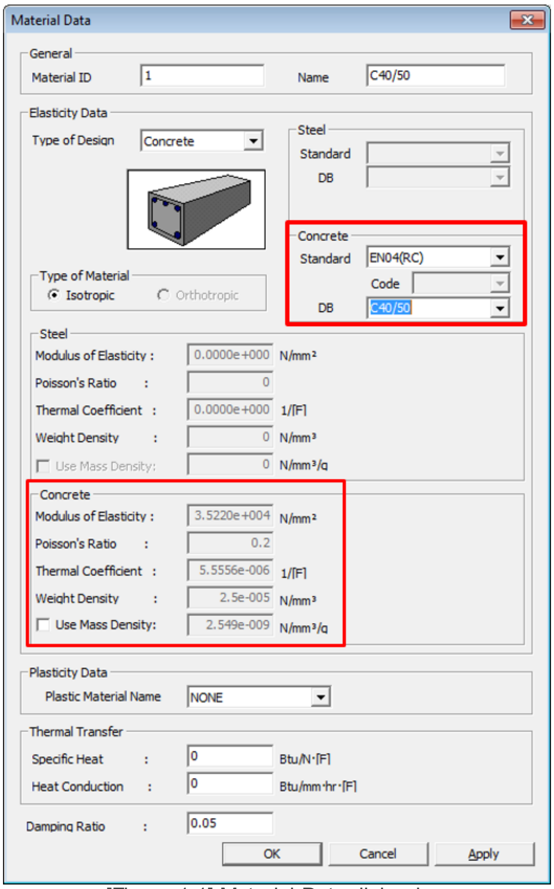
1.2.1.2 Poisson's Ratio

The default value of Poisson's ratio is used as *0.2*. For a different value of Poisson's ratio user defined material needs to be specified as per Section 1.2.1.4 of this guide.

1.2.1.3 Weight Density

The weight density is used as 25 kN/m^3 for all the material from the database. For a different weight density user defined material needs to be specified as per Section 1.2.1.4 of this guide.

❖ *Model > Properties > Material*



[Figure 1.1] Material Data dialog box

1.2.1.4 User Defined Materials

User defined Concrete Material can be specified. **Type of Design** should be used as **Concrete,** otherwise the design cannot be performed for the specified material. Then select the **Standard** as **None** to input the user defined material properties. Type of design should not be selected as User Defined.

1.2.2 Reinforcement

The reinforcement material can be specified in **Modify Concrete Materials** dialog box as shown in Section 1.2.3. If the material is not specified there, then the default material will be taken as specified in **Design/Load Code** Environment in **Tools > Preferences**. Then under Concrete heading user can specify the database for Rebar. The available rebar materials as per Eurocode are as follow:

[Table 1.2] Available Rebar Materials as per EN 1992-1-1:2004

Rebar Material	Yield Strength (f_y) (MPa)
Class A	400
Class B	500
Class C	600

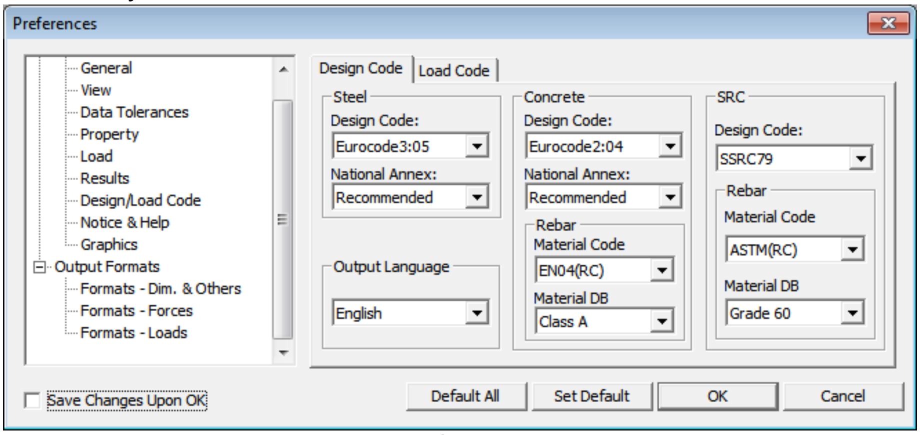
Note for Italian users

For Italian users, the program supports the UNI database consisting of the following materials:

- *FeB22k*
- *FeB32k*
- *Feb38k*
- *Feb44k*

To select the above materials, we need to specify the Material Code as "UNI(RC)".

❖ *Tools > Preferences*



[Figure 1.2] Preferences dialog box

1.2.2.1 Modulus of Elasticity (E_s)

For all the reinforcing materials, modulus of elasticity is used as 200 GPa. Different value of Modulus of Elasticity cannot be specified for reinforcing materials.

1.2.3 Design Strength of Materials

1.2.3.1 Design compressive strength of concrete (f_{cd})

EN1992-1-1:2004 3.1.6(1)

The code specifies the following equation for the calculation of the design compressive strength:

$$f_{cd} = \frac{\alpha_{cc} f_{ck}}{\gamma_c} \tag{1.3}$$

where,

f_{ck}: If standard material is used, the value is taken automatically as specified in the code. For a user defined material, we need to specify the f_{ck} in ***Modify Concrete Materials*** *dialog box shown below.*

α_{cc}: Coefficient to account for:

1. Long term effects on the compressive strength

2. Unfavorable effects resulting from the way the load is applied.

It can be specified in the ***Partial Safety Factor for Materials*** *dialog box as shown in Section 1.2.3.4.*

γ_c : The partial safety factor for concrete. It depends on the design situation. It can be specified in the ***Partial Safety Factor for Materials*** *dialog box as shown in Section 1.2.3.4.*

1.2.3.2 Design yield strength of reinforcement (f_{yd})

EN1992-1-1:2004 3.1.6(2)

The yield strength specified for reinforcing material will be used to calculate the design yield strength as per the following specification of code:

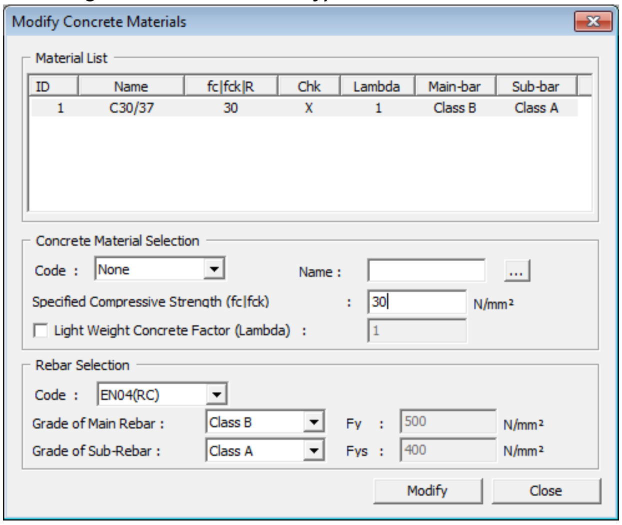
$$f_{yd} = \frac{f_{yk}}{\gamma_s} \tag{1.4}$$

where,

f_{yk}: The characteristic yield strength of reinforcement.

γ_s : The partial safety factor for steel. It depends on the design situation. It can be specified in the ***Partial Safety Factor for Materials*** *dialog box as shown in Section 1.2.3.4.*

❖ *Design > Concrete Design Parameter > Modify Concrete Materials*



[Figure 1.3(a)] Modify Concrete Material dialog box

In the above dialog box, the concrete and rebar material properties can be specified for design.

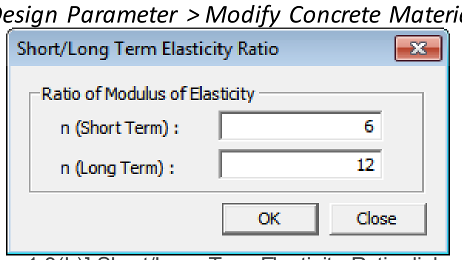
If standard material is used, the value is taken as specified in the code. In that case, this step is not a mandatory step. If material is user defined, then select '**None**' in the **Code** field and enter the name of material to be used in the Name field. Then, each data field is activated and the strength of materials can be entered.

Lightweight Concrete Factor (Lambda)**:** This is irrelevant for design as per Eurocode.

Grade of Main Rebar: The material specified here will be used for the longitudinal reinforcement.

Grade of Sub Rebar: The material specified here will be used for the stirrups.

❖ *Design > Concrete Design Parameter > Modify Concrete Materials> …*



[Figure 1.3(b)] Short/Long Term Elasticity Ratio dialog box

1.2.3.3 Short/Long Term Elasticity Ratio

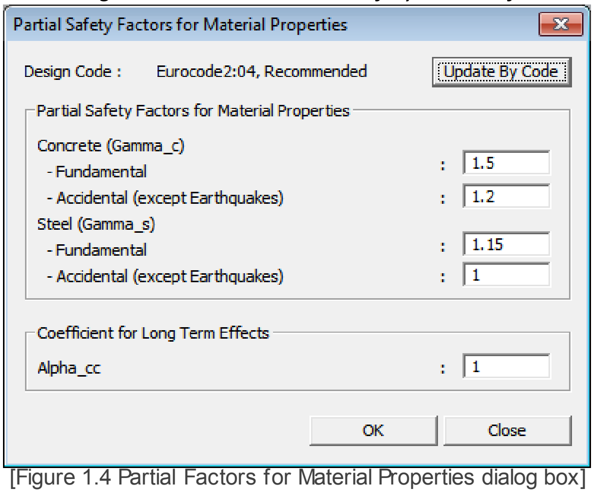
For serviceability check as per Eurocode 2, the ratios of the modulus of elasticity of reinforcement to the modulus of elasticity of concrete for short-term and long term can be entered.

The default value for short-term ratio is Es/Ec and 2(Es/Ec) for long-term ratio.

The ratio can be edited in the **Modify Concrete Materials** Dialog Box. The button next to the Name field, provides access to the **Short/Long Term Elasticity Ratio** dialog box.

1.2.3.4 Partial Safety Factors for Materials

❖ *Design > Concrete Design Parameter > Partial Safety Factors for Material Properties*



[Figure 1.4 Partial Factors for Material Properties dialog box]

[Table 1.3] Recommended Values of Partial Safety Factors for Materials

Design Situations	γ_c	γ_s
Persistent & Transient	1.5	1.15
Accidental	1.2	1.0

As per EN1990:2002, design situations are classified as:

a. Fundamental Design Situations:
   1. Persistent Design Situations
      Relevant during design working life of structure
   2. Transient Design Situation
      Relevant for a shorter duration. eg: execution or repair

b. Seismic Design Situation
   Relevant during the earthquake

c. Accidental Design Situation
   Exceptional conditions like fire events, explosions, blast etc.

Specification 5.2.4(2) of EN1998-1:2004 "*If more specific data are not available, the values of the partial factors γ_c and γ_s adopted for the persistent and transient design situations should be applied*". midas Gen uses the same values of γ_c and γ_s for all three design situations i.e Persistent, Transient & Seismic Design Situations.

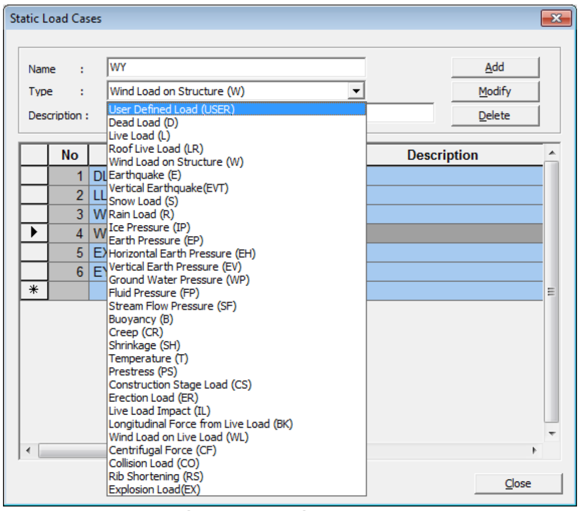
The design situation is identified automatically by the program as per the following table:

[Table 1.4] Classification of Design Situations

Design situations	Description
Fundamental and Seismic	Load combinations not covered in "Accidental Situation"
Accidental	Load Combination including any of the following type of load case, will be classified in Accidental Situation: Live Load Impact (IL) Collision Load (CO)

Load Case type is specified in the dialog box below:

❖ *Load > Static Load Cases*



[Figure 1.5] Static Load Cases dialog box

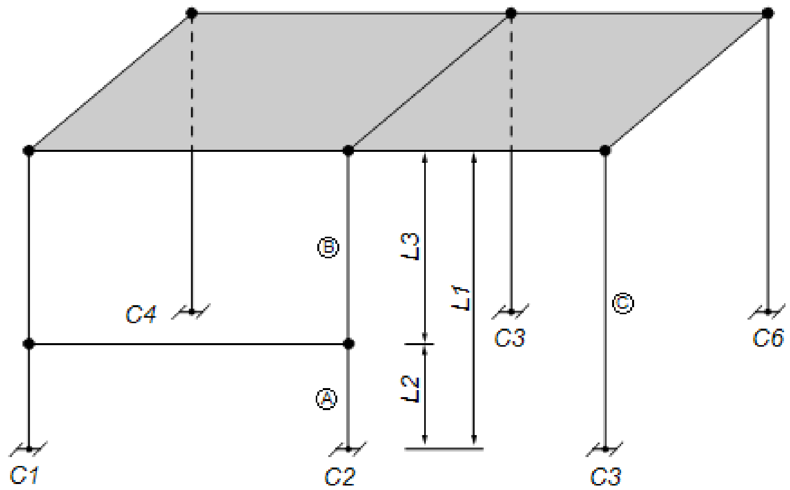
After identifying the design situation respective partial safety factors for materials are used by the program in design.

1.3 Design Information

1.3.1 Member Assignment

The program offers to consider a number of line elements as a single member for the purpose of design. The design forces and the section capacities will be calculated at the i, ¼, ½, ¾, j-point of the member and not of the element. Also, the span for the design will be considered as per the specifications of the member and not of the element.

The unbraced length will be taken on a member basis, instead of element basis. Laterally Unbraced Length is taken from the member.



Unbraced length of a column Ⓐ : $L_y = L2$, $L_z = L1$

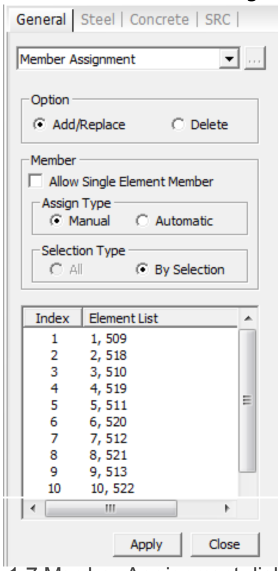
Unbraced length of a column Ⓑ : $L_y = L3$, $L_z = L1$

Unbraced length of a column Ⓒ : $L_y = L_z = L1$

[Figure 1.6] Unbraced Length for column

If the elements to be assigned to a member retain different material and section properties, or the directions of the node connections are different, a member cannot be assigned.

❖ *Design > General Design Parameter > Member Assignment*



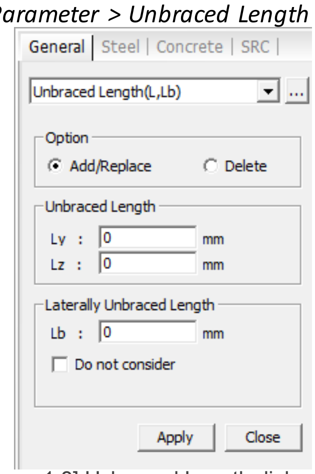
[Figure 1.7 Member Assignment dialog box]

1.3.2 Unbraced Length

When members are defined by Member Assignment, unbraced lengths about the member's strong axis (y-Axis) and weak axis (z-Axis) are automatically calculated by the program considering the connectivity of the members.
If members are not defined then the unbraced length is taken equal to the length of the element for bending about both axis.

The unbraced length can also be specified by the user in **Unbraced Length** dialog box as shown below. If unbraced length is specified as 0, then program will take the unbraced length as the length of the member or the length of the element, whichever is applicable.

❖ *Design > General Design Parameter > Unbraced Length*

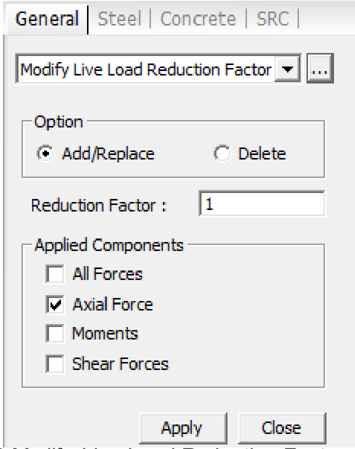


[Figure 1.8] Unbraced Length dialog box

1.3.3 Live Load Reduction Factor

When calculating the Forces for design, the effect of live load can be reduced. Axial force, moments and shear forces due to actions can be reduced. The reduction factor can be specified in the Modify Live Load Reduction Factor dialog box. In order to specify the live load to be reduced to 80%, the factor of 0.8 should be added for the respective forces.

❖ *Design > General Design Parameters > Modify Live Load Reduction Factor*



[Figure 1.9 Modify Live Load Reduction Factor dialog box]

The live load reduction factor needs to be calculated manually. The formula specified by EN 1991-1-1:2002 is:

$$\alpha_n = \frac{2+(n+2)\psi_0}{n} \qquad (1.5)$$

EN 1991-1-1:2002 6.3.1.2(11)

where:

n is the number of storys (>2) above the loaded structural elements from the same category.

Ψ_0 is the factor for combination of variable actions. It is provided in EN 1990, Annex A1, Table A1.1.

1.3.4 Imperfections

Eurocode 1992-1-1:2004 specifies that the unfavorable effects of possible deviations in the geometry of the structure and the position of loads shall be taken into account in the analysis of members and structures. The imperfections should be modelled manually by the user.

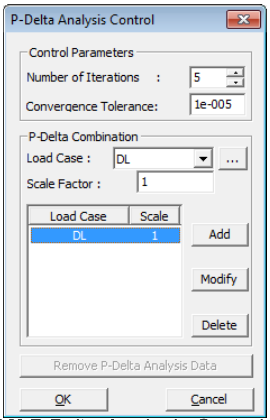
In order to consider the effect of these imperfections, the code provides equivalent transverse forces for these imperfections in Section 5.2 using equations from 5.4 to equation 5.6. These forces need to be calculated and applied manually by the user.

1.3.5 P-Delta Analysis

The amplification of the moments due to second order effects is specified by the code. Second order effects due to both the change of geometry of structure (P-Δ) and the curvature of member (P-δ) need to be considered.

The second order effects can be easily considered in the program by performing P-Delta Analysis. The program performs both P-Δ as well as P-δ analysis. The corresponding magnified moments can be used for the design of the members. In case the P-delta analysis is not performed, the provisions of code will be used to obtain the second order moments. The method of moment magnification as per Eurocode 2 will be discussed in Section 2.2.

❖ *Analysis > P-Delta Analysis Control*



[Figure 1.10] P-Delta Analysis Control dialog box

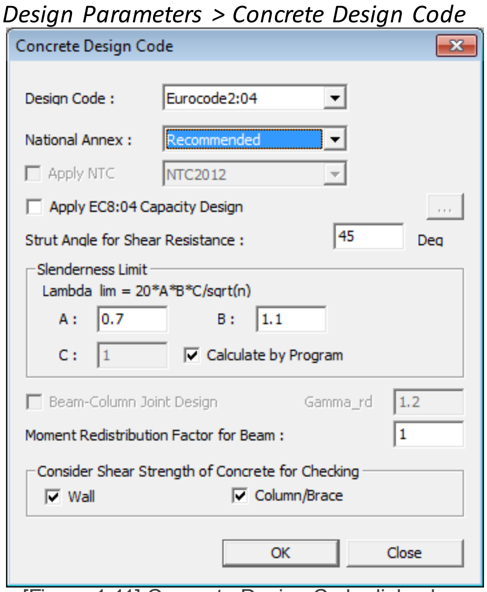
1.3.6 Pattern Loading

At the moment, the program doesn't support the auto generation of the pattern load combinations.

1.3.7 Selection of Design Code

The design code can be selected in the Concrete Design Code dialog box as shown below:

❖ *Design > Concrete Design Parameters > Concrete Design Code*



[Figure 1.11] Concrete Design Code dialog box

In addition to the recommended values, the program supports the following National Annexes for design:

- Italy
- Sweden
- Singapore

Ultimate Limit State

2.1 Design for flexure without axial force

2.1.1 Requirements

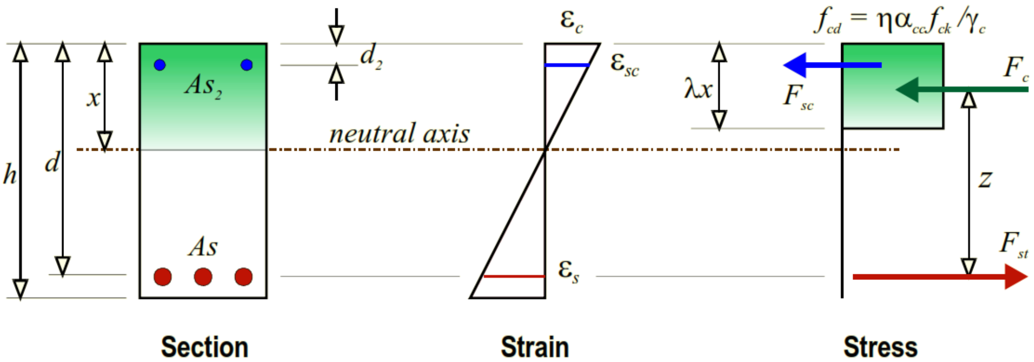
Moment capacity of the section (M_{Rd}) should be greater than the design moment for the section (M_{Ed}).

To satisfy limit state of moment resistance the following condition should be met:

$$M_{Ed} \le M_{Rd}$$

2.1.2 Calculating the moment capacity, M_{Rd}

The distribution of strain and stresses in the section is as follows:



[Figure 2.1] Distribution of strain and stresses in the section

Ref:
EN 1992-1-1:2004
Figure 3.5

where,

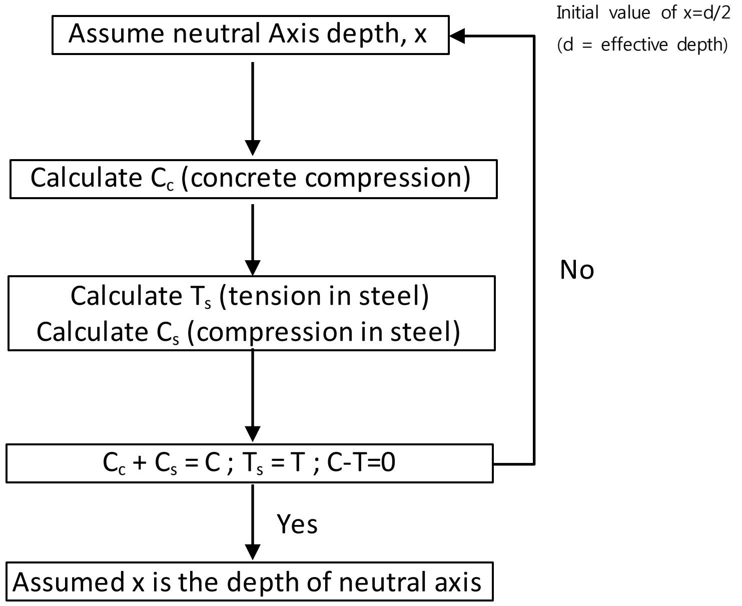
λ: factor defining the effective height of the compression zone.

η: factor defining the effective strength of concrete.

x: distance of the neutral axis from the extreme compression fiber

To calculate the moment capacity C_c, C_s and T_s are required. In order to determine all these forces depth of the neutral axis, x, needs to be calculated.

For this, an iterative process is used. The following steps are involved in the iteration:



[Figure 2.2] Flow chart to calculate depth of Neutral Axis

Note for design of flanged section

*For a flanged section, we need to specify the shape of the section as "T-section" in the **Section Data** dialog box.*

EN1992-1-1:2004 3.1.7(3)

1. Determination of λ & η

[Table 2.1] Factor for effective height of compression zone and factor for effective strength of concrete

Condition	λ	η
f_{ck} ≤ 50MPa	0.8	1.0
50 < f_{ck} ≤ 90MPa	0.8-(f_{ck}-50)/400	1.0-(f_{ck}-50)/200
f_{ck} > 90MPa	0.7	0.8

2. Initial depth of the neutral axis.

   Initial depth is assumed to be d/2, where d is the distance between extreme compression fiber and center of tension reinforcement.

3. Calculate force of concrete, C_c

$$C_c = \eta\, f_{cd} \int_{dA} \lambda\, x \tag{2.1}$$

4. Calculate force of reinforcement, T_s and C_s

$$C_s = A_{sc}\, f_{sc} \tag{2.2}$$
$$T_s = A_{st}\, f_{st} \tag{2.3}$$

where,

A_{sc}: The cross sectional area of compressive reinforcement.
f_{sc}: The stress at the center of the compressive reinforcement.
A_{st}: The cross sectional area of tensile reinforcement.
f_{st}: The stress at the center of the tensile reinforcement.

In order to calculate the stress of reinforcing steel, f_{st} or f_{sc}, the appropriate strain is calculated by the strain compatibility condition as follows:

a) At the extreme compression fiber of concrete, strain equal to ε_{cu} is assumed. Then the strain is calculated at the center of reinforcement assuming a linear stress strain distribution as per Figure 2.1.

$$\varepsilon_s = \frac{d_t - x}{x}\varepsilon_{cu} \tag{2.4}$$

where,

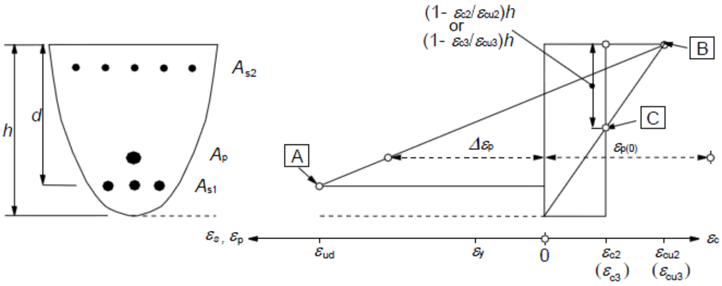
ε_s : The strain at the level of the reinforcement.
ε_{cu}: The ultimate compressive strain in the concrete. ($\varepsilon_{cu} = \varepsilon_{cu1}$)
x : Neutral axis depth.
d_t : Distance of the rebar from extreme compression fiber

EN1992-1-1:2004 Table 3.1

[Table 2.2] Ultimate Strain (ε_{cu1}) in Concrete

Condition	ε_{cu1}
f_{ck} ≤ 50MPa	0.0035
50 < f_{ck} ≤ 90MPa	[2.8+27{(98-f_{cm})/100}^{4}]/1000, f_{cm}=f_{ck}+8MPa
f_{ck} > 90MPa	0.0028

EN1992-1-1:2004
Figure 6.1



A - reinforcing steel tension strain limit

B - concrete compression strain limit

C - concrete pure compression strain limit

[Figure 2.3] Possible strain distributions in the ultimate limit state

b) Calculate the reinforcement stresses corresponding to the calculated reinforcement strains. (from the stress-strain idealizations)

$$f_s = \begin{cases} \varepsilon_s E_s & (\varepsilon_s \le \varepsilon_{yd}) \\ f_{yd} & (\varepsilon_s > \varepsilon_{yd}) \end{cases} \qquad (2.5)$$

The forces of tensile reinforcement and compressive reinforcement are calculated in the above manner.

5. Check if the assumed depth of neutral axis is suitable or not. For this purpose, the convergence criteria is checked. If the following condition is met, then the assumed x is used as depth of neutral axis:

$$\left|\frac{C-T}{T}\right| < 0.01 \quad \text{(Tolerence)}$$

If aforementioned condition is not fulfilled then, new depth of neutral axis is assumed by "Bisection Method (Numerical analysis)".

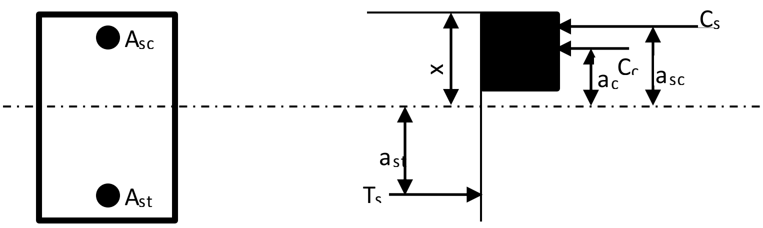
If the above criteria is not met after 20 iterations, then:

- We get output "Not converge" in Message window.
- The model needs to be modified as follows:
  - Increase section size.
  - Modify the rebar information (position, numbers, spacing, etc.)

6. Calculate moment resistance M_{Rd}

Once the neutral axis is obtained, moment resistance can be calculated by multiplying the axial forces with eccentricity from the neutral axis.

$$M_{Rd} = C_c a_c + C_s a_{sc} + T_s a_{st} \qquad (2.6)$$



[Figure 2.4] Forces and distances from neutral axis depth for M_{Rd}

7. Check moment resistance ratio:

$$\frac{M_{Ed}}{M_{Rd}} \le 1$$

where,

M_{Ed} : Design bending moment is chosen for the load combinations which are available as per Section 2.1.5.

M_{Rd} : Moment capacity of the section.

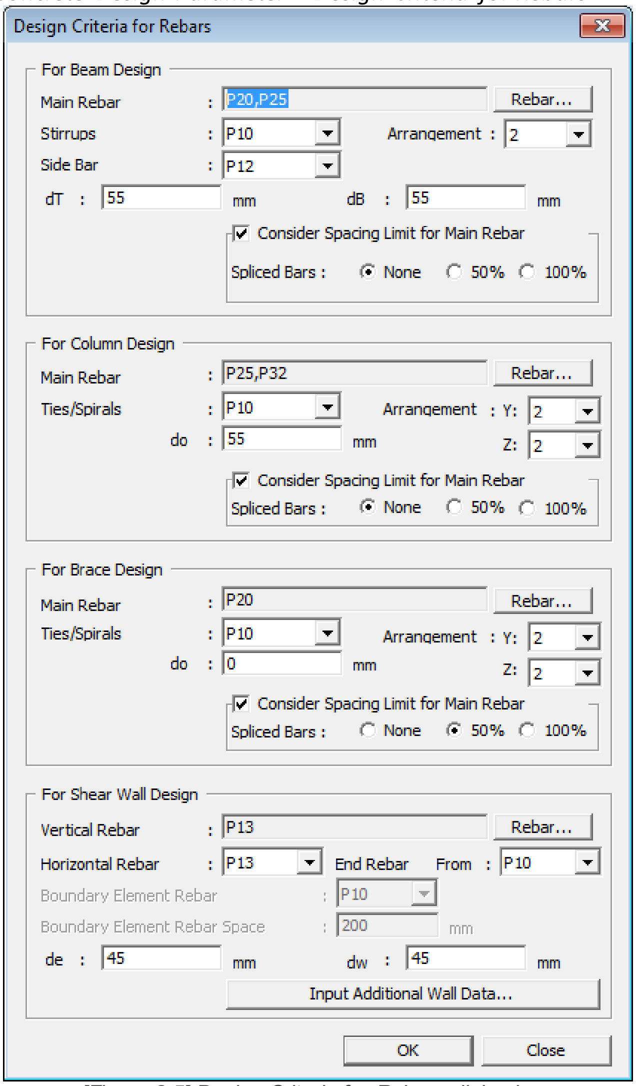
Depending on the ratio, the results are displayed in the various forms as mentioned in Section 2.4.

2.1.3 Design Criteria for Rebars

To choose the size of the rebars which should be used for the reinforcement, the specifications can be provided in **Design criteria for Rebars** dialog box as shown below.

The transverse reinforcement data can also be specified in this dialog box.

- *Design > Concrete Design Parameter > Design Criteria for Rebars*



[Figure 2.5] Design Criteria for Rebars dialog box

where,

dT represents the distance between center of top rebar and extreme top fiber

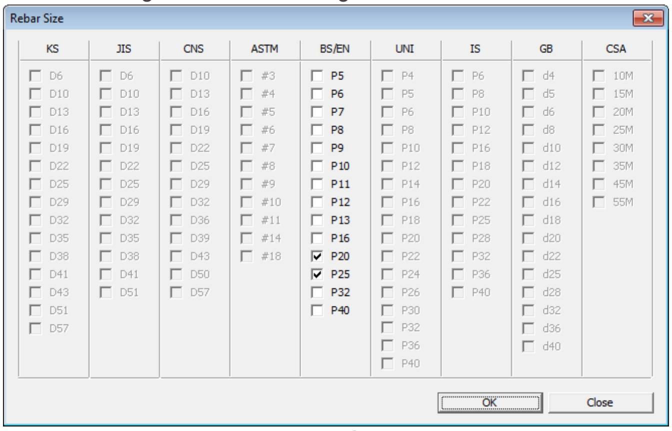
dB represents the distance between center of bottom rebar and the extreme bottom fiber

When the value of dT and dB is specified as zero, then the default value is taken as minimum of:

I. max [H_c/10, B_c/10, 2.5”/63.5 mm]

II. 3”/76.2 mm

❖ Design > Concrete Design Parameter > Design Criteria for Rebars > Rebar…

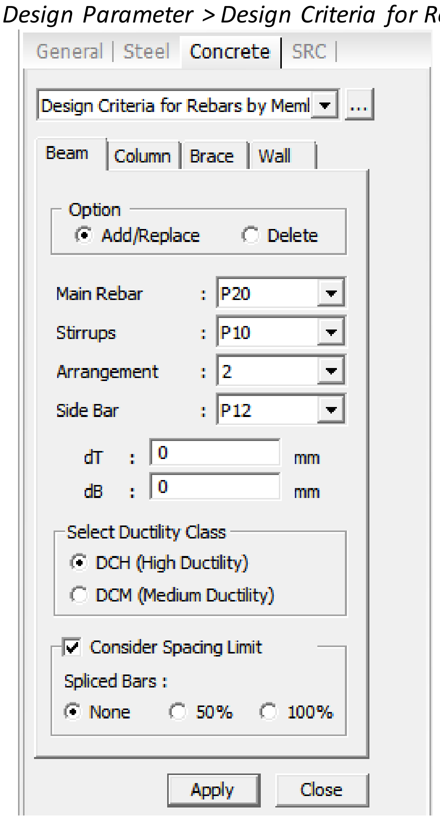


[Figure 2.6] Rebar Size dialog box

The following European rebar sizes are available:
P5, P6, P7, P8, P9, P10, P11, P12, P13, P16, P20, P25, P32, P40.
Maximum of 5 Rebar Sizes can be selected.

The data specified above will be applied to all the members of a model. If the user wants to specify different rebar criteria for certain members then that can be specified in **Design Criteria for Rebars by Member** dialog box. For that member, information provided here will override the information defined in **Design Criteria for Rebar** dialog box.

❖ *Design > Concrete Design Parameter > Design Criteria for Rebar by Member*



[Figure 2.7] Design Criteria for Rebars by Members dialog box

2.1.4 Concrete checking for beams

midas Gen is capable of both design and checking of sections. The difference in design and check can be explained as below:

If the user performs the Concrete Code Design function then based on the section size and the factored load, rebar data such as rebar size and spacing is determined by the program. Therefore, the design can be performed when the section size is defined without rebar data.

If the user needs to perform the strength and serviceability check for the user specified rebar data (rebar diameter, number of rebars and design parameters), then the user can perform the Concrete Code Check function. The rebar data can be specified as mentioned in the section below.

2.1.4.1 Rebar Input for Beam Checking

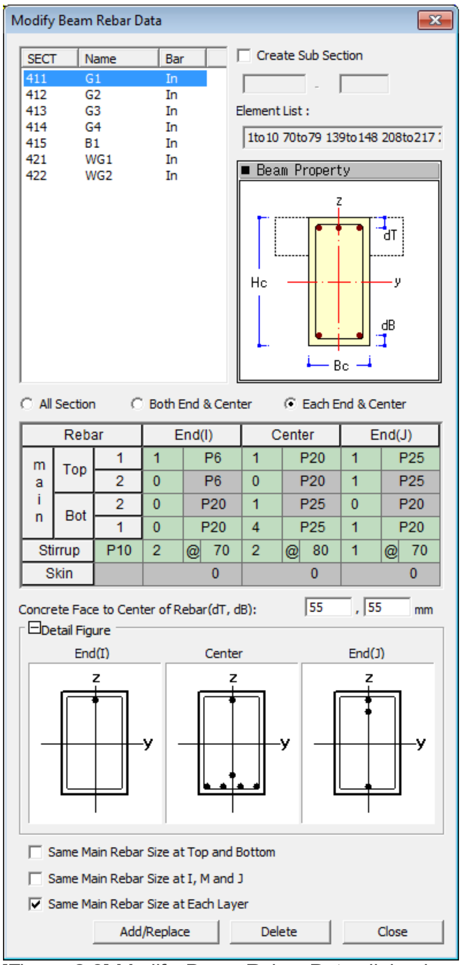
The rebar data for concrete code checking can be specified in the **Modify Beam Rebar data**. In midas Gen, both top and bottom rebar must be defined to perform concrete code checking.

The data can be entered for layer 1 and layer 2 of the top and the bottom reinforcement.

The values of dT and dB need to be specified appropriately. dT and dB cannot be specified as zero.

For transverse reinforcement the rebar size, number of legs and spacing of the stirrups can be specified.

❖ *Design > Concrete Design Parameter > Modify Beam Rebar Data*

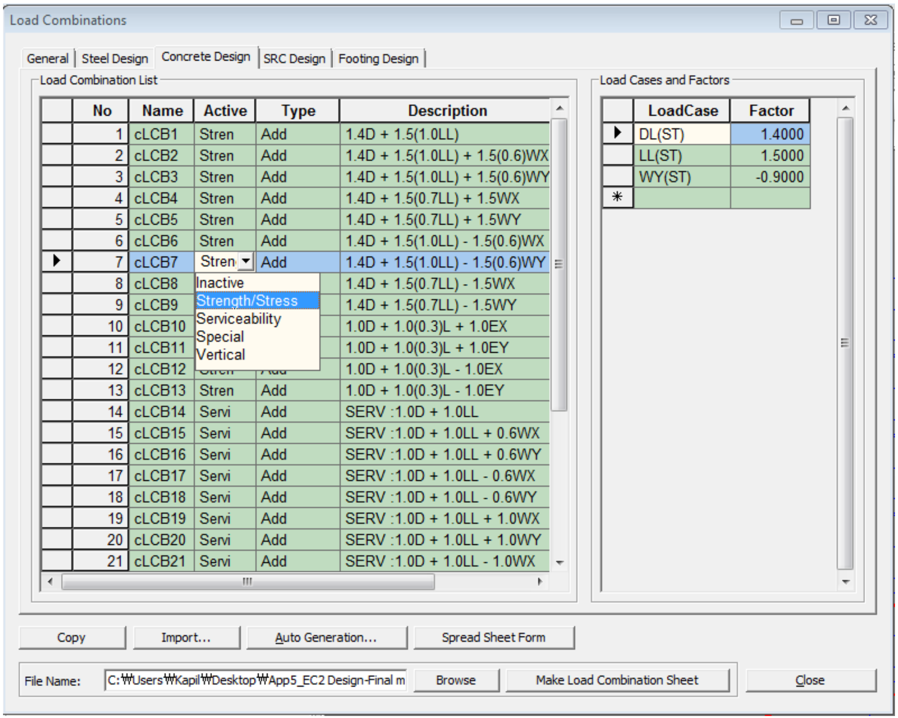


[Figure 2.8] Modify Beam Rebar Data dialog box

2.1.5 Design load combinations

The load combinations specified as **Strength/Stress** in the **Concrete Design** tab of **Load Combinations** dialog box will be used for concrete design. The program also supports the Auto Generation of the load combinations as per EN 1990:2002. The limitations mentioned in the Section 1.3.6 are applied to the auto generation of the load combinations.

❖ *Results>Load Combinations*



[Figure 2.9] Load Combinations dialog box

2.2 Design for flexure with Axial Force

2.2.1 Requirements

For limiting the compressive strain in concrete, the following conditions need to be checked:

Check for Axial Force $\frac{N_{Ed}}{N_{Rd}} \leq 1$

Check for Biaxial Moment $\frac{M_{Ed}}{M_{Rd}} \leq 1$

Check for Moment about major axis $\frac{M_{Edy}}{M_{Rdy}} \leq 1$

Check for Moment about minor axis $\frac{M_{Edz}}{M_{Rdz}} \leq 1$

If any of the above ratios is not satisfied then the section is reported to be Not Good.

2.2.2 Magnification of Design Moments

When an element is subjected to an axial load combined with a moment, it will deflect. This deflection will increase the moment at any section in the element by an amount equal to the axial force multiplied by the deflection at that point. This extra moment will cause the resistance of the element to be reduced below that calculated ignoring the deflections. In many practical situations, the effect of deflections is so small that it can be ignored. So, the program compares the slenderness ratio of the member with the allowable slenderness limit in order to determine whether the magnification of moment is required or not.

2.2.2.1 Slenderness ratio

The actual slenderness ratio of a member is calculated using:

EN1992-1-1:2004
5.8.3.2(1)

$\lambda = l_0 / i$ (2.7)

where,

l_0 is the effective length of the member.

i is the radius of gyration.

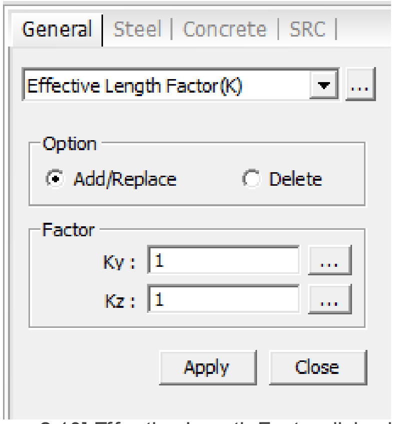
Effective Length will be calculated as:

$l_{o,y} = K_y \times L$ (2.8)

where,

L is the unbraced length as specified in Section 1.3.2.
K_y is the effective length factor. The effective length factor can be specified as shown below.

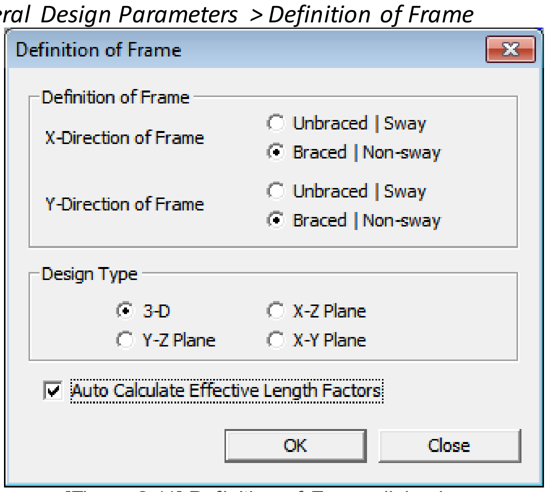
❖ *Design > General Design Parameter > Effective Length Factor (K)*



[Figure 2.10] Effective Length Factor dialog box

Effective Length factor can also be calculated by the program automatically depending on the information provided in **Definition of Frame** dialog box as shown below:
Refer to online help for the explanation of auto calculation.

❖ *Design > General Design Parameters > Definition of Frame*



[Figure 2.11] Definition of Frame dialog box

2.2.2.2 Limiting value of slenderness ratio

EN1992-1-1:2004 5.8.3.1(1)

$$\lambda_{min} = \frac{A.B.C}{\sqrt{n}} \tag{2.7}$$

where,

$A = 1/(1+0.2\phi_{ef})$. It can be specified by user. Default value is 0.7 (code recommendation)

$B = \sqrt{1+2\omega}$. It can be specified by user. Default value is 1.1 (code recommendation)

$C = 1.7 - r_m$.

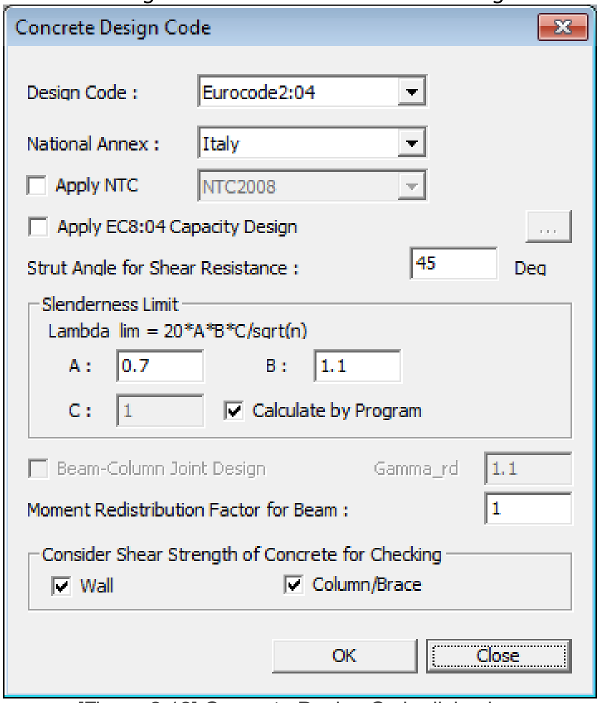
$r_m = M_{01}/M_{02}$

M_{01} and M_{02} are end moments of column. M_{02} is numerically greater of both. $M_{01}/M_{02} > 0$ for single curvature bending and less than 0 for double curvature bending.

Code recommends that If r_m is not known, C=0.7 may be used. Constant value of C can be specified. Also, the program can calculate the factor C and r_m based on M_{01} and M_{02}.

$n = N_{Ed}/A_c f_{cd}$. this is the normalized normal force.

❖ *Design > Concrete Design Parameter > Concrete Design Code*



[Figure 2.12] Concrete Design Code dialog box

2.2.2.3 Magnification of Moments

The slenderness ratio, Λ (as obtained in 2.2.2.1) is compared to limiting slenderness ratio, Λ_{min}. If P-Δ Analysis has not been performed and $\Lambda > \Lambda_{min}$, then the moments are magnified as per the specifications of the code in order to account for the second order moments. If $\Lambda < \Lambda_{min}$ or P-Δ Analysis has been performed, then the specifications of the code are not used to magnify the design moments.

EN 1992-1-1:2004 specifies the following two methods of moment magnification.

i. Based on Nominal Stiffness
ii. Based on Nominal Curvature

midas Gen uses Nominal Curvature Method.

EN1992-1-1:2004 5.8.8.2(1)

As per Nominal Curvature Method, the overall design moment, M_{Ed} is computed as:

$$M_{Ed} = M_{0Ed} + M_2 \qquad (2.8)$$

where,

$$M_{0Ed} = 0.6\ M_{02} + 0.4\ M_{01} \geq 0.4\ M_{02}$$

This is valid only if no transverse load exists between supports. In case the transverse load exists between the supports, $M_{0Ed} = M_{02}$. In that case, it is recommended to perform P- Δ Analysis.

$M_2 = N_{Ed}$ x e_2 *M_2 is the additional second order moment.*

where,

$e_2 = (1/r) l_0^2/c$ e_2 is the deflection.

l_0 is effective length as specified in Section 2.2.2.1.
*c depends on curvature distribution, program uses c = 10 as recommended by code. The value of **c** cannot be changed by user.*

$1/r = K_r K_\phi\ 1/r_0$ *Curvature*

$K_r = (n_u - n)/(n_u - n_{bal})$ *Correction factor for axial load*

$n = N_{ed}/A_c f_{cd}$ *Relative axial force.*

$n_u = 1 + \omega$

$\omega = 0.105.$ *(Recommended) Different value cannot be specified.*

$n_{bal} = 0.4$ *(Recommended) Different value cannot be specified.*

$K_\phi = 1$ *(Factor for accounting creep)*

$1/r_0 = \varepsilon_{yd}/(0.45d)$

$\varepsilon_{yd} = f_{yd}/E_s$

The above calculations are performed for major and minor directions separately.

For the wall the magnification is performed for in-plane bending. If design is also performed for out-of-plane bending, then the above check will also be performed for out-of-plane bending. The choice of design for out-of-plane bending can be specified in **Input Additional Wall Data** dialog box.

2.2.3 Determination of the Eccentric Axial Load Capacity

The following procedure is followed to determine the eccentric load capacity of the column:

1. Calculate the eccentricities of bi-axially loaded column:

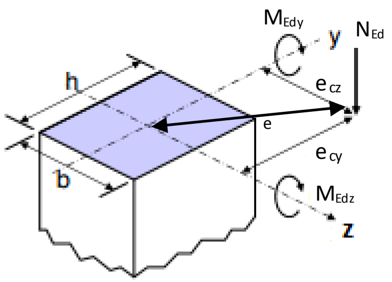
$$e_{cy} = |M_{Edz}/N_{Ed}|$$

$$e_{cz} = |M_{Edy}/N_{Ed}|$$

$$e = |M_{Ed}/N_{Ed}|$$

$$\text{Angle of axis of bending} = \tan^{-1}|E_{cy}/E_{cz}|$$

Angle of rotation of neutral axis at the ultimate limit state is determined by the program.



[Figure 2.13] Forces and Moments on a member with eccentric axial load

where,

$M_{Ed} = \sqrt{M_{Edy}^2 + M_{Edz}^2}$

2. Calculate the axial load capacity for concentric loading

Maximum Axial Compression

$N_{Rd} = (\eta.f_{cd}).(A_g\text{-}A_{st}) + f_{yd}.A_{st}$ (2.9)

where,

N_{Rd} is Axial load (compression) capacity for concentric loading
η is the factor for effective strength of concrete
f_{cd} is design strength of concrete as mentioned in Section 2.1.3
A_g is the gross area of column $A_g = b \cdot h$
A_{st} is the total area of steel in column.
f_{yd} is design yield strength of steel as mentioned in Section 2.1.3

Maximum Axial Tension

$N_{Rdt} = -f_{yd} \cdot A_{st}$ (2.10)

where,

N_{Rdt} is Axial Load (Tension) Capacity for concentric loading
f_{yd} design yield strength of steel
A_{st} is the area of steel

3. Compute capacity of concrete stress block.

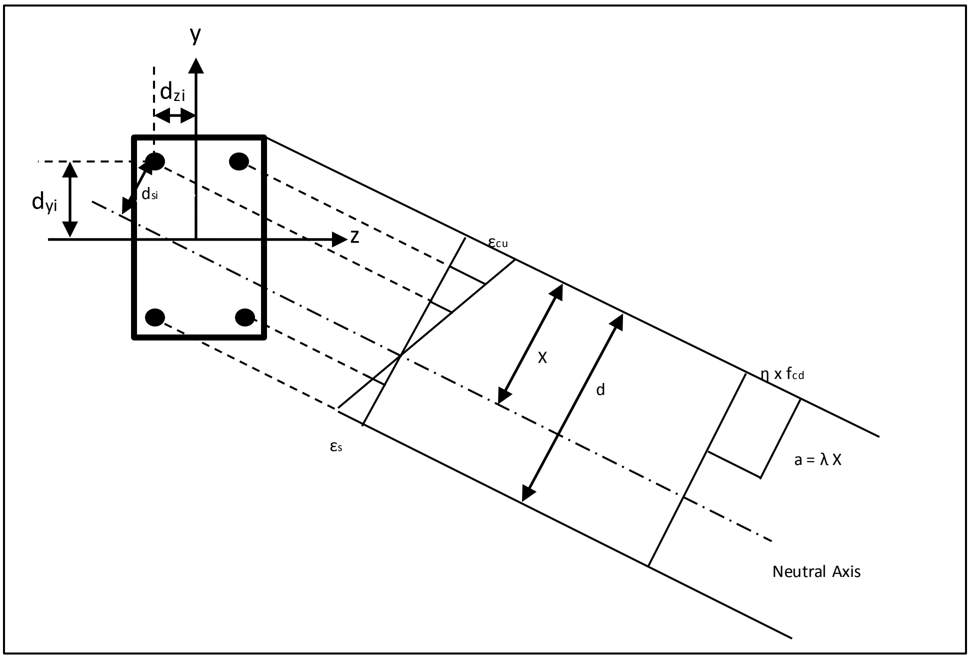
Height of compression zone

X is the height of the compression zone. For the first trial, the balanced failure is assumed hence $X=c_b$.

$c_b = \frac{\varepsilon_{cu}}{\varepsilon_{cu}+\varepsilon_s} d\ A_{st}$ (2.11)

where,

c_b is the depth of neutral axis for section failing in balanced condition
d is the distance of extreme compression fiber from farthest reinforcement



[Figure 2.14] Stress strain distribution in concrete column with eccentric axial load

Effective height of compression zone

$a = \lambda \,.\, X$ A_{st} (2.12)

where,

λ is the factor for effective height of compression zone.

A_{com} is the effective area of concrete in compression. It is calculated based on a.

Compression Force in Concrete

$C_c = \eta \times f_{cd} \times A_{com}$ A_{st} (2.13)

Moment due to compression force

$M_{RdCy} = C_c \,.\, D_{Ccz}$ (2.14)

$M_{RdCz} = C_c \,.\, D_{Ccy}$ (2.15)

where,

D_{Ccy} is distance of centroid of compression zone from geometric center of section along y-axis

D_{Ccz} is distance of centroid of compression zone from geometric center of section along z-axis

4. Compute capacity of reinforcement

F_{si} is force of the i^{th} reinforcement

$F_{si} = A_{si} \,.\, f_{si}$ (2.16)

where,

f_{si} is stress in the i^{th} reinforcement

$$f_s = \begin{cases} \varepsilon_s E_s & (\varepsilon_s \le \varepsilon_{yd}) \\ f_{yd} & (\varepsilon_s > \varepsilon_{yd}) \end{cases}$$

where,

ε_{si} is strain in the i^{th} reinforcement

At the extreme compression fiber of concrete, strain equal to ε_{cu} is assumed. Then the strain is calculated at the center of reinforcement assuming a linear stress strain distribution as shown in Figure 2.14.

A_{si} is the area of the i^{th} rebar

Moment due to force in rebar

i. About the element local y-axes

$M_{RdNyi} = F_{si} \times d_{zi}$ (2.17)

ii. About the element local z-axes

$M_{RdNzi} = F_{si} \times d_{yi}$ (2.18)

where,

d_{zi} is distance of i^{th} reinforcement from the geometric center of the section in the element local z-axis (as shown in Figure 2.14)
d_{yi} is distance of i^{th} reinforcement from the geometric center of the section in the element local y-axis (as shown in Figure 2.14)

Cumulative axial force and moment resistance

Axial force and the moment due to all the rebars are calculated as follows:

$$N_s = \Sigma\,(F_{si})$$
$$M_{RdNy} = \Sigma\,(M_{RdNyi})$$
$$M_{RdNz} = \Sigma\,(M_{RdNzi})$$

5. Compute capacity (N_{Rd},M_{Rd}) of the section

$N_{Rd} = C_c + N_s \quad d_{yi}$ (2.19)
$M_{Rdy} = M_{RdCy} + M_{RdNy}$
$M_{Rdz} = M_{RdCz} + M_{RdNz}$
$M_{Rd} = \sqrt{M_{Rdy}^2 + M_{Rdz}^2}$

6. Compare the eccentricity with the actual eccentricity

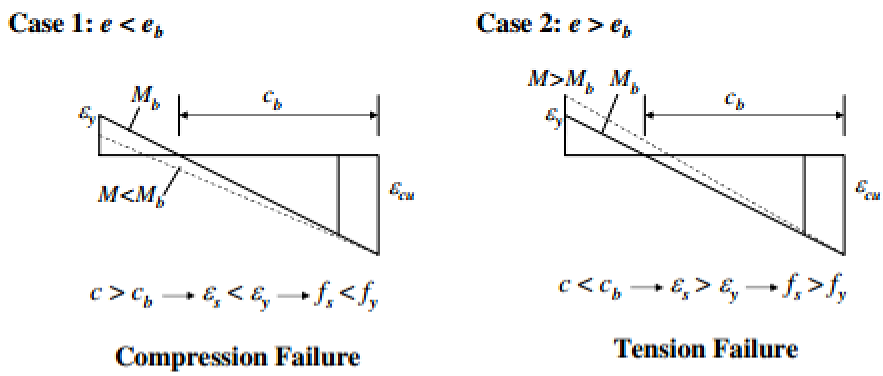
Eccentricity

$$e_c = M_{Rd}/N_{Rd}$$

Actual eccentricity

$$e = M_{Ed}/N_{Ed}$$

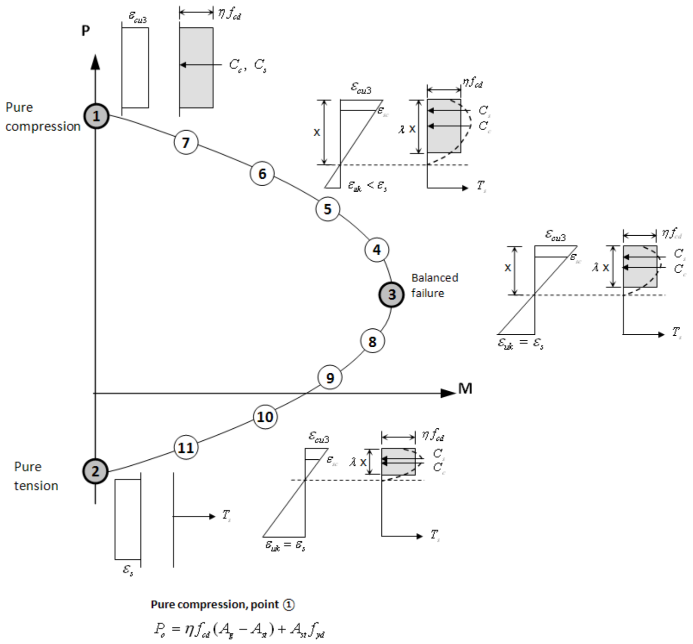
If $e_c = e$, then X is the height of the compression zone. For the first trial $e_c = e_b$ (balanced eccentricity).
Otherwise new depth is assumed.
Then new value of X is assumed as follow:
$e < e_b$, then section is compression controlled and larger value of x is assumed.
$e > e_b$, then section is tension controlled and smaller value of x is assumed.



[Figure 2.15] Comparison of Tension Controlled and Compression Controlled Column

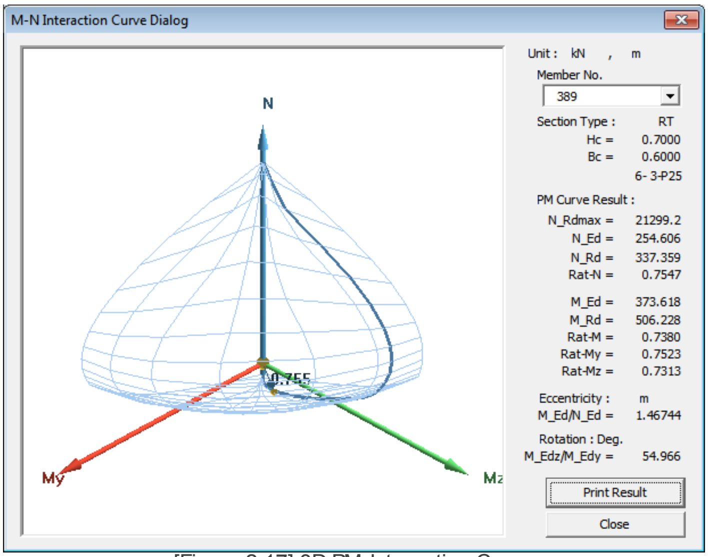
7. Check P-M Curve

The P-M curve is generated for a fixed angle of rotation of neutral axis.



[Figure 2.16] 2D PM Interaction Curve

3D PM Curve is generated by changing the angle of rotation of neutral axis as follows:



[Figure 2.17] 3D PM Interaction Curve

The output is given in the form of 2-D P-M Interaction Curve as well as 3-D P-M-M Interaction Curve.

Check the ratio

The following ratios are checked to verify the capacity of the axially loaded member (wall/column):

$$\frac{N_{Ed}}{N_{Rd}} \leq 1$$

$$\frac{M_{Ed}}{M_{Rd}} \leq 1$$

$$\frac{M_{Edy}}{M_{Rdy}} \leq 1$$

$$\frac{M_{Edz}}{M_{Rdz}} \leq 1$$

where,

M_{Ed} : Design bending moment is chosen for the load combinations which are available as per 2.1.5.

M_{Rd} : Moment Capacity of the section.

Depending on the ratio, the results are displayed in various formats box as mentioned in Section 2.4.

2.2.4 Design Criteria for Rebars

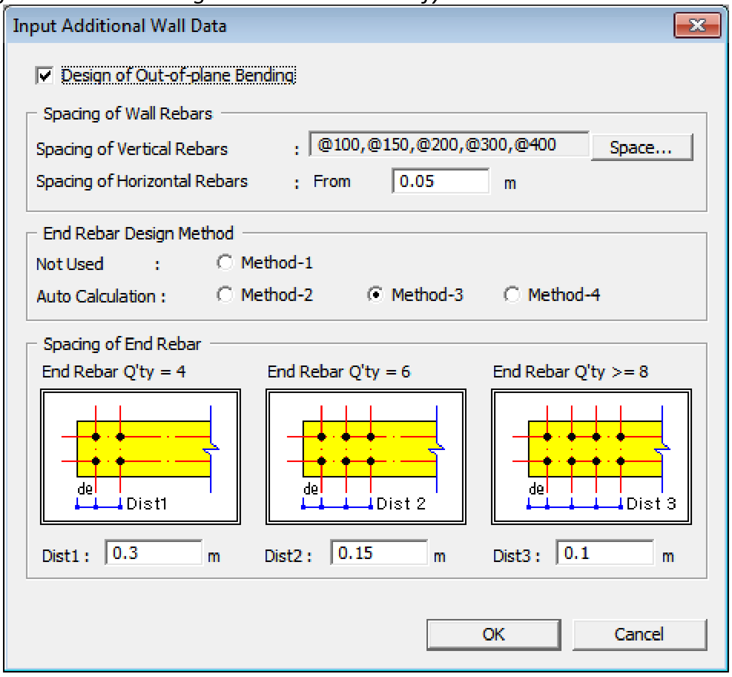
To choose the size of the rebars that should be used for providing the reinforcement, the specifications can be provided in **Design criteria for rebars** dialog box as shown in Section 2.1.3.

The stirrup data can also be specified in this dialog box.

Data can be specified for both wall and column design.

For wall design the End rebar design method and the spacing of the end rebar can be specified in **Input Additional Wall Data** dialog box as shown below:

- *Design > Concrete Design Parameter > Modify Column Rebar Data*



[Figure 2.18] Input Additional Wall Data dialog box

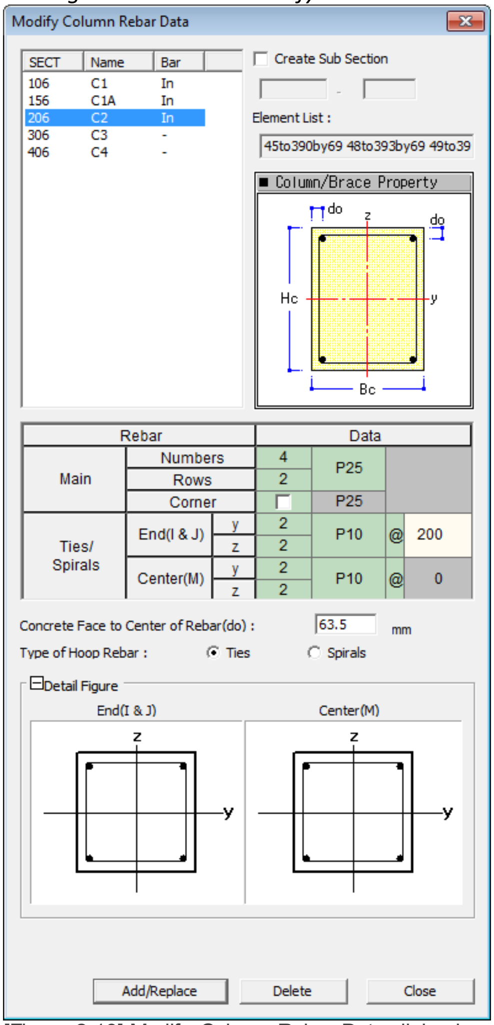
2.2.5 Concrete checking for columns & walls

Concrete Code Checking can be performed for column members & wall members as well. The rebar data can be specified for axially loaded members and Ultimate Limit State and Serviceability Limit State can be verified based on that rebar data.

2.2.5.1 Rebar Input for Column Checking

The rebar data for the column can be specified in **Modify Column Rebar Data** dialog box as shown below.

❖ *Design > Concrete Design Parameter > Modify Column Rebar Data*

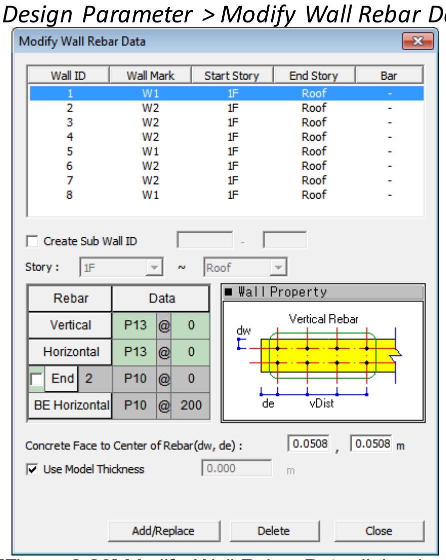


[Figure 2.19] Modify Column Rebar Data dialog box

2.2.5.2 Rebar Input for Wall Checking

The rebar data for the wall can be specified in **Modify Wall Rebar Data** dialog box as shown below.

❖ *Design > Concrete Design Parameter > Modify Wall Rebar Data*



[Figure 2.20] Modify Wall Rebar Data dialog box

2.2.6 Design load combinations

The specifications in Section 2.1.5 are applied.

2.3 Design for Shear

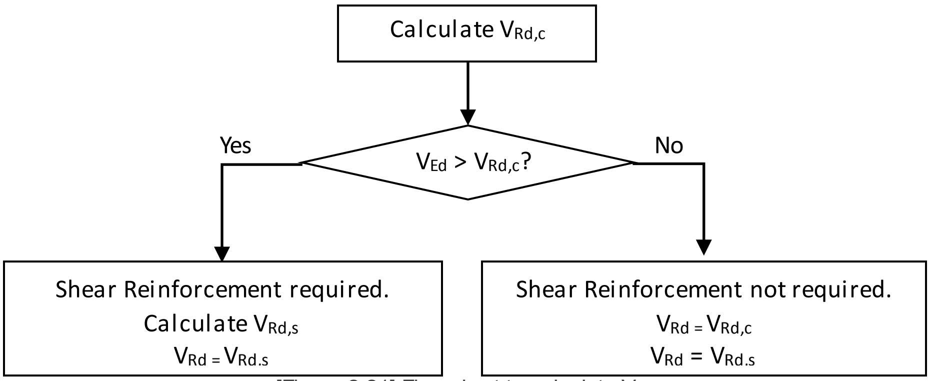
2.3.1 Requirements

Shear resistance of the section (V_{Rd}) should be greater than the design shear force for the section (V_{Ed}).
To satisfy Limit state of Shear Resistance the following condition should be met:

$$V_{Ed} \leq V_{Rd}$$

2.3.2 Calculation of Shear Resistance (V_{Rd})

If V_{Ed} is smaller than the shear resistance of concrete, then shear reinforcement is not required and shear resistance is calculated by concrete only. If design shear force exceeds shear resistance calculated from concrete then the shear resistance is calculated by shear reinforcement only.



[Figure 2.21] Flow chart to calculate V_{Rd}

2.3.2.1 Members not requiring design shear reinforcement

In member for which $V_{Ed} \leq V_{Rd,c}$, no shear reinforcement is required. In those members the program provides the minimum specified shear reinforcement as per Section 4.1.2 and 4.2.2.

For such sections, the shear resistance

$V_{Rd} = V_{Rd,c}$ d_{yi} (2.20)

For calculating the design shear resistance of concrete, larger of the following two values is adopted:

EN1992-1-1:2004
6.2.2(1)

$$V_{Rd,c} = \left[C_{Rd,c} k \,(100 \rho_l f_{ck})^{1/3} + k_1 \sigma_{cp}\right] b_w d \qquad (2.21)$$

$$V_{Rd,c} = \left[0.035\, k^{3/2} f_{ck}^{1/2} + k_1 \sigma_{cp}\right] b_w d \qquad (2.22)$$

where,

$C_{Rd,c} = 0.18/\gamma_c$

$k = 1 + \sqrt{200/d} \leq 2.0$

$\rho_l = A_{sl}/(b_w d) \leq 0.02$

$\sigma_{cp} = N_{Ed}/A_c$, *In beam design, σ_{cp} is applied as zero since axial force is not considered.*

$k_1 = 0.15$

A_{sl} is the area of the tensile reinforcement, which extends $\geq$ (l_{bd} + d) beyond the section considered. For beam section, program considers A_{sl} as the area of the tensile reinforcement provided. For column sections, the A_{sl} is used as the $A_{st}/2$ i.e half of the area of the longitudinal reinforcement.

2.3.2.2 Members requiring design shear reinforcement

For the members for which the design shear force exceeds the shear resistance provided by concrete, the shear resistance is calculated as the resistance provided by shear reinforcement.

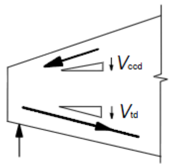
$V_{Rd} = V_{Rd,s} + V_{ccd} + V_{td}$ d (2.23)

where,

EN1992-1-1:2004
6.2.1(2)

V_{ccd} *: shear component of the force in the compression area, in the case of inclined compression chord.*

V_{td} *: shear component of the force in the tensile reinforcement, in the case of inclined tensile chord.*

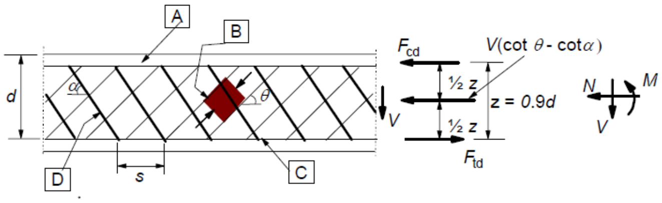


[Figure 2.22] Shear component for members with inclined chords

Since, inclined chord is not considered therefore the shear resistance is calculated using shear reinforcement only.

$$V_{Rd} = V_{Rd,s} \tag{2.24}$$

Design of shear reinforcement is based on truss model as specified in Section 6.2.3 of EN 1992-1-1:2004



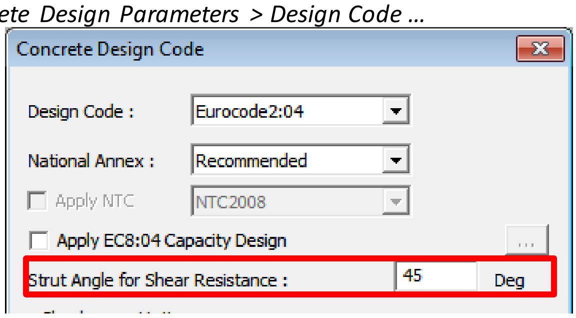
A - compression chord, B - struts, C - tensile chord, D - shear reinforcement

[Figure 2.23] Truss model and notation for shear reinforced members

θ is the angle between the concrete compression strut and the beam axis perpendicular to the shear force. α is the angle between shear reinforcement and the beam axis perpendicular to the shear force. The program provides the shear reinforcement perpendicular to the beam axis. So, α = 90°. Any other value of α cannot be specified by the user.

θ can be specified by user in **Concrete Design Code** dialog box as explained below:

❖ *Design > Concrete Design Parameters > Design Code ...*



[Figure 2.24] Concrete Code Design dialog box

Shear resistance of members with shear reinforcement can be calculated depending on the type of shear reinforcement as specified in the table below.

[Table 2.3] $V_{Rd,s}$ and $V_{Rd,max}$, $A_{sw,max}$

Parameter	Formula	Remarks
$V_{Rd,s}$	$\frac{A_{sw}\ (0.9\ d)\ f_{ywd}}{s} \cot\theta$	A_{sw} is cross-sectional area of the shear reinforcement. s is the spacing of stirrups. f_{ywd} is design yield strength of the shear reinforcement. v_1 is Strength reduction factor for concrete cracked in shear. α_{cw} is Coefficient taking account of the state of the stress in the compression chord. α_{cw} is always applied as 1.0 in beam design.
$V_{Rd,max}$	$\frac{f_{cd}\ (0.9\ d\ b\ )}{\cot\theta + \tan\theta}\ \alpha_{cw}\ v_1$	
$A_{sw,max}$	$\frac{0.5\ \alpha_{cw} v_1 f_{cd}\ b\ \ \ s}{f_{ywd}}$	

EN1992-1-1:2004 6.2.3(4)

EN1992-1-1:2004 6.2.3(3)

Using, $V_{Rd,s} = V_{Ed}$, spacing s of the shear reinforcement is calculated.

$V_{Rd,max}$ is the design value of the maximum shear force which can be sustained by the member, limited by crushing of the compression struts.
A_{sw}/s is calculated and compared with $A_{sw,max}/s$.

[Table 2.4(a)] Strength reduction factor for concrete cracked in shear, v_1

National Annex	$f_{ywd} \geq 0.8f_{ywk}$	$f_{ywd} < 0.8f_{ywk}$	
		$f_{ck} < 60MPa$	$f_{ck} \geq 60MPa$
Recommended	$0.6\left(1-\frac{f_{ck}}{250}\right)$	0.6	$0.9-\frac{f_{ck}}{200} > 0.5$
Singapore	$0.6\left(1-\frac{f_{ck}}{250}\right)$	0.54(1-0.5 cosα) = 0.54	$(0.84-f_{ck}/200)(1-0.5\cos\alpha) \geq 0.5$ $= (0.84-f_{ck}/200) \geq 0.5$

[Table 2.4(b)] Strength reduction factor for concrete cracked in shear, v_1

National Annex	$f_{ywd} \geq 0.8f_{ywk}$		$f_{ywd} < 0.8f_{ywk}$	
	$f_{ck} \leq 70MPa$	$f_{ck} > 70MPa$	$f_{ck} < 60MPa$	$f_{ck} \geq 60MPa$
Italy	0.5	$0.7\left(1-\frac{f_{ck}}{250}\right)$	0.7	$\frac{0.9-\frac{f_{ck}}{200}}{0.85} > 0.5$

[Table 2.5] Recommended values of Coefficient α_{cw}

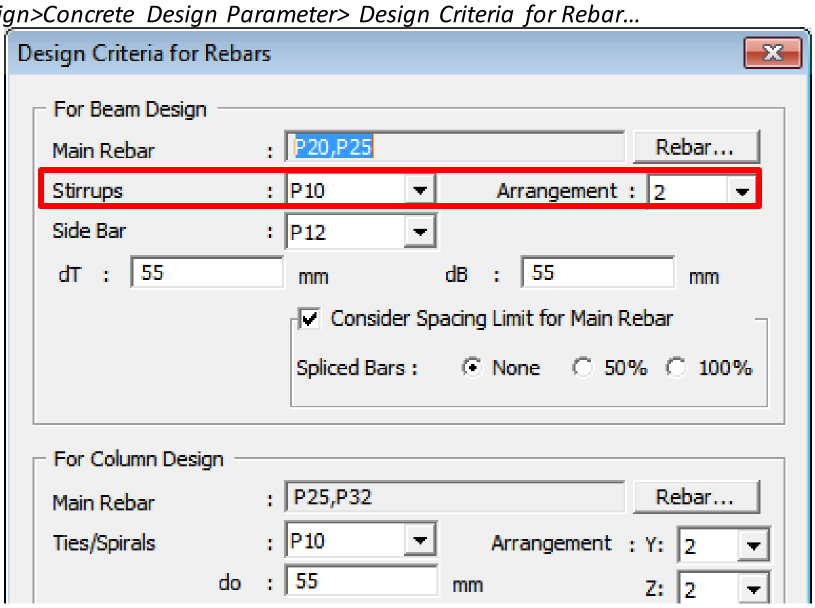
Condition	α_{cw}
$0<\sigma_{cp} \leq 0.25f_{cd}$	$1+\sigma_{cp}/f_{cd}$
$0.25 f_{cd} <\sigma_{cp} \leq 0.5f_{cd}$	1.25
$0.5 f_{cd} <\sigma_{cp} \leq 1.0f_{cd}$	$2.5(1-\sigma_{cp}/f_{cd})$

σ_{cp} : The mean compressive stress, measured positive, in the concrete due to the design axial force. In beam design, σ_{cp} is applied as zero since axial force is not considered.

2.3.3 Design Criteria for Rebars

Size of the rebar to be used for providing the shear reinforcement can be specified in **Design Criteria for Rebars** dialog box. The number of legs to be used for shear reinforcement can also be specified.

❖ *Design>Concrete Design Parameter> Design Criteria for Rebar...*



[Figure 2.25] Design Criteria for Rebars dialog box

2.3.4 Shear in Concrete Code Checking

When Beam Checking or Column checking is performed, then checks for shear are also applied. The data for the transverse reinforcement can be specified in the program. The data can be specified in **Modify Beam Rebar Data**, **Modify Column Rebar Data** and **Modify Wall Rebar Data** dialog box. Refer to section 2.1.4.1, 2.2.5.1 and 2.2.5.2 for the usage of these dialog boxes. The program allows the user to specify rebar size, rebar spacing and the number of legs for stirrup.

For beams the data can be specified for i-end, j-end and the middle section.

For columns the same data can be specified for the two ends of the member and different data can be specified for center of the column.

2.3.5 Design Load Combinations

The specifications of section 2.1.5 are applied.

In case the shear reinforcement is required, the governing Load combination for shear design is not decided on the basis of the magnitude of the shear force. The governing load combination is decided on the basis of the ratio of the shear force and shear capacity.

Now, if there are two shear forces V_{Ed1} and V_{Ed2} such that $V_{Ed1}>V_{Ed2}$. $V_{Rd,s}$ (Shear Strength provided by steel) and $V_{Rd,c}$ (Shear Strength provided by concrete) will be calculated. If $V_{Ed1}/V_{Rd,s}$ is less than the $V_{Ed2}/V_{Rd,c}$, then V_{Ed2} will be governing load combination for shear design, even if V_{Ed2} is smaller of the two shear forces.

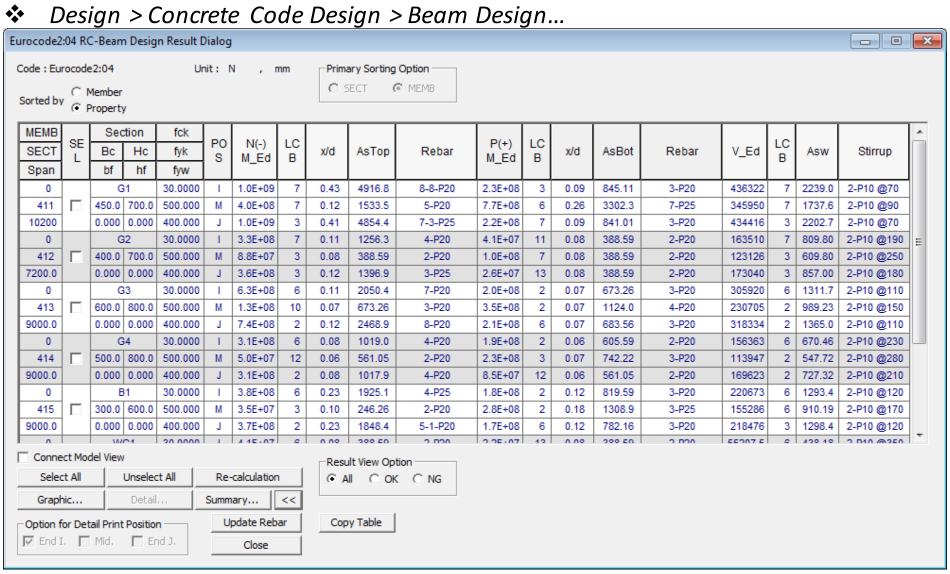
2.4 Verification of Design/Check Results

midas Gen provides the results of design/check in various formats. The following design outputs are available.

2.4.1 Design Result Dialog Box

The design results can be checked in **Beam Design Result Dialog/Column Design Result Dialog/ Wall Design Result Dialog** box as shown below.

❖ *Design > Concrete Code Design > Beam Design...*



MEMB / SECT / Span	SEL	Section Bc / bf	Section Hc / hf	fck / fyk / fyw	POS	N(-) M_Ed	LCB	x/d	AsTop	Rebar	P(+) M_Ed	LCB	x/d	AsBot	Rebar	V_Ed	LCB	Asw	Stirrup
0		G1		30.0000	I	1.0E+09	7	0.43	4916.8	8-8-P20	2.3E+08	3	0.09	845.11	3-P20	436322	7	2239.0	2-P10 @70
411	☐	450.0	700.0	500.000	M	4.0E+08	7	0.12	1533.5	5-P20	7.7E+08	6	0.26	3302.3	7-P25	345950	7	1737.6	2-P10 @90
10200		0.000	0.000	400.000	J	1.0E+09	3	0.41	4854.4	7-3-P25	2.2E+08	7	0.09	841.01	3-P20	434416	3	2202.7	2-P10 @70
0		G2		30.0000	I	3.3E+08	7	0.11	1256.3	4-P20	4.1E+07	11	0.08	388.59	2-P20	163510	7	809.80	2-P10 @190
412	☐	400.0	700.0	500.000	M	8.8E+07	3	0.08	388.59	2-P20	1.0E+08	7	0.08	388.59	2-P20	123126	3	609.80	2-P10 @250
7200.0		0.000	0.000	400.000	J	3.6E+08	3	0.12	1396.9	3-P25	2.6E+07	13	0.08	388.59	2-P20	173040	3	857.00	2-P10 @180
0		G3		30.0000	I	6.3E+08	6	0.11	2050.4	7-P20	2.0E+08	2	0.07	673.26	3-P20	305920	6	1311.7	2-P10 @110
413	☐	600.0	800.0	500.000	M	1.3E+08	10	0.07	673.26	3-P20	3.5E+08	2	0.07	1124.0	4-P20	230705	2	989.23	2-P10 @150
9000.0		0.000	0.000	400.000	J	7.4E+08	2	0.12	2468.9	8-P20	2.1E+08	6	0.07	683.56	3-P20	318334	2	1365.0	2-P10 @110
0		G4		30.0000	I	3.1E+08	6	0.08	1019.0	4-P20	1.9E+08	2	0.06	605.59	2-P20	156363	6	670.46	2-P10 @230
414	☐	500.0	800.0	500.000	M	5.0E+07	12	0.06	561.05	2-P20	2.3E+08	3	0.07	742.22	3-P20	113947	2	547.72	2-P10 @280
9000.0		0.000	0.000	400.000	J	3.1E+08	2	0.08	1017.9	4-P20	8.5E+07	12	0.06	561.05	2-P20	169623	2	727.32	2-P10 @210
0		B1		30.0000	I	3.8E+08	6	0.23	1925.1	4-P25	1.8E+08	2	0.12	819.59	3-P20	220673	6	1293.4	2-P10 @120
415	☐	300.0	600.0	500.000	M	3.5E+07	3	0.10	246.26	2-P20	2.8E+08	2	0.18	1308.9	3-P25	155286	6	910.19	2-P10 @170
9000.0		0.000	0.000	400.000	J	3.7E+08	2	0.23	1848.4	5-1-P20	1.7E+08	6	0.12	782.16	3-P20	218476	3	1298.4	2-P10 @120

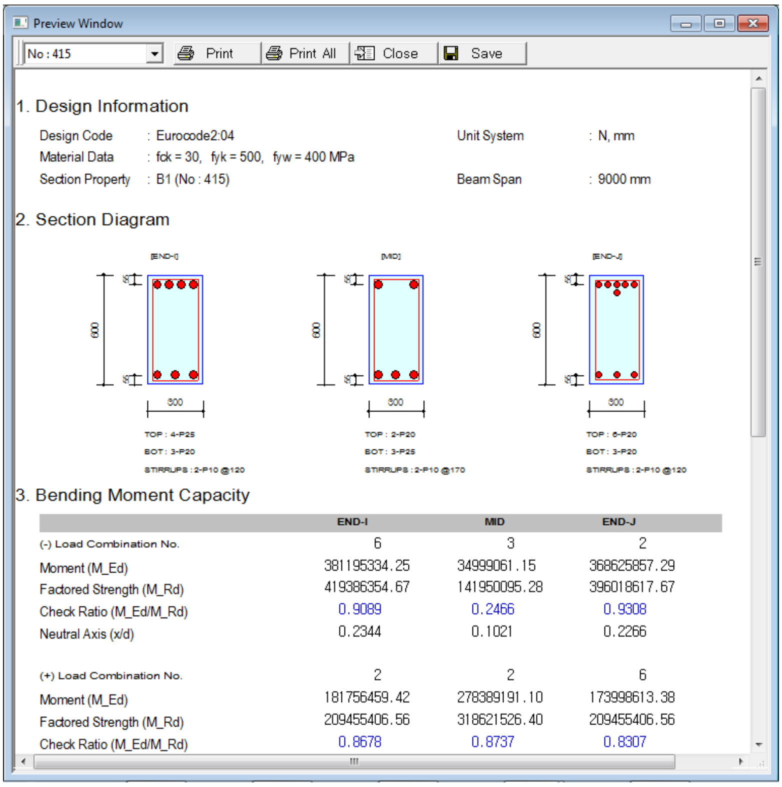
[Figure 2.26] Beam Design Result dialog box

Similarly, the design results can be checked for column and walls. The dialog box for design results of column members can be accessed from **Design > Concrete Code Design > Column Design.** The dialog box for design results of wall can be accessed from **Design > Concrete Code Design > Wall Design.**

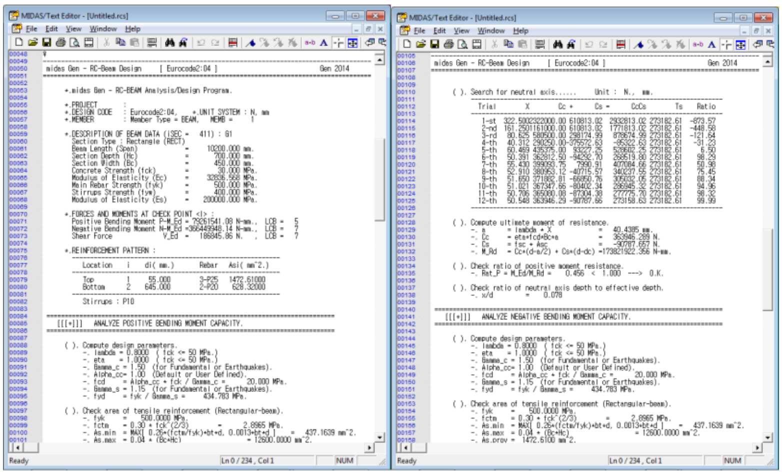
2.4.2 Design/Check Reports

The program provides the results in the following kind of report formats:

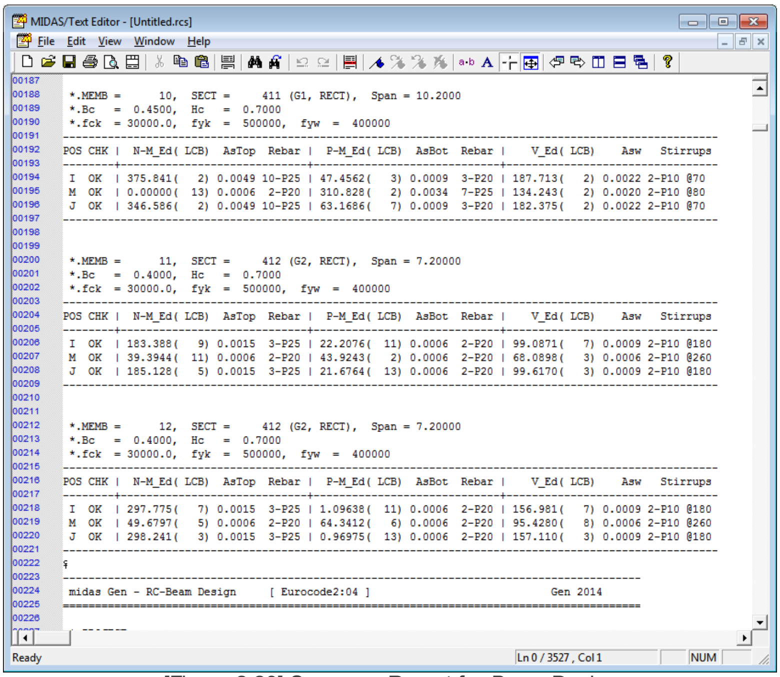
i. Graphic Report
ii. Detail Report
iii. Summary Report



[Figure 2.27] Graphic Report for Beam Design



[Figure 2.28] Detailed Report for Beam Design



```
 *.MEMB =      10,  SECT =     411 (G1, RECT),  Span = 10.2000
 *.Bc   =  0.4500,  Hc    =  0.7000
 *.fck  = 30000.0,  fyk   =  500000,  fyw  =  400000
--------------------------------------------------------------------------------------------
POS CHK |  N-M_Ed( LCB)  AsTop  Rebar |  P-M_Ed( LCB)  AsBot  Rebar |   V_Ed( LCB)    Asw   Stirrups
--------+-----------------------------+-----------------------------+-----------------------
 I  OK  | 375.841(   2) 0.0049 10-P25 | 47.4562(   3) 0.0009  3-P20 | 187.713(   2) 0.0022 2-P10 @70
 M  OK  | 0.00000(  13) 0.0006  2-P20 | 310.828(   2) 0.0034  7-P25 | 134.243(   2) 0.0020 2-P10 @80
 J  OK  | 346.586(   2) 0.0049 10-P25 | 63.1686(   7) 0.0009  3-P20 | 182.375(   2) 0.0022 2-P10 @70
--------------------------------------------------------------------------------------------


 *.MEMB =      11,  SECT =     412 (G2, RECT),  Span = 7.20000
 *.Bc   =  0.4000,  Hc    =  0.7000
 *.fck  = 30000.0,  fyk   =  500000,  fyw  =  400000
--------------------------------------------------------------------------------------------
POS CHK |  N-M_Ed( LCB)  AsTop  Rebar |  P-M_Ed( LCB)  AsBot  Rebar |   V_Ed( LCB)    Asw   Stirrups
--------+-----------------------------+-----------------------------+-----------------------
 I  OK  | 183.388(   9) 0.0015  3-P25 | 22.2076(  11) 0.0006  2-P20 | 99.0871(   7) 0.0009 2-P10 @180
 M  OK  | 39.3944(  11) 0.0006  2-P20 | 43.9243(   2) 0.0006  2-P20 | 68.0898(   3) 0.0006 2-P10 @260
 J  OK  | 185.128(   5) 0.0015  3-P25 | 21.6764(  13) 0.0006  2-P20 | 99.6170(   3) 0.0009 2-P10 @180
--------------------------------------------------------------------------------------------


 *.MEMB =      12,  SECT =     412 (G2, RECT),  Span = 7.20000
 *.Bc   =  0.4000,  Hc    =  0.7000
 *.fck  = 30000.0,  fyk   =  500000,  fyw  =  400000
--------------------------------------------------------------------------------------------
POS CHK |  N-M_Ed( LCB)  AsTop  Rebar |  P-M_Ed( LCB)  AsBot  Rebar |   V_Ed( LCB)    Asw   Stirrups
--------+-----------------------------+-----------------------------+-----------------------
 I  OK  | 297.775(   7) 0.0015  3-P25 | 1.09638(  11) 0.0006  2-P20 | 156.981(   7) 0.0009 2-P10 @180
 M  OK  | 49.6797(   5) 0.0006  2-P20 | 64.3412(   6) 0.0006  2-P20 | 95.4280(   8) 0.0006 2-P10 @260
 J  OK  | 298.241(   3) 0.0015  3-P25 | 0.96975(  13) 0.0006  2-P20 | 157.110(   3) 0.0009 2-P10 @180
--------------------------------------------------------------------------------------------

--------------------------------------------------------------------------------------
 midas Gen - RC-Beam Design     [ Eurocode2:04 ]                          Gen 2014
======================================================================================
```

[Figure 2.29] Summary Report for Beam Design

Serviceability Limit State

The serviceability limit state is verified only when we perform Concrete Code Check. It is not verified when Concrete Code Design is performed.

3.1 Serviceability Type Load Combination

The load combinations specified as **Serviceability** in the **Concrete Design** Tab of **Load Combinations** dialog box will be used for serviceability limit state check. The program supports the auto generation of the load combinations as per EN 1990:2002.

3.1.1 Definition of Short Term and Long Term Load

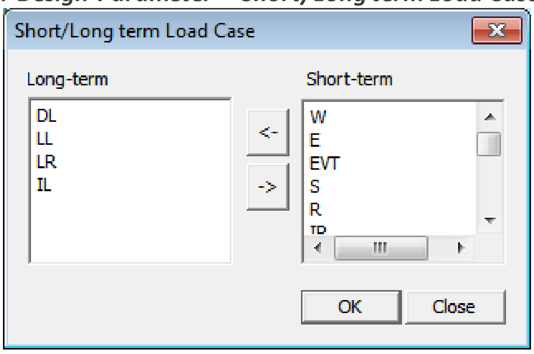
For the purpose of crack control, the **Load Cases** need to be specified as either short term load or long term load.

Depending on the type of the load case, the program classifies the load cases automatically. Information regarding the classification of load cases can be viewed/modified in **Short/Long term Load Case** dialog box as shown below.

[Table 3.1] Classification of load based on duration

Type of load	Description
Long term	If the load case is any of the following types, it is classified as long term: D: Dead Load L: Live Load. LR: Roof Live Load. IL: Live Load Impact
Short term	If the type of load case is other than specified above, then it will be classified as short term load case

❖ ***Design> General Design Parameter > Short/Long term Load Case***



[Figure 3.1] Short/Long term Load Case dialog box

If a load combination consists of any of the short term load case then the load combination will be classified as short term type. Otherwise it will be classified as long term type.

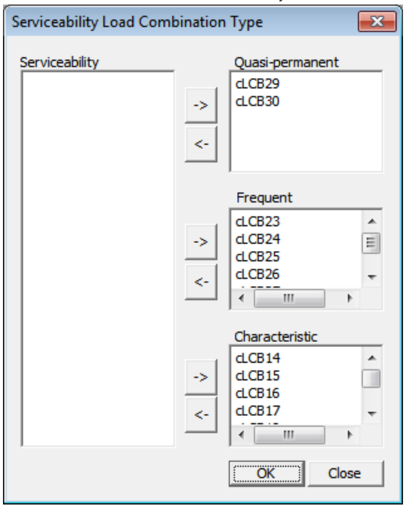
3.1.2 Classification of Serviceability type Load Combinations

EN 1990:2002 classifies the serviceability type load combinations in following three types:

i. Quasi-Permanent
ii. Frequent
iii. Characteristic

The load combinations that are auto generated are automatically classified in the above types. The information regarding the classification of the load combinations can be viewed/modified in **Serviceability Load Combination Type** dialog box as shown below.

❖ *Design> General Design Parameter > Serviceability Load Combination Type*

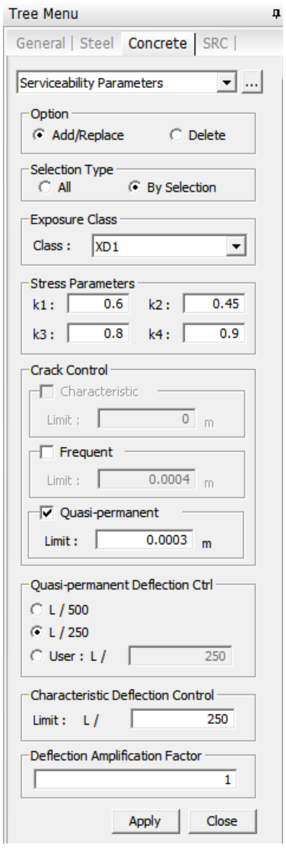


[Figure 3.2] Serviceability Load Combination Type dialog box

3.2 Serviceability Parameters

Various parameters should be specified for performing the serviceability limit state check. The default parameters are known to the program. Depending on the national annex selected in Concrete Design Code dialog box, the parameters are automatically updated. The parameters can be viewed/modified in the program.

❖ *Design> General Design Parameter > Serviceability Parameters*



[Figure 3.3] Serviceability Parameters dialog box

3.3 Stress Limitation

The compressive stress in concrete should be limited to avoid:

i. formation of micro-cracks which might reduce durability
ii. excessive creep

The program applies the stress checks for both situations. The first step in applying the stress check is to determine whether the section is cracked or uncracked for the applicable load cases. The section is uncracked if the following criteria is fulfilled:

$$\sigma_c \text{ (tension)} \le \sigma_{ca} \text{ (tension)}$$

where,

σ_c (tension) = $M_u Z_{bar} / I_{yy}$, stress in extreme tension fiber

M_u is the bending moment for a load combination.

Z_{bar} is the distance of Neutral Axis from extreme tension fiber.

I_{yy} is the moment of inertia.

I_{yy} and Z_{bar} are calculated assuming elastic behavior of concrete in an uncracked transformed section.

EN1992-1-1:2004 3.1.8(1)

σ_{ca} (tension) = max [f_{ctm} , $(1.6-h/1000)f_{ctm}$] (3.1)

[Table 3.2] Mean Value of Axial Tensile Strength, f_{ctm}

EN1992-1-1:2004 Table 3.1

Condition	f_{ctm}
≤ C50/60	$0.30f_{ck}^{2/3}$
> C50/60	$2.12 \ln(1+(f_{cm}/10))$

For column members σ_c (tension) is calculated considering the axial load and the biaxial bending:

Σ_c (tension) = $P_u/A_c + (M_{uy} Z_{bar})/I_{yy} + (M_{uz} Y_{bar}) / I_{zz}$ (3.2)

If σ_c (tension) ≥ σ_{ca} (tension), then the section is cracked. For cracked sections, the program updates the section properties for stress check.

3.3.1 Stress Verification to avoid micro cracking

EN1992-1-1:2004 7.2(2)

EN1992-1-1:2004 7.2(5)

EN 1992-1-1:2004 specifies "*Longitudinal cracks may occur if the stress level under the characteristic combination of loads exceeds a critical value. In the absence of other measures it may be appropriate to limit the compressive stress to a value $k_1 f_{ck}$ in areas exposed to environments of exposure classes XD, XF and XS*" and "*Unacceptable cracking or deformation may be assumed to be avoided if, under the characteristic combination of loads, the tensile stress in the reinforcement does not exceed $k_3 f_{yk}$*". Therefore, to fulfill these two specification, program applies the stress check for both reinforcement as well as concrete.

The stress verification is performed for characteristic type of serviceability load combinations. After determining that whether the section is cracked or not, the appropriate method is applied as explained below:

3.3.1.1 Un-cracked Sections

In order to satisfy the stress check for concrete, the following criteria should be met:

$$\sigma_c \text{ (Comp.)} \le \sigma_{ca} \text{ (Comp.)}$$

The stress is calculated at the extreme compression fiber of the section.

σ_c (Comp.) = $M_u*(H-Z_{bar})/I_{yy}$ (3.3)

where,

M_u is the bending moment for a load combination.

$(H-Z_{bar})$ is the distance of Neutral Axis from extreme compression fiber.

I_{yy} is the moment of inertia.

I_{yy} and Z_{bar} are calculated assuming elastic behavior of concrete in an uncracked transformed section.

For column members σ_c (Comp) is calculated considering the axial load and the biaxial bending:

σ_c (Comp.) = $P_u/A_c + M_{uy}$ (H-Z_{bar}) $/I_{yy} + M_{uz}$ (B-Y_{bar}) $/I_{zz}$ (3.4)

where,

H is the whole depth of cross-section along z-axis.

B is the whole width of cross-section along y-axis.

The limiting value of the stress in concrete is calculated as:

σ_{ca} (Comp.) = $k_1 f_{ck}$ (3.5)

k_1 can be specified in Serviceability Parameters. The following values are automatically adopted:

[Table 3.3] Coefficient k_1~ k_4

	k_1	k_2	k_3	k_4
Recommended	0.6	0.45	0.8	1.0
Italy	0.6	0.45	0.8	0.9
Singapore	0.6	0.45	0.8	1.0

The parameter k_4 is not used by the program.

In order to satisfy the stress check for reinforcement, the following criteria should be met:

$$\sigma_s \le \sigma_{sa}$$

Stress in reinforcement is calculated as below:

$\sigma_s = M_u*(d-z_{bar})*n/I_{yy}$ (3.6)

n is the Long term ratio of modulus of Elasticity.

The limiting value of the stress in the reinforcement is calculated as:

$\sigma_{sa} = k_3 f_{yk}$ (3.7)

k_3 can be specified in Serviceability Parameters as defined in Section 3.2.

For column members, the check is applied only for concrete. The stress in reinforcement is not checked.

3.3.1.2 Cracked Sections

The stresses are calculated for various load cases using the suitable modular ratio and then they are added to get the stresses due to the particular load combination.

The following components are used:

1. Dead Load Cases

   $\sigma_{c,D} = M_u\_D*z_{bar}/Iyy$

   $\sigma_{s,D} = M_u\_D *(d-z_{bar})*n/I_{cr}$ (Long term ratio is used)
2. Live Load Cases

   $\sigma_{c,L} = M_u\_L*z_{bar}/Iyy$

   $\sigma_{s,L} = M_u\_L *(d-z_{bar})*n/I_{cr}$ (Long term ratio is used)
3. Other Load Cases

   $\sigma_{c,E} = M_u\_E*z_{bar}/Iyy$

   $\sigma_{s,E} = M_u\_E *(d-z_{bar})*n/I_{cr}$ (Short term ratio is used)

where,

M_u_D is the bending moment for a load combination.

(Z_{bar}) is the distance of Neutral Axis from extreme compression fiber.

I_{cr} is the moment of inertia.

I_{cr} and Z_{bar} are calculated assuming elastic behavior of concrete in a cracked transformed section. The neutral axis is located by equating moment of areas. Then the I_{cr} is calculated about the neutral axis.

Then the stress in concrete are calculated as:

$$\sigma_C = \sigma_{C,D} + \sigma_{C,L} + \sigma_{C,E}$$

$$\sigma_S = \sigma_{S,D} + \sigma_{S,L} + \sigma_{S,E}$$

EN1992-1-1:2004
7.2(3)

For concrete, $\sigma_c \le k_1$ x f_{ck}

For steel, $\sigma_s \le k_3$ x f_{yk}

If a column members is cracked, then this procedure is not carried out for it.

3.3.2 Check for linear Creep

EN 1992-1-1:2004 specifies *"If the stress in the concrete under the quasi-permanent loads is less than $k_2 f_{ck}$, linear creep may be assumed. If the stress in concrete exceeds $k_2 f_{ck}$, non-linear creep should be considered."* After determining whether the section is cracked or not under quasi-permanent load combinations, the appropriate method is applied as explained below:

3.3.2.1 Uncracked Sections

Method specified in 3.3.1.1 is used to calculate the compressive stress and the allowable compressive stress.
Quasi-Permanent type of combinations are used.
The allowable stress is calculated as σ_{ca} (comp.) = k_2 x f_{ck}.
If σ_c (comp.) ≤ σ_{ca} (comp.) and σ_s (comp.) ≤ σ_{sa} (comp.) then linear creep may be assumed.

3.3.2.2 Cracked sections

Method specified in 3.3.1.1 is used to calculate the compressive stress and the allowable compressive stress.
Quasi-Permanent Type of combinations are used.
The allowable stress is calculated as σ_{ca} (comp.) = k_2 x f_{ck}.
If σ_c (comp.) ≤ σ_{ca} (comp.) and σ_s (comp.) ≤ σ_{sa} (comp.) then linear creep may be assumed.
If the column member are cracked, then this procedure is not carried out for them.

3.4 Crack width

EN1992-1-1:2004 7.3.4(1)

For beam sections, cracking shall be limited to satisfy the following condition.

Crack width, w_k ≤ Crack width limit, w_{max}

Crack width is only calculated if the stress in concrete at the extreme tension fiber exceeds the allowable tension stress.

3.4.1 Calculate crack widths

EN1992-1-1:2004 7.3.4(2)

The crack width is calculated using the following formula:

$$w_k = S_{r,max}(\varepsilon_{sm} - \varepsilon_{cm}) \tag{3.8}$$

1. ***Determine ε_{sm}-ε_{cm}***

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{\sigma_s - k_t \dfrac{f_{ct,eff}}{\rho_{p,eff}}\left(1 + \alpha_e \rho_{p,eff}\right)}{E_s} \geq 0.6 \frac{\sigma_s}{E_s} \tag{3.9}$$

where,

ε_{sm} *The mean strain in the reinforcement under the relevant combination of loads, including the effect of imposed deformations and taking into account the effects of tensile stiffening.*

ε_{cm} *The mean strain in the concrete between cracks.*

σ_s *The stress in the tension reinforcement.*

α_e E_s/E_{cm}.

k_t *A factor dependent on duration of the load.*

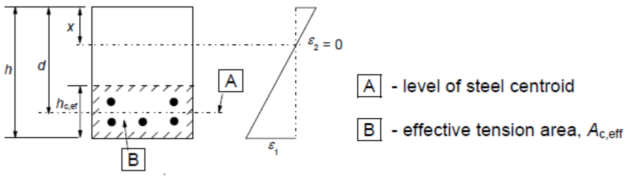
[Table 3.4] Factor k_t

Condition	k_t
Short term loading	0.6
Long term loading	0.4

$$\rho_{p,eff} = \frac{A_s + \xi_1^2 A_p'}{A_{c,eff}} = \frac{A_s}{A_{c,eff}} \tag{3.10}$$

A_p' : The area of pre or post-tensioned. Since the tendon is not considered in program, A_p' =0.
$A_{c,eff}$: The effective area of concrete in tension, b_w x $h_{c,ef}$.

$$h_{e,eff} = \min\left[2.5(h-d), \frac{h-x}{3}, \frac{h}{2}\right] \tag{3.11}$$



[Figure 3.5] Calculation of Effective tension area

2. *Determine $s_{r,max}$*

The maximum crack spacing, $s_{r,max}$ is calculated as shown in the table below.

$$s_{r.\max} = k_3 c + \frac{k_1 k_2 k_4 \phi}{\rho_{p,eff}} \tag{3.12}$$

EN1992-1-1:2004 7.3.4(2)

where,

ϕ is bar diameter. In case different sizes are used, ϕ_{eq} should be calculated as:

$$\phi_{eq} = \frac{n_1\phi_1^2 + n_2\phi_2^2}{n_1\phi_1 + n_2\phi_2}$$

The program uses the ϕ of the outer layer.
c is cover to the longitudinal reinforcement.
k_1 : A coefficient accounting the bond properties of rebar (0.8 for high bond bars)
k_2 : Coefficient accounting for distribution of strain. (0.5 for bending)
k_3 : 3.4 (recommended values)
k_4 : 0.425(recommended values)

These values can't be changed.

3.4.2 Limiting Crack Width, w_{max}

For reinforced members without prestressing tendon, limiting values of crack width, w_{max}, are given in the table below.

[Table 3.5] Limiting Crack Width, w_{max}

Exposure Class	Serviceability Load combination Type		
	Quasi-Permanent	Frequent	Characteristic
X0	0.4	User defined	Not Checked
XC1			
XC2	0.3		
XC3			
XC4			
XD1	0.3		
XD2			
XD3			
XS1	0.3		
XS2			
XS3			
XF1*	Not Checked		0.2
XF2*			
XF3*			
XF4*			
XA1*			
XA2*			
XA3*			

3.4.2.1 Exposure Class

Exposure class can be specified in Serviceability Parameters as mentioned in Section 3.2.

3.5 Deflection Check

EN 1992-1-1:2004 specifies to apply deflection check for certain sections that do not meet the depth/span ratio criteria. But midas Gen calculates the deflection for all the members and compares the deflection with the allowable value irrespective of the span/depth ratio.

There is no deflection check for the complete structure. Deflection check is applied for each member separately.

Deflection verification is performed by comparing the relative deflection of the member to deflection limit. Deflection is verified for Quasi-permanent and Characteristic load combinations. The limit value is specified by the user in **Serviceability Parameter** dialog box.

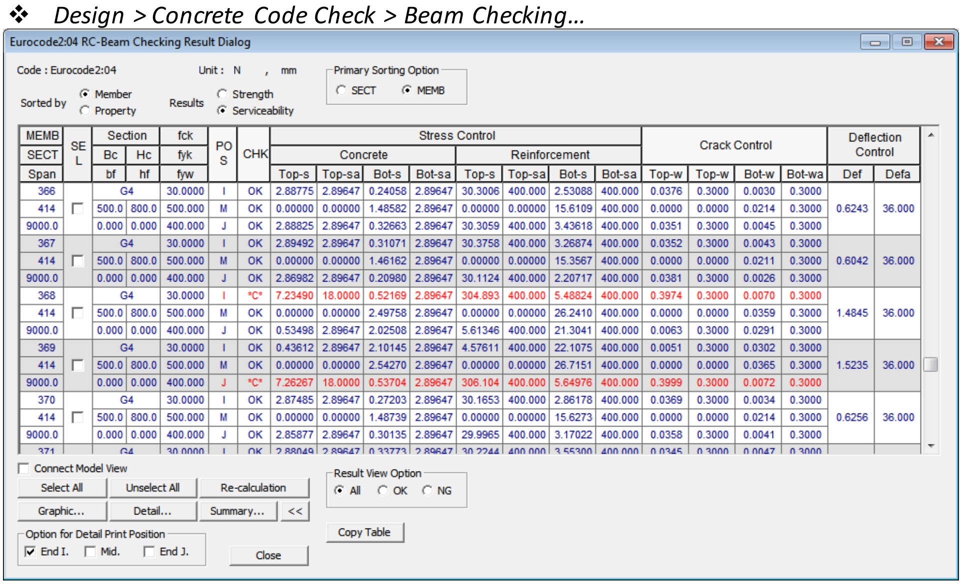
3.6 Verification of Results

The checking results can be checked in various formats in midas Gen.

3.6.1 Check Result dialog box

The checking results can be checked in **Beam Checking Result Dialog** box as shown below.

❖ *Design > Concrete Code Check > Beam Checking...*



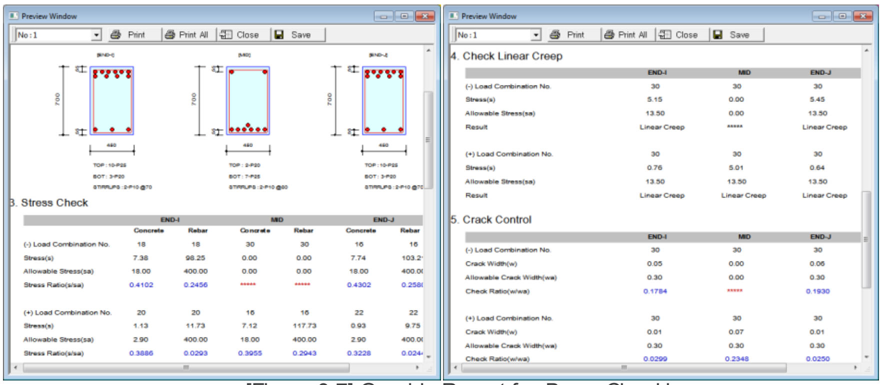
[Figure 3.6] Beam Checking Result dialog box

Similarly, the checking results can be checked for column sections and walls. The dialog box for checking results of column members can be accessed from **Design > Concrete Code Check > Column Checking.** The dialog box for checking results of walls can be accessed from **Design > Concrete Code Check > Wall Checking.**

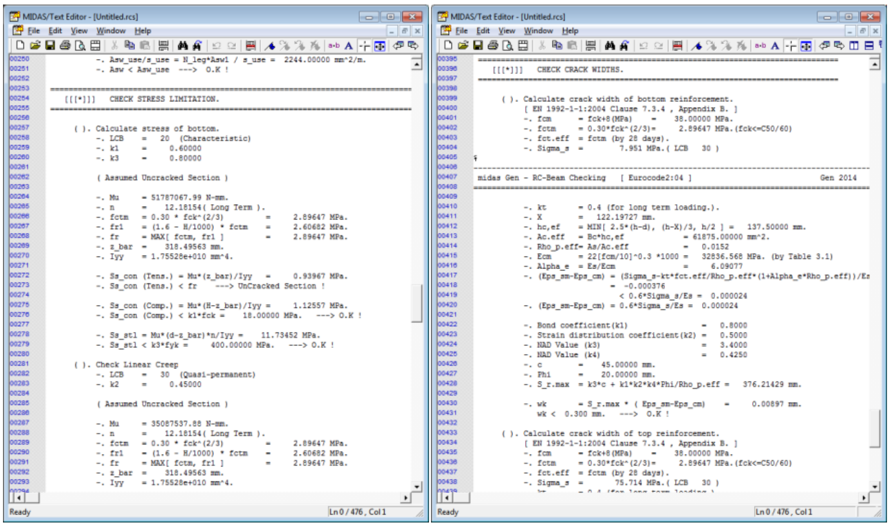
3.6.2 Design/Check Reports

The program provides the results in the following kind of report formats:

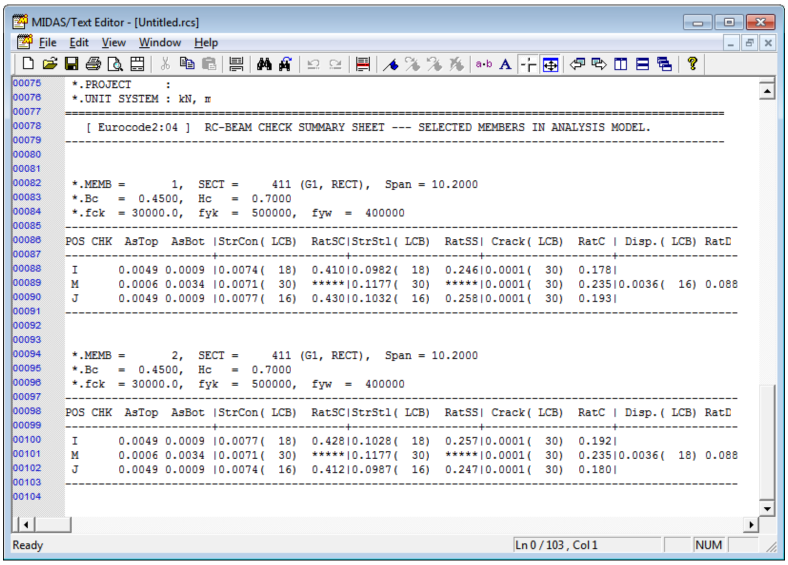
i. Graphic Report
ii. Detail Report
iii. Summary Report



[Figure 3.7] Graphic Report for Beam Checking



[Figure 3.8] Detail Report for Beam Checking



[Figure 3.9] Summary Report for Beam Checking

Detailing of Members

When the program provides the reinforcement to the section, then checks are applied for minimum and maximum allowable area of steel. Minimum areas of reinforcement are given in order to prevent a brittle failure, wide cracks and also to resist forces arising from restrained actions. Along with that the program also applies the checks for the spacing of the rebars. There should be sufficient space between the resulting bars of members to allow access for vibrators and good compaction of the concrete. The details of these checks are discussed in this section.

4.1 Detailing rules for Beam Design

4.1.1 Longitudinal Reinforcement

The following specifications of EN1992-1-1:2004 are considered by the program while providing the reinforcement.

Maximum area of longitudinal reinforcement is calculated as:

$$A_{s,max} = 0.04\,A_c \qquad (4.1)$$

EN1992-1-1:2004 9.2.1.1 (3)

Minimum area of longitudinal reinforcement is calculated as:

$$A_{s,min} = 0.26\frac{f_{ctm}}{f_{yk}}\,b_t d \geq 0.0013 b_t d \qquad (4.2)$$

EN1992-1-1:2004 9.2.1.1(1)

where,

b_t denotes the mean width of the tension zone. For rectangular sections, b_t is equal to section width. For a T-beam width of web is used by the program.

f_{ctm} is taken as specified in 3.1.

For providing the adequate spacing in the bars, the program takes care of the following code specifications:

The clear distance (horizontal and vertical) between individual parallel bars or horizontal layers of parallel bars should be not less than the maximum of:

i. $k_1 \cdot$ bar diameter
ii. ($d_g + k_2$ mm) where dg is the maximum size of aggregate.
iii. 20 mm

The recommended values of k_1 and k_2 are used which are specified as 1 and 5 mm respectively.

4.1.2 Shear Reinforcement

Minimum required shear reinforcement is calculated by the program as below:

$$\rho_{w,min} = 0.08\sqrt{f_{ck}}/f_{yk} \qquad (4.3)$$

EN1992-1-1:2004 9.2.2(5)

where,

ρ_w is the shear reinforcement ratio

The maximum longitudinal spacing between shear assemblies is taken as the minimum of:

$$s_{l,max} = 0.75d\,(1 + \cot\alpha) = 0.75d \text{ (for } \alpha = 90^o) \qquad (4.4)$$

$$s = A_{sw} / (b_w \cdot \rho_{w,min}) \qquad (4.5)$$

EN1992-1-1:2004 9.2.2(6)

where,

A_{sw} is the area of shear reinforcement within length s

s is the spacing of the shear reinforcement

b_w is the breadth of the web of the member

α is the angle between shear reinforcement and the longitudinal axis. It is applied as 90º in midas Gen.

To consider constructability, the program rounds off the required spacing to the lower 10 mm value.

4.2 Detailing Rules for column design

4.2.1 Longitudinal Reinforcement

EN 1992-1-1:2004 specifies that longitudinal bars should have a diameter of not less than φ_{min}.

Varying values of φ_{min} are specified in National Annexes. EN1992-1-1:2004 9.5.2(1)

This needs to be taken care by the user. When specifying the design criteria for rebars in **Design > Concrete Design Parameter > Design Criteria for Rebars**, the bars bigger than φ_{min} in diameter should be chosen by the user.

The minimum allowed amount of longitudinal reinforcement for a column is specified as greater of the two values.

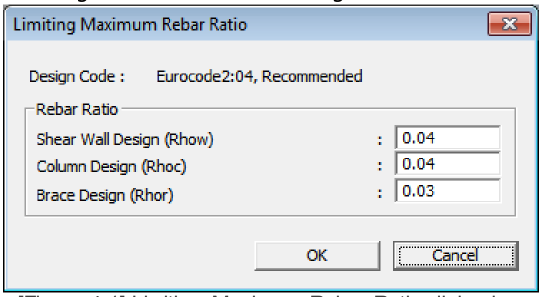
i. $A_{s,min} = 0.10\ N_{Ed}/f_{yd}$ EN1992-1-1:2004 9.5.2(2)

ii. $0.002\ A_c$

The maximum value of amount of longitudinal reinforcement is specified as $A_{s,max}$. The recommended value of $A_{s,max}$ is $0.04\ A_c$. EN1992-1-1:2004 9.5.2(3)

The value of $A_{s,max}$ can be viewed/modified in **Limiting Maximum Rebar Ratio** dialog box as shown below:

❖ *Design > Concrete Design Parameters > Limiting Maximum Rebar Ratio*



[Figure 4.1] Limiting Maximum Rebar Ratio dialog box

4.2.2 Shear Reinforcement

For column members, the diameter of the transverse reinforcement should not be less than, greater of the two below: EN1992-1-1:2004 9.5.3(1)

i. 6 mm

ii. ¼ times the maximum diameter of the longitudinal bars

This needs to be taken care by the user. When specifying the design criteria for rebars in **Design > Concrete Design Parameter > Design Criteria for Rebars**, the suitable bar diameter should be chosen.

In case the shear reinforcement is not required, the minimum reinforcement is provided as:

$$\rho_{w,min} = 0.08\sqrt{f_{ck}}/f_{yk} \quad (4.6)$$

$$s = A_{sw} / \rho_w \cdot b_w \cdot \sin\alpha \quad (4.7)$$

The s is calculated and used for maximum spacing.

The spacing of the transverse reinforcement along the column should not exceed $s_{cl,tmax}$:

The recommended value is the least of the following three distances:

i. 20 times the minimum diameter of the longitudinal bars

ii. Lesser dimension of the column

iii. 400 mm

This specification is taken care by the program itself.

To consider constructability, the program rounds off the required spacing to the lower 10 mm value.

4.3 Detailing Rules for Wall design

4.3.1 Vertical Reinforcement

EN1992-1-1:2004 9.6.2(1)

The maximum amount of the vertical reinforcement should be applied as:

$$A_{sv,max} = 0.04\ A_c \quad (4.8)$$

The ratio can be viewed/edited in Limiting Maximum Rebar Ratio dialog box as shown in previous section.

The minimum amount of vertical reinforcement should be applied as:

$$A_{sv,min} = 0.002\ A_c \quad (4.9)$$

This is the recommended value and it cannot be edited by the user.

4.3.2 Horizontal Reinforcement

EN1992-1-1:2004 9.6.3(1)

The minimum horizontal reinforcement is provided as per the following specifications:

$$\rho_{w,min} = \max\,[0.25A_{s,y}/A_c,\ 0.001] \quad (4.10)$$

EN1992-1-1:2004 9.6.3(2)

The maximum spacing of the horizontal reinforcement shall be limited to minimum of the following:

I. $2*A_{s,v}/(\rho_{w,min}\ h_w)$

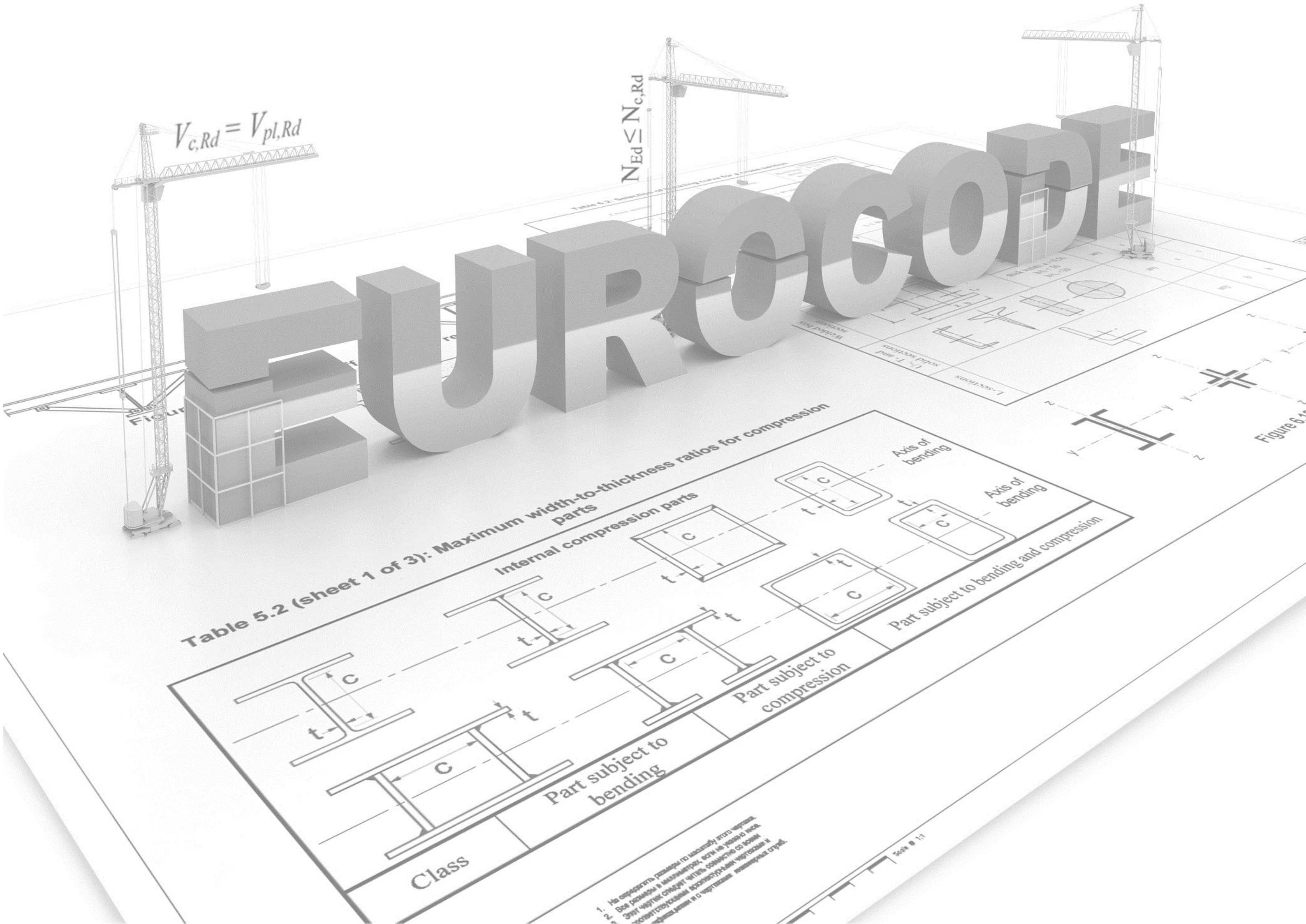
II. 400 mm

For wall design, the detailing rules for shear reinforcement are same as that of column design.

CHAPTER 3

RC Design Tutorial

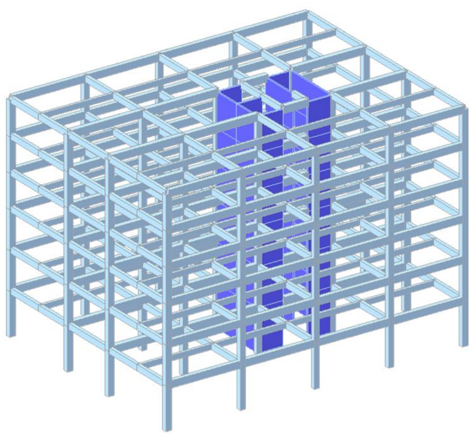
Eurocode2 Design Guide for midas Gen



Eurocode Design of a Multi-story RC Building

- Part I – EC2 in Gen
- Part II – Model & Design Parameters
- Part III – ULS Member Design
- Part IV – ULS Member Checks
- Part V – SLS Member Checks

Eurocode Design of Reinforced Concrete Building as per EN 1992-1-1: 2004



Overview

- **Eurocode Design of Reinforced Concrete Building**
- **Model**
  - *- 6-story Reinforced Concrete Building*
  - *- Element: Wall, Beam*
- **Load & Boundary Condition**
  - *- Self Weight*
  - *- Floor Loads*
  - *- Wind Loads*
  - *- Seismic Loads*
  - *- Supports*
- **Analysis**
  - *- Linear Static Analysis*

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Reinforced Concrete Design Features in midas Gen

- **Gen provides automatic design for beam, column and shear wall.**
- **Section checking with the given data.**
- **Ultimate limit state and Serviceability limit state design and/or checking.**
- **Default load combinations as per Eurocode 2.**
- **Static wind loads as per Eurocode 1-4: 2005**
- **Static seismic loads and response spectrum function as per Eurocode 8-1: 2004**
- **Capacity design as per Eurocode 8-1 can be applied by checking on "Apply EC8:04 Capacity Design" option in Concrete Design Code dialog box.**
- **Available Section shapes**

  ✓ **Column: Rectangle, Circular, Hollow circular**

  ✓ **Wall: Rectangle**

  ✓ **Beam: Rectangle, T-shape**

Note:

Torsion should be checked by the user.

For meshed slab and wall design, we can use Meshed Slab/Wall Design function.

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Ultimate Limit State (ULS) Design

(1) Bending without axial force

▪Assuming K and K' have been determined:

where:

$$K = M / bd^2 f_{ck}$$

$$K' = 0.598\delta - 0.18\delta^2 - 0.21$$

where:

$\delta \leq 1.0$ = Moment Redistribution Ratio(Factor)

▪If $K \leq K'$ (singly reinforced)

$$A_{s1} = M / f_{yd} z$$

where:

$A_{s1}$is area of compression steel (in layer 1).

$$f_{yd} = f_{yk} / \gamma_s$$

$$z = d[0.5 + 0.5(1 - 3.53K)^{0.5}] \leq 0.95d$$

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▪If $K > K'$ (Doubly Reinforced)

$A_{s2} = (M - M')/f_{sc}(d - d_2)$

where:

A_{s2} is area of compression steel (in layer 2).

$M' = K'bd^2 f_{ck}$

$f_{sc} = 700(x_u - d_2)/x_u$

$f_{sc} = f_{yd}$

where:

d_2 is effective depth to compression steel.

$x_u = (\delta - 0.4)d$

$A_{s1} = M'/f_{yd}z + A_{s2}f_{sc}/f_{yd}$

For Minimum and Maximum Required Rebar Area

$A_{s,\min} = 0.26(f_{ctm}/f_{yk})b_t d \geq 0.0013 b_t d$

(2) Bending with axial force

Slenderness Ratio

Second order effects may be ignored if the slenderness λ is below a certain value λ_{lim}.

$\lambda = l_0 / i$

$\lambda_{\lim} = 20 \cdot A \cdot B \cdot C / \sqrt{n}$

Design Bending moment

$M_{Ed} = \max[M_{0Ed} + M_2, M_{02}, M_{01} + 0.5M_2]$

▪where:

M_{Ed} is design moment.

M_{0Ed} is equivalent first order moment including the effect of imperfection(at about mid height) and may be taken as = M_{0e}

where:

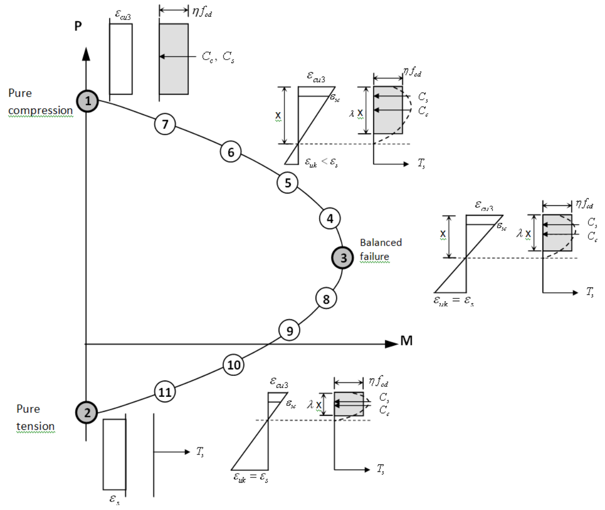
$M_{0e} = (0.6M_{02} + 0.4M_{01}) \geq 0.4M_{02}$

M_{02}, M_{01} is first order end moments at ULS including allowances for imperfections. $|M_{02}| \geq |M_{01}|$

$M_2 = N_{Ed} e_2$; nominal second order moment in slender column

Capacity - Axial force and uni-axial bending moment

▪The combinations of and that cause failure of a given column section are illustrated by an interact ion diagram as shown below.



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▪Pure compression, point ①

$$P_o = \eta f_{cd}(A_g - A_{st}) + A_{st} f_{yd}$$

Buckling failure is not considered.

▪Pure tension, point ②

$$P_o = -A_{st} f_{yd}$$

▪Balanced failure, point ③

The load and moment at balanced failure, P_b and M_b, can be calculated by substituting $f_s = f_{yd}$ and $\eta = \eta_b$ into the above equations.

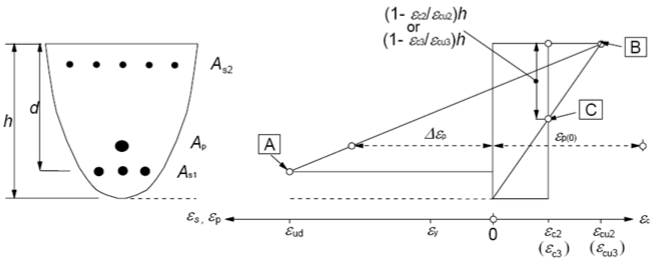
$$\eta_b = \frac{0.003E_s}{f_{yd} + 0.003E_s} \lambda d$$

Where,	λ=0.8	for $f_{ck} \le 50MPa$
	λ=0.8-(f_{ck}-50)/400	for $50 < f_{ck} \le 90MPa$
	λ=0.7	for $f_{ck} > 90MPa$

▪For symmetrically reinforced members, the loads and moments at the points ④~⑪ may be calcul ated by the formula below.

$$P_u = \eta f_{cd} \lambda x b + A_s^{'} f_s^{'} - A_s f_s$$

$$M_u = \eta f_{cd} \lambda x b(\frac{h}{2} - 0.5\lambda x) + A_s^{'} f_s^{'} (\frac{h}{2} - d^{'}) + A_s f_s (d - \frac{h}{2})$$



A - reinforcing steel tension strain limit

B - concrete compression strain limit

C - concrete pure compression strain limit

(3) Shear

- Shear resistance of a member with shear reinforcement is equal to:

$$V_{Rd} = V_{Rd,s}$$

▪In regions of the member where $V_{Ed} \leq V_{Rd,c}$ no calculated shear reinforcement is necessary.

▪In regions where $V_{Ed} > V_{Rd,c}$ sufficient shear reinforcement should be provided in order that $V_{Ed} \leq V_{Rd}$.

▪Members not requiring design shear reinforcement

$$V_{Rd,c} = [C_{Rd,c} k (100 \rho_1 f_{ck})^{1/3} + k_1 \sigma_{cp}] b_w d$$

With a minimum of

$$V_{Rd,c} = (v_{\min} + k_1 \sigma_{cp}) b_w d$$

▪Members requiring design shear reinforcement

The shear resistance, V_{Rd} is the smaller value of:

$$V_{Rd,s} = (A_{sw} / s) z f_{ywd} \cot\theta$$

and

$$V_{Rd,\max} = \alpha_{cw} b_w z v_1 f_{cd} / (\cot\theta + \tan\theta)$$

Serviceability Limit States (SLS) Design

(1) Stress Limitation

▪The compressive stress shall be limited to a value $k_1 f_{ck}$ in order to avoid **longitudinal cracks und er the characteristic combination of loads**. A value of K_1 can be defined by the user and default v alue is '**0.6**'.

▪If the stress in the concrete under the **quasi-permanent loads** is less than $k_2 f_{ck}$, linear creep may b e assumed. If the **stress in concrete exceeds $k_2 f_{ck}$, non-linear creep should be considered**. A valu e of K_2 can be defined by the user and default value is '**0.45**'.

▪**Unacceptable cracking or deformation** may be assumed to be avoided if, **under the characteris tic combination of loads**, the tensile stress in the reinforcement does not exceed $k_3 f_{yk}$. A value of K_3 can be defined by the user and default value is '**0.8**'.

▪Where the stress is caused by an imposed deformation, the tensile stress should not exceed k4fyk. A value of K_4 can be defined by the user and default value is '1.0'.

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(2) Crack Control

▪A limiting calculated crack width, wmax, taking into account the proposed function and nature of the structure and the costs of limiting cracking, should be established.

Exposure Class	Reinforced members and prestress members with unbounded tendons	Prestressed members with bonded tendons
	Quasi-permanent load combination	Frequent load combination
X0,XC1	**0.3 (Default value)**	0.2
XC2,XC3,XC4 XD1,XD2,XS1,XS2,XS3	0.4	0.2
		Decompression

(3) Deflection Control

▪The appearance and general utility of the structure could be impaired when the calculated sag of a be am, slab or cantilever subjected to quasi-permanent loads exceeds span/250.

▪For the deflection subjected to characteristic loads can be checked by user defined limit. Default limi t is Span/250.

Beam detailing

The following data are required to be input for Beam design:

- **Beam section size (b, h)**
- **Cover to rebar center** $default = \min\{\max(h/10, 63.5mm), 76.2mm\}$
- **Bar size**
  - ✓ **Main rebar: Up to 5 sizes simultaneously selected, which GEN will use to find the most appropriate.**
  - ✓ **Stirrup/Link: One size can be selected.**
  - ✓ **P5, P6, P7, P8, P9, P10, P11, P12, P13, P16, P20, P25, P32, and P40 are available.**
- **Arrangement (= Number of legs of the transverse or shear reinforcement)**
  - ✓ **Only one case can be selected among the numbers from 2 to 20.**

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Beam detailing

The following conditions are applied to Beam design:

- **Maximum rebar ratio of main rebar, EN 1992-1-1 9.2.1.1**

  $A_{s,\max} = 0.04 A_c$
- **Minimum rebar ratio of main rebar, EN 1992-1-1 9.2.1.1**

  $A_{s,\min} = \max\left(0.26 f_{ctm} / f_{yk} b_t d, 0.0013 b_t d\right)$
- **Minimum spacing (= clear distance) of bars, EN 1992-1-1 8.2**

  $= \max\left(D_{bar}, d_g + 5mm, 20mm\right)$
- **Maximum stirrup spacing, EN 1992-1-1 9.2.2**

  $S_{\max} = \min\{A_{sw}/(b_w \rho_{w,\min}), 0.75d(1+\cot\alpha)\}$ $\rho_{w,\min} = 0.08\sqrt{f_{ck}}/f_{yk}$

Beam detailing

The following are the Design results provided by Gen:

Main rebar

- Required rebar area satisfying minimum bar spacing
- Number of bars at top and bottom satisfying minimum bar spacing
- Capacity ratio at I-end, middle, and J-end of beam member
- Up to two layers of rebar can be designed

Stirrups/Links

- Required rebar area per unit length
- Spacing of stirrups
- Capacity ratio at I-end, middle, and J-end of beam member
- Check for crushing of compression struts

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Column detailing

The following data are required to be input for Column design:

- Column section size (b, h)
- Cover to rebar center $default = \min\{\max(h/10, 63.5mm), 76.2mm\}$
- Bar size
  - ✓ Main rebar: Up to 5 sizes simultaneously selected, among which GEN will find the most appropriate.
  - ✓ Tie/Spiral: One size can be selected.
  - ✓ P5, P6, P7, P8, P9, P10, P11, P12, P13, P16, P20, P25, P32, and P40 are available.
- Arrangement (= Number of legs of the transverse reinforcement)
  - ✓ Different number of legs can be applied in the y and z direction.

Column detailing

The following conditions are applied to Column design:

- **Maximum rebar ratio of main rebar, EN 1992-1-1 9.5.2**

  $A_{s,\max} = 0.03 A_c$, **which can be modified.**
- **Minimum rebar ratio of main rebar, EN 1992-1-1 9.5.2**

  $A_{s,\min} = \max\left(0.10 N_{ED} / f_{yd}, 0.002 A_c\right)$
- **Minimum spacing (clear distance) of bars, EN 1992-1-1 8.2**

  $= \max\left(D_{bar}, d_g + 5mm, 20mm\right)$
- **Maximum stirrup spacing, EN 1992-1-1 9.5.3 & 9.2.2**

  $S_{cl,t\max} = \min\left\{20D_{bar}, b, h, 400mm, A_{sw} / \left(b_w \rho_{w,\min}\right)\right\}$ $\rho_{w,\min} = 0.08\sqrt{f_{ck}} / f_{yk}$

  The maximum spacing is reduced by a factor 0.6 at the i and j-end of the column.

Column detailing

The following are the design results provided by Gen:

<u>Main rebar</u>

- **Number of bars satisfying minimum bar spacing**
- **Capacity ratio for the most critical part among I-end, middle, and J-end of column member**
- **Biaxial P-M interaction diagram**

Note. Two layers of rebar or bundle bars are not applicable.

<u>Stirrup/Links</u>

- **Required rebar area per unit length**
- **Spacing of ties/spirals**
- **Capacity ratio for the most critical part of column member (I-end, middle, and J-end)**
- **Check for crushing of compression struts**

Shear Wall detailing

The following data are required to be input for Shear Wall design:

- **Wall section size (L, h)**
- **Cover to rebar center** $default = 50.8mm$
- **Bar size**
  - ✓ **Vertical rebar: Up to 5 sizes simultaneously selected, among which GEN will find the most appropriate.**
  - ✓ **End rebar: One size can be selected, then program will find the most appropriate, greater than or equal to the one selected.**
  - ✓ **Horizontal rebar: One size can be selected.**
  - ✓ **P5, P6, P7, P8, P9, P10, P11, P12, P13, P16, P20, P25, P32, and P40 are available.**
- **Spacing of vertical rebar**
  - ✓ **Select as many spacings as you want program to try**
- **Spacing of horizontal rebar**
- **Design method**

Shear Wall detailing

The following conditions are applied to Shear Wall design:

- **Maximum rebar ratio of vertical rebar, EN 1992-1-1 9.6.2**

  $A_{s,\max} = 0.04A_c$, **which can be modified.**
- **Minimum rebar ratio of vertical rebar, EN 1992-1-1 9.6.2**

  $A_{s,\min} = 0.002A_c$
- **Maximum spacing of horizontal rebars, EN 1992-1-1 9.6.3**

  $S_{\max} = \min\{2A_{s,v}/(\rho_{v,\min}h), 400mm\}$ $\rho_{v,\min} = \max(0.25A_{s,v}/A_c, 0.001)$

Shear Wall detailing

Followings are the design results provided by Gen:

Vertical rebar

- **Spacing of vertical rebar**
- **Capacity ratio for the most critical part among top and bottom of wall**
- **Uniaxial P-M interaction diagram**

Horizontal

- **Required rebar area per unit length**
- **Spacing of horizontal rebar**
- **Capacity ratio for the most critical part among top and bottom of wall**
- **Check for crushing of compression struts**

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PART II - Contents

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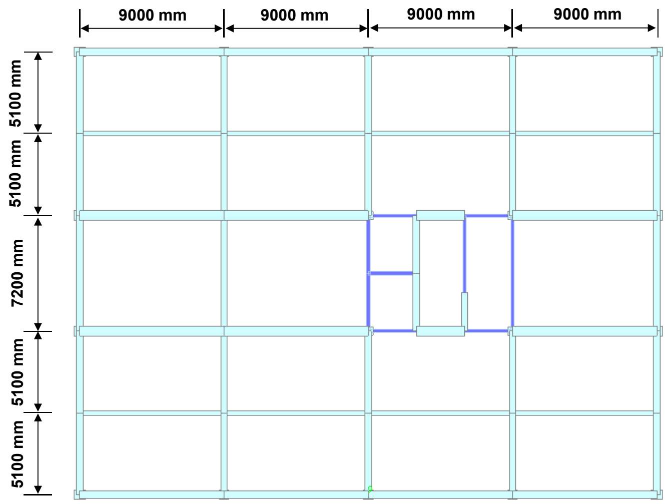
Typical Floor Plan



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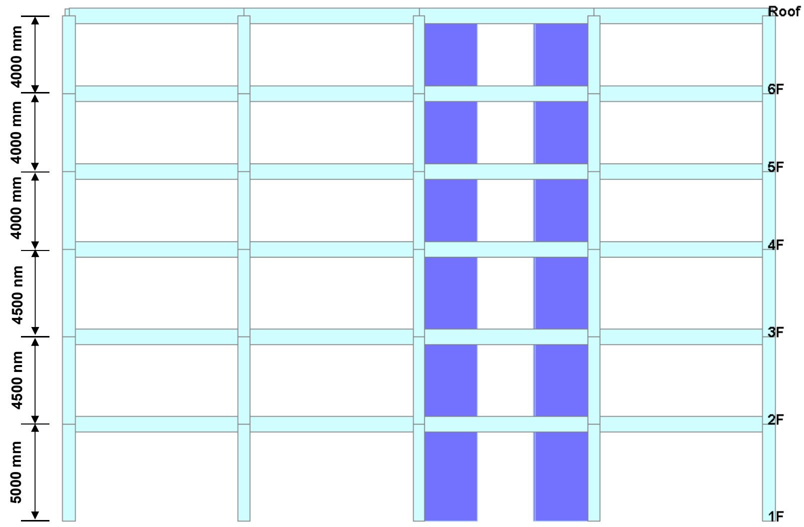
Typical Sectional Elevation



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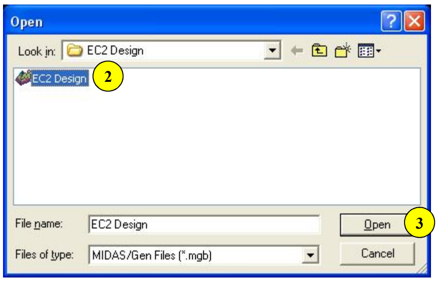
Opening the Pre-generated Model File



1. File > Open Project…
2. Select "EC2 Design".
3. Click [Open] *button.*

This tutorial is intended to illustrate design procedure as per Eurocode2. Therefore, the geometry creation, boundary assignment, load application will be skipped. For the aforementioned, refer to "Seismic Design for RC Building" tutorial.

In this tutorial, slab is not included in the model and considered as a rigid diaphragm.

Analysis

1. Analysis > Perform Analysis

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Parameters for ULS Design

- ***Load Combinations***
- ***Design Code***
- ***Sway Frame Definitions***
- ***Member Assignment***
- ***Live Load Reduction Factor Modifications***
- ***Unbraced Lengths (L, Lb)***
- ***Partial Safety Factors***
- ***Concrete and Rebar Properties***

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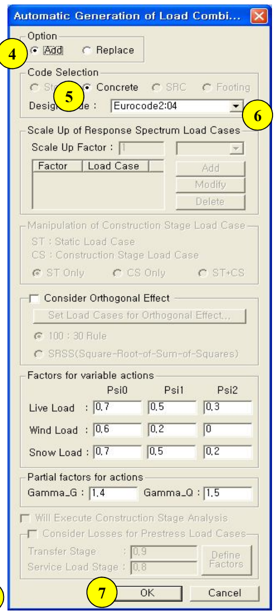
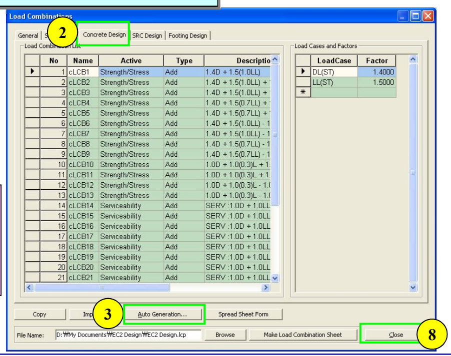
Load Combinations

1. Results > Combinations…
2. Click on "Concrete Design" tab.
3. Click [Auto Generation…] button.
4. Option: Add
5. Code Selection: Concrete
6. Design Code: Eurocode2:04
7. Click [OK] Button.
8. Click [Close] Button.





The program automatically creates design load combinations which can be also modified or deleted by the user.

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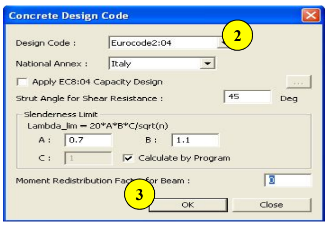
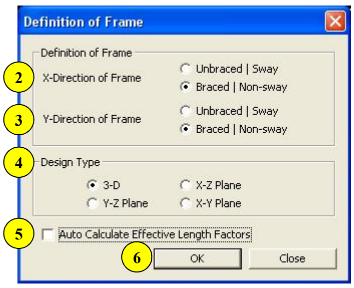
Design Code



1. Design > Concrete Design Parameter > Design Code…
2. Design Code: Eurocode2:04
3. Click [OK] button.

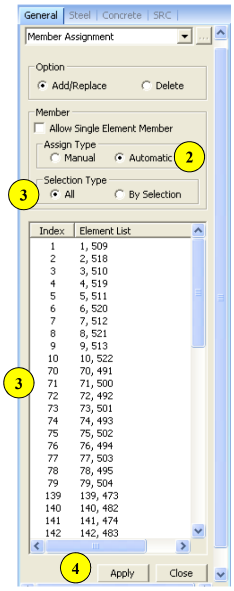
Sway Frame Definitions



1. Design > General Design Parameter > Definition of Frame…
2. X-Direction of Frame: Braced | Non-sway
3. Y-Direction of Frame: Braced | Non-sway
4. Design Type: 3-D
5. Check off "Auto Calculate Effective Length Factors".
6. Click [OK] button.

In the non-sway frame, applying 1 for the effective length factor will give conservative results.

Member Assignment



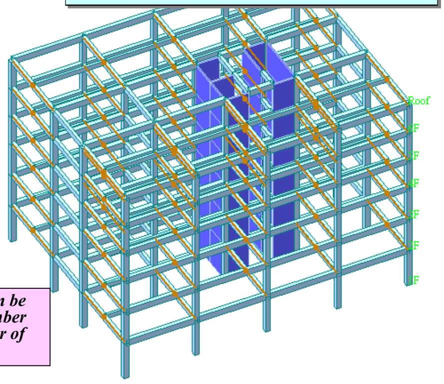
1. Design > General Design Parameter > Member Assignment…

2. Assign Type: Automatic

3. Selection Type: All

4. Click [Apply] button.

5. Click [Close] button.



A single Member can be assigned when the member is consisted of a number of beam elements.

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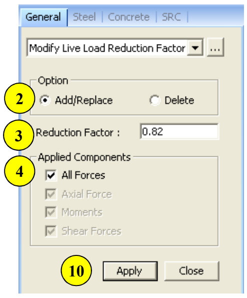
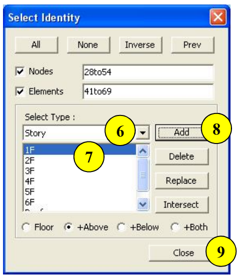
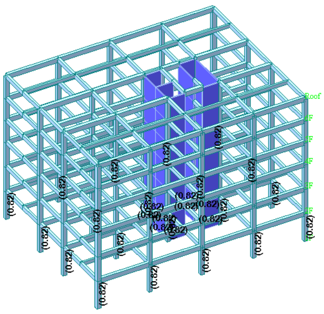
Live Load Reduction Factors (1)







1. Design > General Design Parameter > Modify Live Load Reduction Factor…

2. Option: Add/Replace

3. Reduction Factor: 0.82

4. Applied Components: All Forces

5. View > Select > Identity…

6. Select Type: Story

7. Select "1F"

8. Click [Add] button.

9. Click [Close] button.

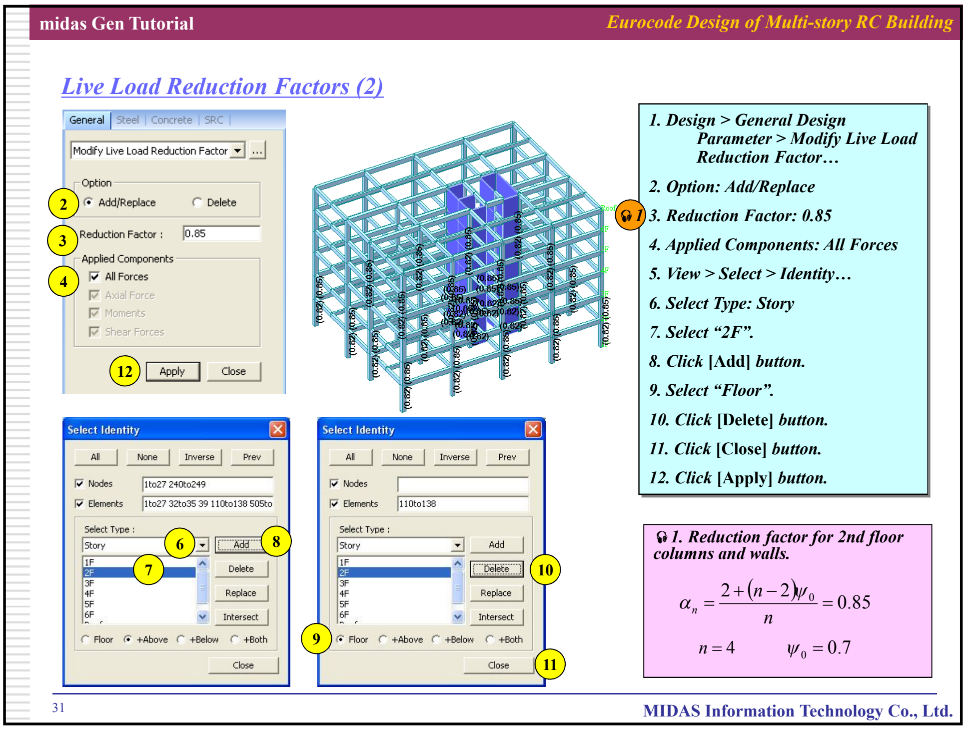
10. Click [Apply] button.

1. Reduction factor for 1st floor columns and walls.

$$\alpha_n = \frac{2+(n-2)\psi_0}{n} = 0.82$$

$$n = 5 \qquad \psi_0 = 0.7$$

EN 1991-1-1 6.3.1.2 (11)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Eurocode Design of Multi-story RC Building
Live Load Reduction Factors (2)
General | Steel | Concrete | SRC
Modify Live Load Reduction Factor
Option
Add/Replace
Delete
Reduction Factor : 0.85
Applied Components
All Forces
Axial Force
Moments
Shear Forces
Apply
Close
Select Identity
All
None
Inverse
Prev
Nodes 1to27 240to249
Elements 1to27 32to35 39 110to138 505to
Select Type :
Story
Add
Delete
Replace
Intersect
Floor +Above +Below +Both
Close
Elements 110to138
1. Design > General Design Parameter > Modify Live Load Reduction Factor…
2. Option: Add/Replace
3. Reduction Factor: 0.85
4. Applied Components: All Forces
5. View > Select > Identity…
6. Select Type: Story
7. Select "2F".
8. Click [Add] button.
9. Select "Floor".
10. Click [Delete] button.
11. Click [Close] button.
12. Click [Apply] button.
1. Reduction factor for 2nd floor columns and walls.
$\alpha_n = \frac{2+(n-2)\psi_0}{n} = 0.85$
$n = 4$ $\psi_0 = 0.7$
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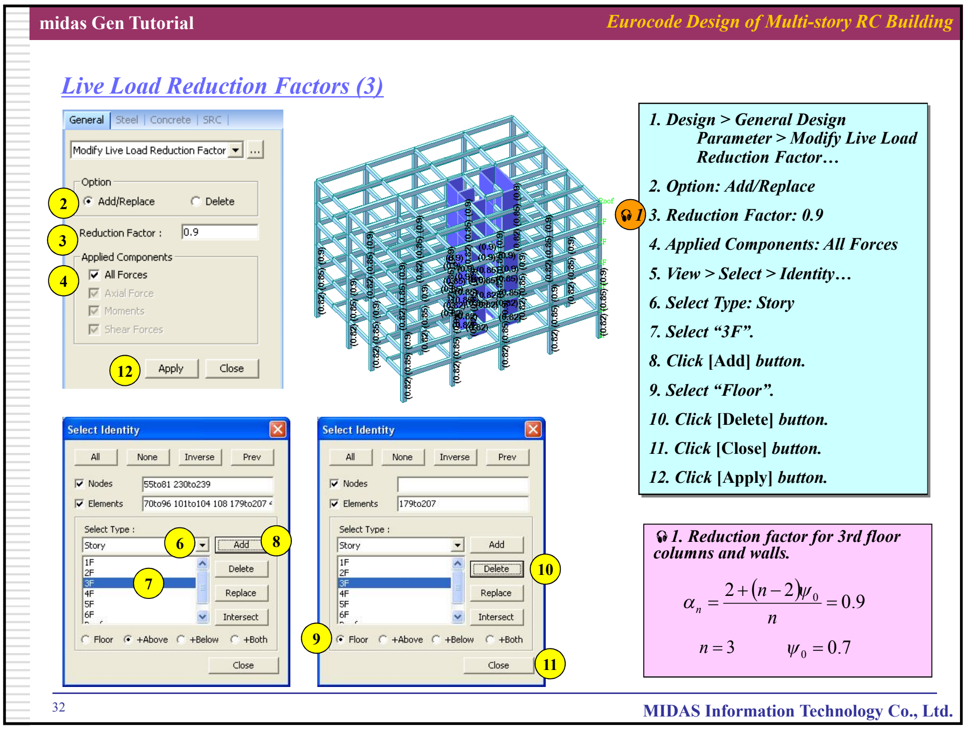
midas Gen Tutorial
Eurocode Design of Multi-story RC Building
Live Load Reduction Factors (3)
General | Steel | Concrete | SRC
Modify Live Load Reduction Factor
Option
Add/Replace
Delete
Reduction Factor : 0.9
Applied Components
All Forces
Axial Force
Moments
Shear Forces
Apply
Close
Select Identity
All
None
Inverse
Prev
Nodes 55to81 230to239
Elements 70to96 101to104 108 179to207
Select Type :
Story
Add
Delete
Replace
Intersect
Floor +Above +Below +Both
Close
Elements 179to207
1. Design > General Design Parameter > Modify Live Load Reduction Factor…
2. Option: Add/Replace
3. Reduction Factor: 0.9
4. Applied Components: All Forces
5. View > Select > Identity…
6. Select Type: Story
7. Select "3F".
8. Click [Add] button.
9. Select "Floor".
10. Click [Delete] button.
11. Click [Close] button.
12. Click [Apply] button.
1. Reduction factor for 3rd floor columns and walls.
$\alpha_n = \frac{2+(n-2)\psi_0}{n} = 0.9$
$n = 3$ $\psi_0 = 0.7$
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Unbraced Lengths (L, Lb)

1. Design > General Design Parameter > Unbraced Length(L, Lb)…

2. Option: Add/Replace

3. Unbraced Length – Ly: 0 mm

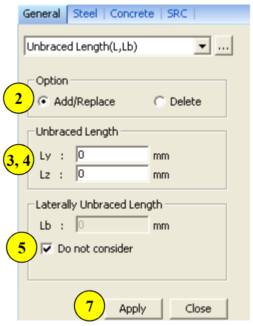
4. Lz: 0 mm

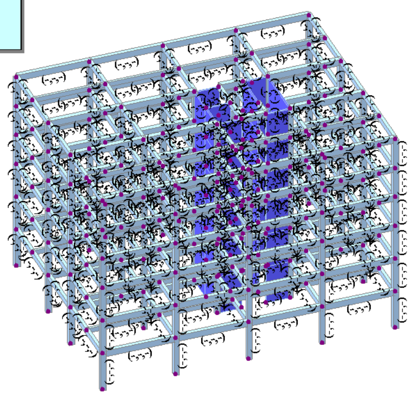
5. Laterally Unbraced Length: Check on "Do not consider".

6. View > Select > Select All

7. Click [Apply] button.

1. If "0" is entered for Ly and Lz, unbraced lengths will be calculated by the program based on the nodal coordinates of the beam elements.





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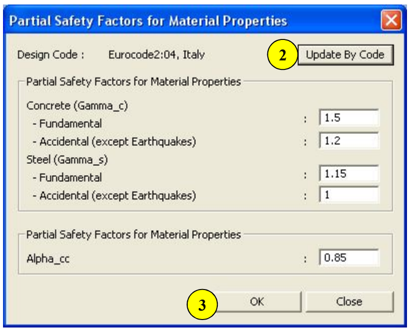
Partial Safety Factors



1. Design > Concrete Design Parameter > Partial Safety Factors for Material Properties…

2. Click [Update By Code] button.

3. Click [OK] button.

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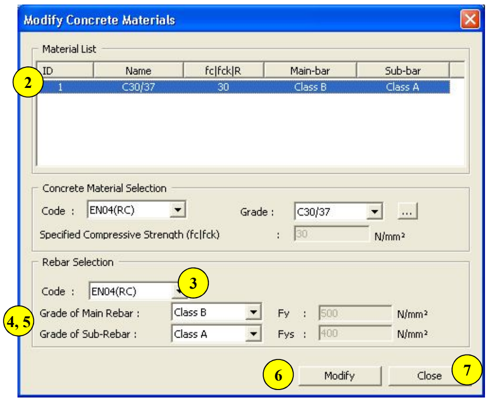
Concrete and Rebar Properties



1. Design > Concrete Design Parameter > Modify Concrete Materials…

2. Select "C30/37" from Material List.

3. Rebar Selection – Code: EN04(RC)

4. Grade of Main Rebar: Class B

5. Grade of Sub-Rebar: Class A

6. Click [Modify] *button.*

7. Click [Close] *button.*

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Design Criteria for Rebar (1)

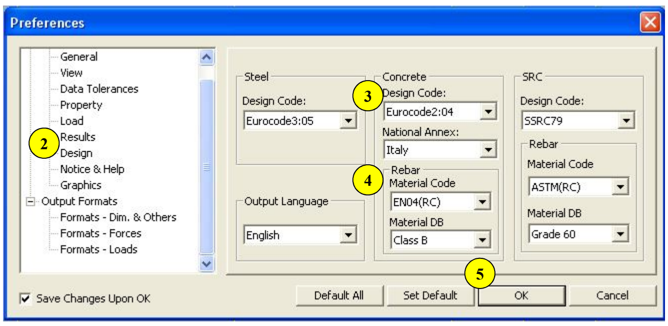
1. Tools > Preferences…

2. Click on "Design".

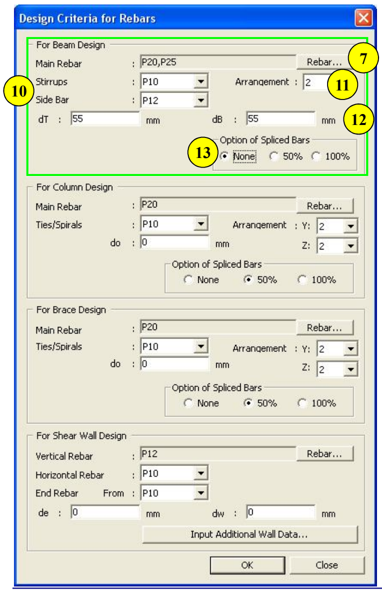
3. Concrete – Design Code: Eurocode2:04

4. Rebar – Material Code: EN04(RC)

5. Click [OK] *button.*



Design Criteria for Rebar (2) – Beam Design



6. Design > Concrete Design Parameter > Design Criteria for Rebar…

7. For Beam Design – Main Rebar: click [Rebar…] *button.*

8. Select P20 and P25.

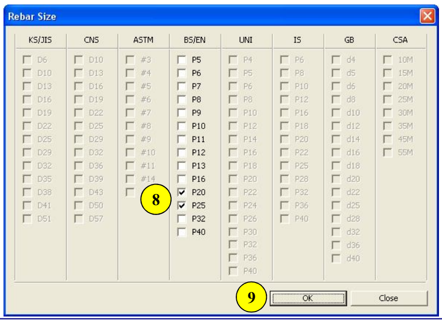
9. Click [OK] *button.*

10. Stirrups: P10, Side Bar: P12

11. Arrangement: 2

12. dT: 55 mm, dB: 55 mm

13. Option of Spliced Bars: None



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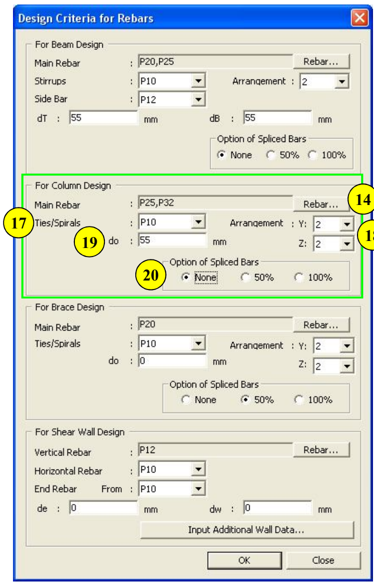
Design Criteria for Rebar (3) – Column Design



14. For Column Design – Main Rebar: click [Rebar…] *button.*

15. Select P25 and P32.

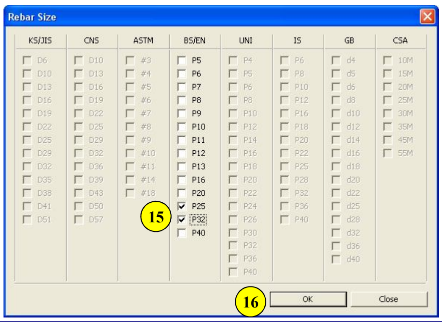
16. Click [OK] *button.*

17. Ties/Spirals: P10

18. Arrangement: X: 2, Z: 2

19. do: 55mm

20. Option of Spliced Bars: None



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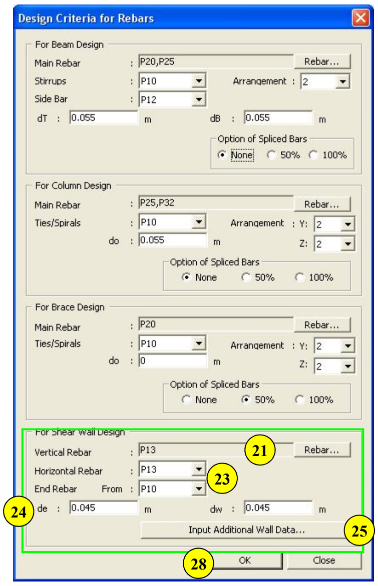
Design Criteria for Rebar (4) –Wall Design



21. For Shear Wall Design – Vertical Rebar: click [Rebar…] button.

22. Select P13 and Click [OK] button.

23. Horizontal Rebar: P13, End Rebar From: P10

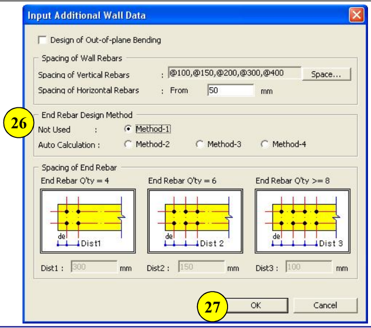
24. de: 45 mm, dw: 45 mm

25. Click [Input Additional Wall Data…] button.

26. End Rebar Design Method: Method-1

27. Click [OK] button.

28. Click [OK] button.



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ULS Design

Concrete Beam Design

1 Section for Design

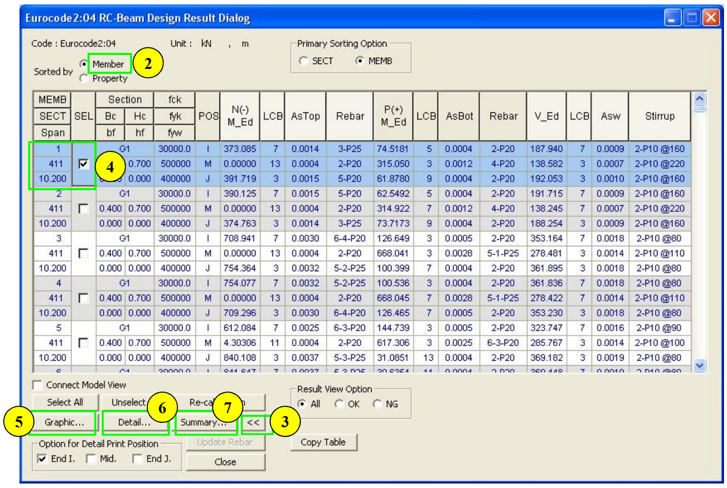
Concrete Column Design

Concrete Wall Design

1. The "Section for Design" function provides Member design of concrete sections based on the section data defined by the user. It allows you to find the appropriate section without re-analysis.

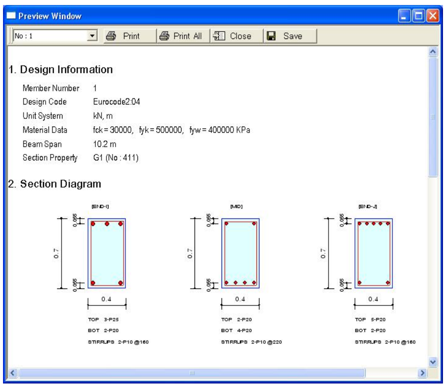
Concrete Beam Design (1)

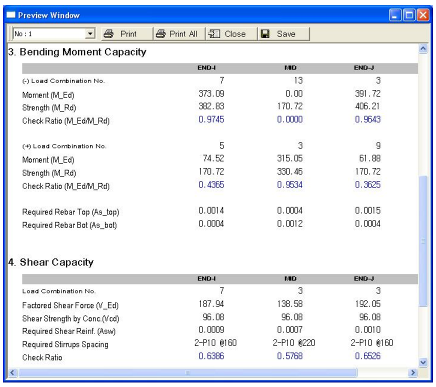
1. Design > Concrete Code Design > Beam Design…
2. Sorted by: Member
3. Click [>>] to expand the dialog box.
4. SEL: select MEMB "1".



Concrete Beam Design (2)

5. Click [Graphic…] *button.*





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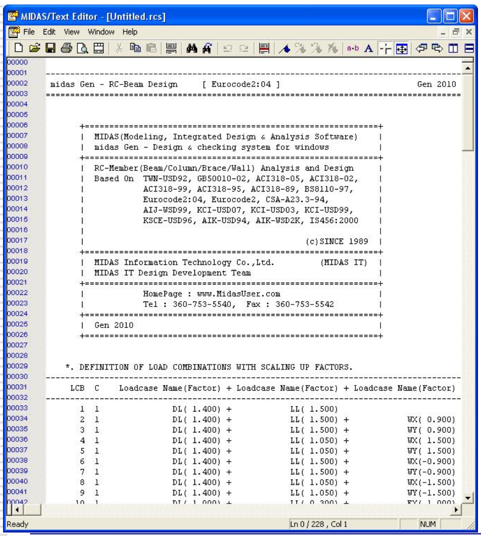
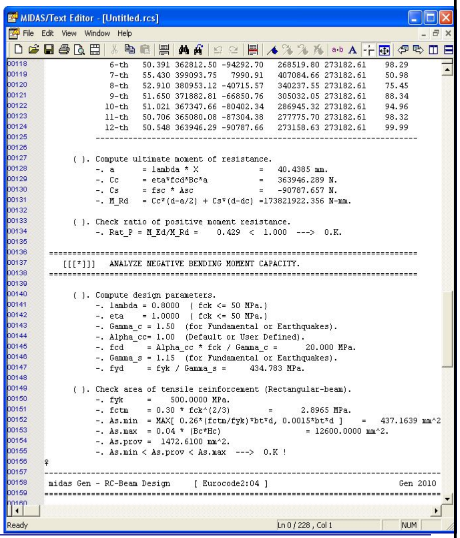
Concrete Beam Design (3)

6. Click **[Detail…]** *button.*





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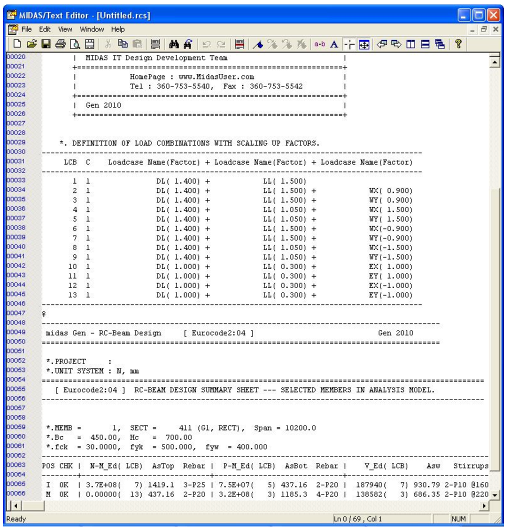
Concrete Beam Design (4)

7. Click **[Summary…]** *button.*



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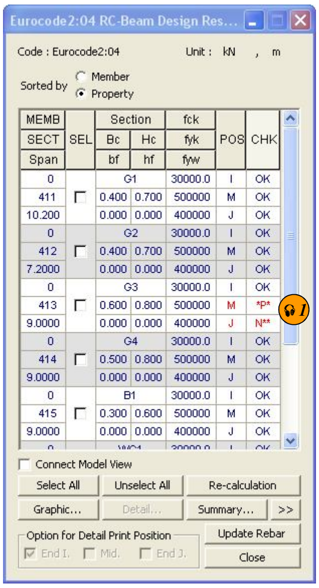
Section for Design (1)



MEMB / SECT / Span	SEL	Section (Bc / bf)	(Hc / hf)	fck / fyk / fyw	POS	CHK
0		G1		30000.0	I	OK
411	☐	0.400	0.700	500000	M	OK
10.200		0.000	0.000	400000	J	OK
0		G2		30000.0	I	OK
412	☐	0.400	0.700	500000	M	OK
7.2000		0.000	0.000	400000	J	OK
0		G3		30000.0	I	OK
413	☐	0.600	0.800	500000	M	*P*
9.0000		0.000	0.000	400000	J	N**
0		G4		30000.0	I	OK
414	☐	0.500	0.800	500000	M	OK
9.0000		0.000	0.000	400000	J	OK
0		B1		30000.0	I	OK
415	☐	0.300	0.600	500000	M	OK
9.0000		0.000	0.000	400000	J	OK

1. Design > Concrete Code Design > Beam Design…

2. Sorted by: Property

1. Red N means that negative moment is larger than the resistance for the given section .

Red P means that the positive moment is larger than the resistance for the given section.

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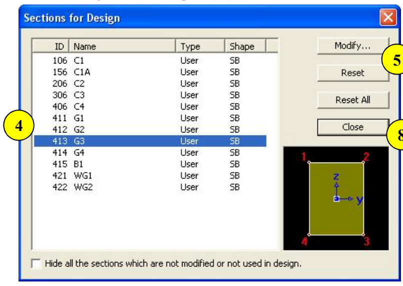
Section for Design (2)



3. Design > Section for Design…

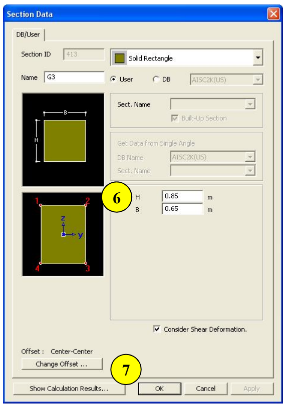
4. Select "413 G3" section.

5. Click [Modify] button.

6. Change H from 0.8m to 0.85m and Change B from 0.6m to 0.65m.

7. Click [OK] button.

8. Click [Close] button.



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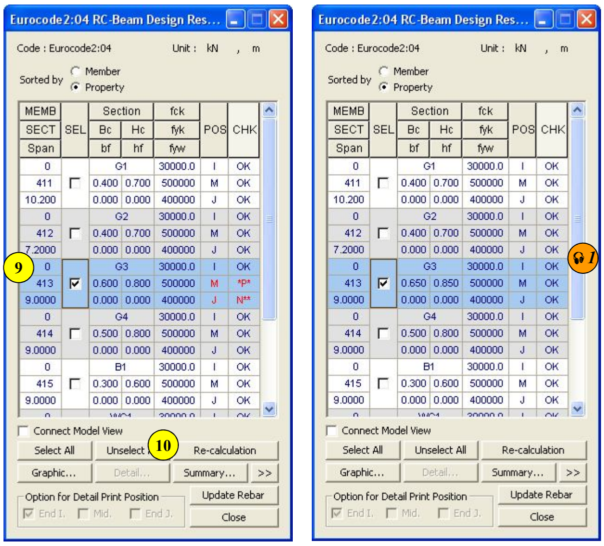
Section for Design (3)



9. SEL: select SECT "413".

10. Click [Re-calculation] *button.*

1. Check results of Section 413 G1 change to OK.

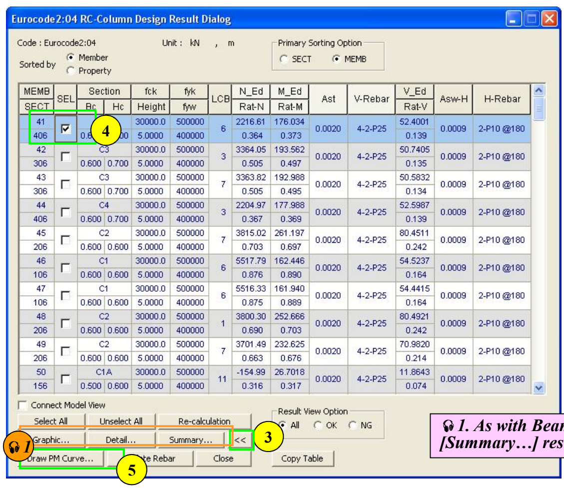
Concrete Column Design (1)

1. Design > Concrete Code Design > Column Design…

2. Sorted by: Member

3. Click [>>] to expand the dialog box.

4. SEL: select MEMB "41".

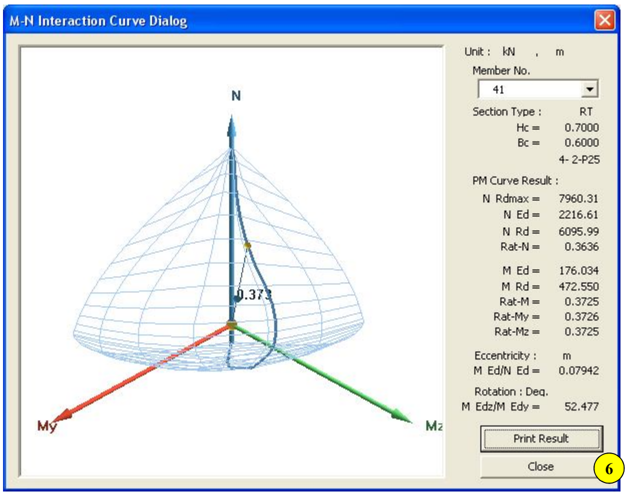


1. As with Beam we may check [Graphic…], [Detail…] & [Summary…] results.

Concrete Column Design (2)

5. Click **[Draw PM Curve…]** *button.*

6. Click **[Close]** *button.*



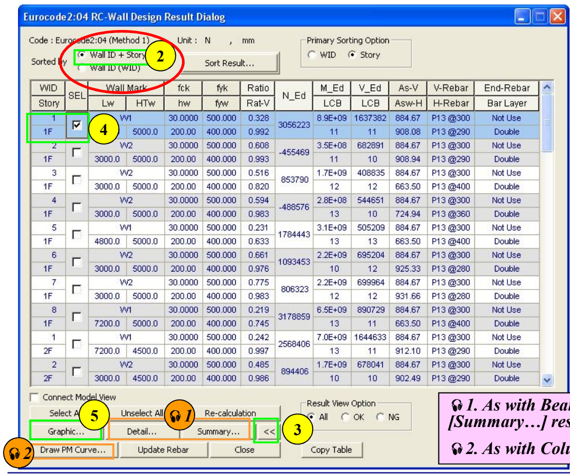
Concrete Wall Design (1)

1. Design > Concrete Code Design > Wall Design…

2. Sorted by: Wall ID + story

3. Click [>>] *to expand the dialog box.*

4. SEL: select WID "1" Story "1F".

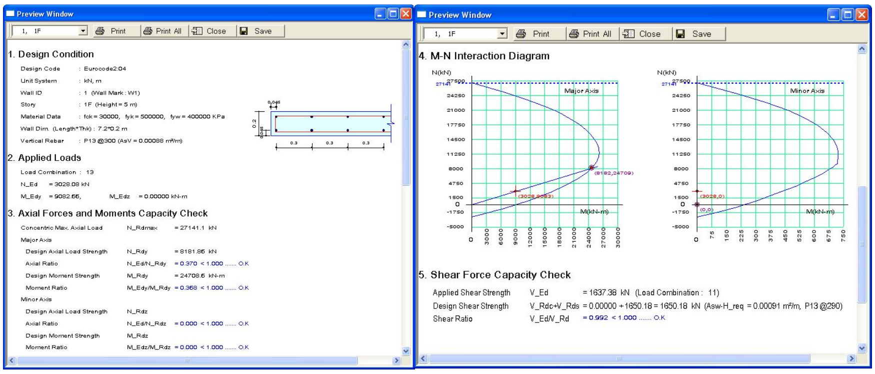


1. As with Beam we may check [Detail…] & [Summary…] results.

2. As with Column we may Draw PM Curve.

Concrete Wall Design (2)

5. Click [Graphic…] *button.*



Manually Entering Rebar and ULS Checking

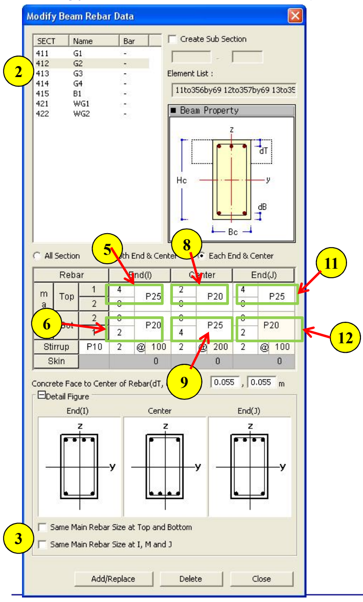
Enter Rebar Data using "Design > Concrete Design Parameter > Modify Beam/Column/Wall Rebar Data" or "Design > Concrete Code Design > Beam/Column/Wall Design > [Update Rebar] button" *1*

1. In this tutorial, "Modify Beam Rebar Data" will only be illustrated. In the same manner, Column and Wall Section Data can also be defined.

1. Rebar will be MANUALLY entered using "Design > Concrete Design Parameter > Modify Beam/Column/Wall Rebar Data"

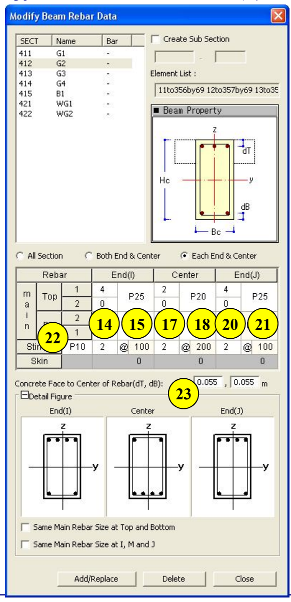
1. Rebar can be AUTOMATICALLY entered using "Design > Concrete Code Design > Beam/Column/Wall Design > [Update Rebar] button" (this is illustrated later).

Modify Beam Section Data (1)



1. *Design > Concrete Design Parameter > Modify Beam Rebar Data…*
2. *SECT: check on ID "412".*
3. *Uncheck "Same Main Rebar Size at Top and Bottom" and "Same Main Rebar Size At I,M and J".*
4. *For Main Rebar at "End(I)"*
5. *For Top Rebar: in front of "Top" and "1" : "4" "P25"*
6. *Bottom Rebar: In front of "Bot" and "1" :"2" "P20"*
7. *For Main Rebar at "Center"*
8. *For Top Rebar: in front of "Top" and "1" : "2" "P20"*
9. *Bottom Rebar: In front of "Bot" and "1" :"4" "P25"*
10. *For Main Rebar at "Center"*
11. *For Top Rebar: in front of "Top" and "1" : "4" "P25"*
12. *Bottom Rebar: In front of "Bot" and "1" :"2" "P20"*

Modify Beam Section Data (2)



13. *Stirrup in "End(I)"*
14. *Arrangement: "2"*
15. *Stirrups Space: "100" mm*
16. *Stirrup in "Center"*
17. *Arrangement: "2"*
18. *Stirrups Space: "200" mm*
19. *Stirrup in "End(J)"*
20. *Arrangement: "2"*
21. *Stirrups Space: "100" mm*
22. *Stirrup: "P10"*
23. *dT, dB : 0.055m,0.055m*
24. *Click* [Add/Replace] *Button*

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ULS Beam Member Code Check

1 6-1. Beam Code Checking

1. In this tutorial, only "Beam Code Checking" will be illustrated. In the same manner, Column/Wall Code Checking can be performed.

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Beam Code Checking (1)

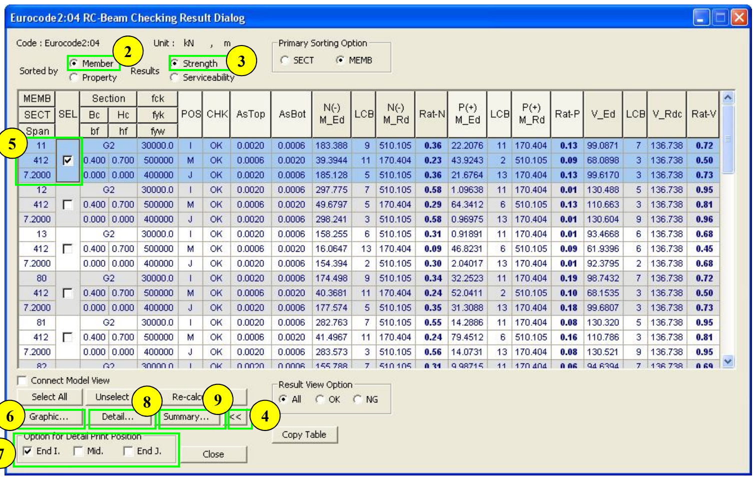
1. Design > Concrete Code Check > Beam Checking…

2. Sorted by: Member

3. Results: Strength

4. Click [>>] to expand the dialog box.

5. SEL: MEMB "11"



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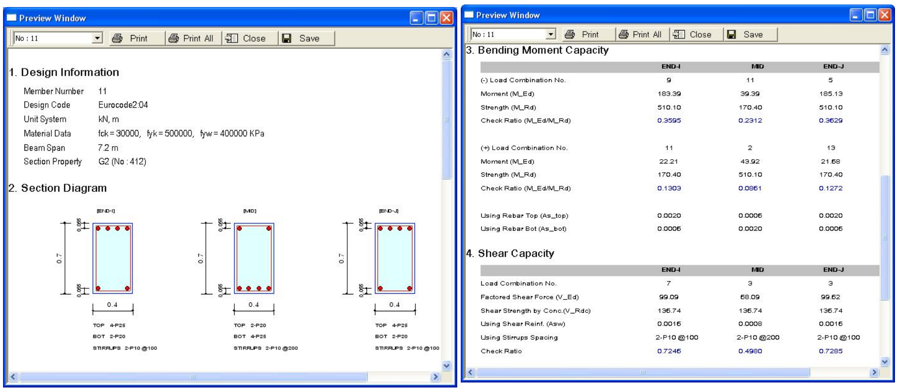
Beam Code Checking (2)

6. Click **[Graphic…]** *button.*



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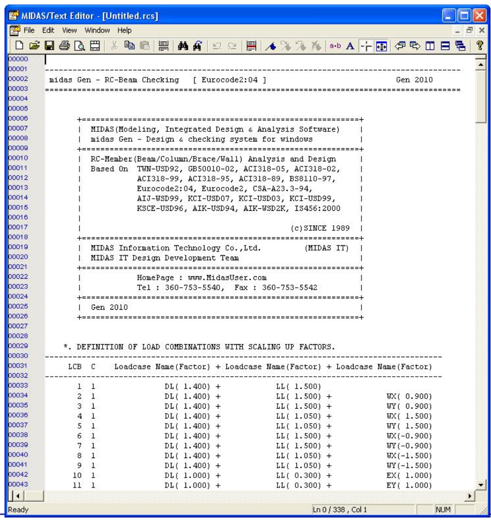
Beam Code Checking (3)

7. Option for Detail Print Position: check on "End I." "Mid." "End J.".

8. Click **[Detail…]** *button*



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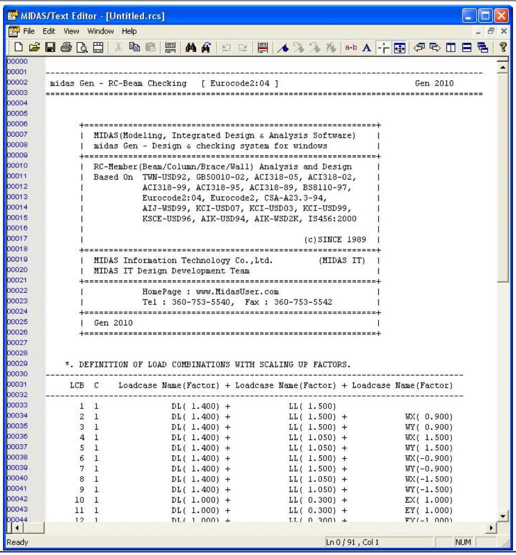
Beam Code Checking (4)

9. Click **[Summary…]** *button.*



```
MIDAS/Text Editor - [Untitled.rcs]
File  Edit  View  Window  Help

 ---------------------------------------------------------------------------------------
 midas Gen - RC-Beam Checking   [ Eurocode2:04 ]                          Gen 2010
 =======================================================================================


      +============================================================+
      |  MIDAS(Modeling, Integrated Design & Analysis Software)    |
      |  midas Gen - Design & checking system for windows          |
      +============================================================+
      |  RC-Member(Beam/Column/Brace/Wall) Analysis and Design     |
      |  Based On  TWN-USD92, GB50010-02, ACI318-05, ACI318-02,    |
      |            ACI318-99, ACI318-95, ACI318-89, BS8110-97,     |
      |            Eurocode2:04, Eurocode2, CSA-A23.3-94,          |
      |            AIJ-WSD99, KCI-USD07, KCI-USD03, KCI-USD99,     |
      |            KSCE-USD96, AIK-USD94, AIK-WSD2K, IS456:2000    |
      |                                                            |
      |                                           (c)SINCE 1989    |
      +============================================================+
      |  MIDAS Information Technology Co.,Ltd.       (MIDAS IT)    |
      |  MIDAS IT Design Development Team                          |
      +============================================================+
      |            HomePage : www.MidasUser.com                    |
      |            Tel : 360-753-5540,  Fax : 360-753-5542         |
      +============================================================+
      |  Gen 2010                                                  |
      +============================================================+


   *. DEFINITION OF LOAD COMBINATIONS WITH SCALING UP FACTORS.
 -------------------------------------------------------------------------------------
     LCB  C    Loadcase Name(Factor) + Loadcase Name(Factor) + Loadcase Name(Factor)
 -------------------------------------------------------------------------------------
       1  1             DL( 1.400) +          LL( 1.500)
       2  1             DL( 1.400) +          LL( 1.500) +          WX( 0.900)
       3  1             DL( 1.400) +          LL( 1.500) +          WY( 0.900)
       4  1             DL( 1.400) +          LL( 1.050) +          WX( 1.500)
       5  1             DL( 1.400) +          LL( 1.050) +          WY( 1.500)
       6  1             DL( 1.400) +          LL( 1.500) +          WX(-0.900)
       7  1             DL( 1.400) +          LL( 1.500) +          WY(-0.900)
       8  1             DL( 1.400) +          LL( 1.050) +          WX(-1.500)
       9  1             DL( 1.400) +          LL( 1.050) +          WY(-1.500)
      10  1             DL( 1.000) +          LL( 0.300) +          EX( 1.000)
      11  1             DL( 1.000) +          LL( 0.300) +          EY( 1.000)
      12  1             DL( 1.000) +          LL( 0.300) +          EX(-1.000)

Ready                                        Ln 0 / 91 , Col 1        NUM
```

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Parameters for SLS Checking

Concrete long-term and short-term Modulus of elasticity

Serviceability Load Combination

Enter Rebar Data using "Design > Concrete Design Parameter > Modify Beam Rebar Data or "Design > Concrete Code Design > Beam Design > [Update Rebar] button " *1*

Serviceability Limit Control Parameters

1. For serviceability check, entering rebar data is required.

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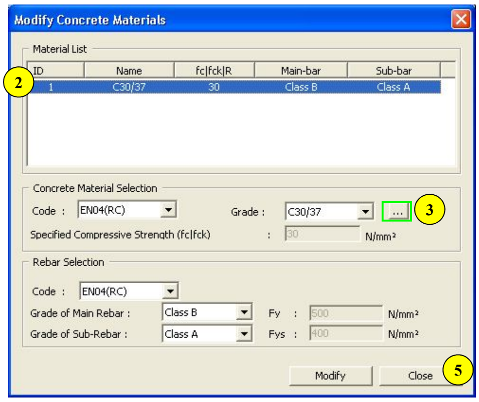
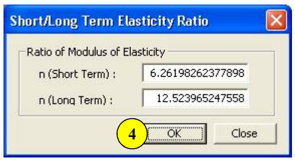
Short/Long Term Elasticity Ratio



1. *Design > Concrete Design Parameter > Modify Concrete Materials…*
2. *Select "C30/37" from Material List.*
3. *Click* ... *button.*
4. *Click* [OK] *button.*
5. *Click* [Close] *button.*



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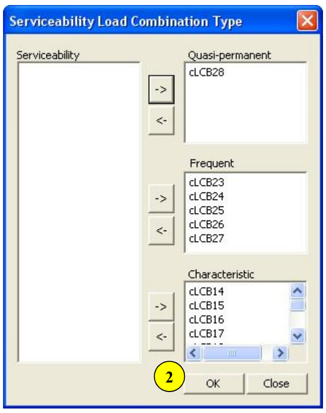
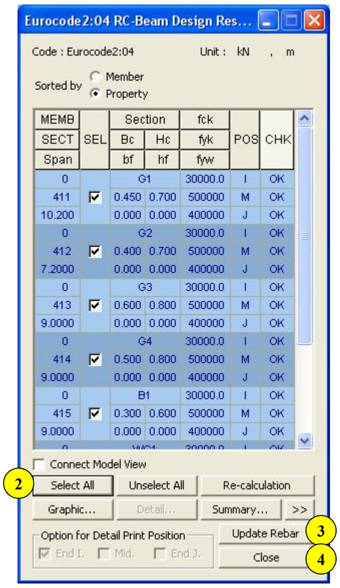
Serviceability Load Combination Type



1. *Design > General Design Parameter > Serviceability Load Combination Type…*
2. *Click* [OK] *button.*

Once the load combinations are generated using "Auto Generation" as per Eurocode2 as in Step 3-1, the program automatically assigns the "Quasi-permanent", "Frequent" and "Characteristic" load combinations.

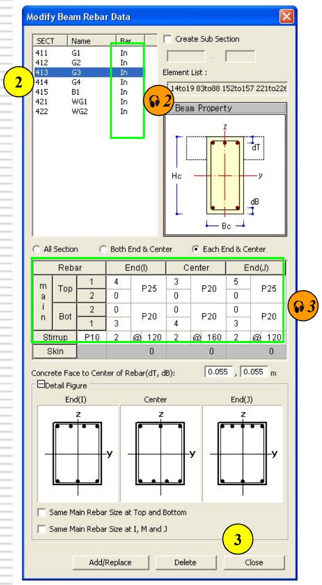
Automatic Rebar Input



1. Design > Concrete Code Design > Beam Design…
2. SEL: click [Select All] *button.*
3. Click [Update Rebar] *button.*
4. Click [Close] *button.*

1. By clicking [Update Rebar] button, the rebars designed in this dialog box will be automatically entered into the selected sections.

View Rebar Data on Section

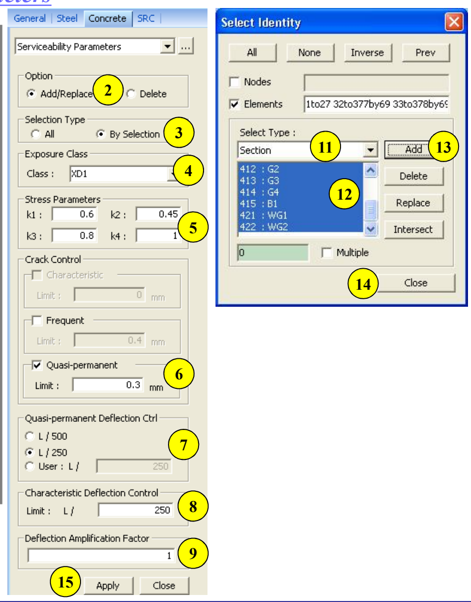


1. Design > Concrete Design Parameter > Modify Beam Rebar Data…
2. SEL: check on ID "413".
3. Click [Close] *button.*

1. In this page, check the Rebar Data entered using [Update Rebar] in the previous page.
2. "In" signifies that Rebar are placed.
3. The entered Rebar Data are displayed.

Enter Serviceability Limit Control Parameters

1. *Design > Concrete Design Parameter > Serviceability Parameters…*
2. *Option: Add/Replace*
3. *Selection Type: By Selection*
4. *Exposure Class: XD1*
5. *Stress Parameters- k1: 0.6, k2: 0.45, k3: 0.8, k4: 1*
6. *Quasi-permanent – Limit: 0.3 mm*
7. *Quasi-permanent Deflection Ctrl: L/250*
8. *Characteristic Deflection Control – Limit: L/250*
9. *Deflection Amplification Factor: 1*
10. *View > Select > Identity…*
11. *Select Type: Section*
12. *Select "411: G1", "412: G2", "413: G3", "414: G4", "415: B1", "421: WG1", "422: WG2"*
13. *Click [Add] Button.*
14. *Click [Close] Button.*
15. *Click [Apply] Button.*



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SLS Checks

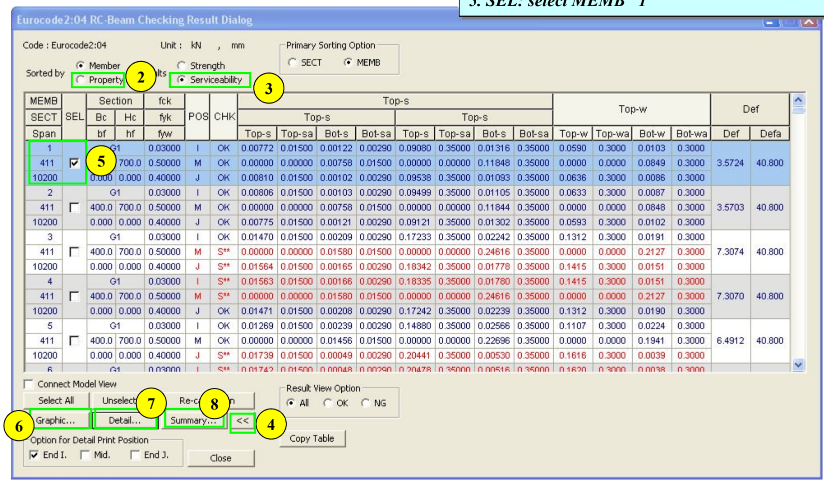
1 Serviceability Checking for Concrete Beam

1. Serviceability check is provided for Beam members for the following limit states.

- ***Stress limitation***
- ***Crack control***
- ***Deflection control***

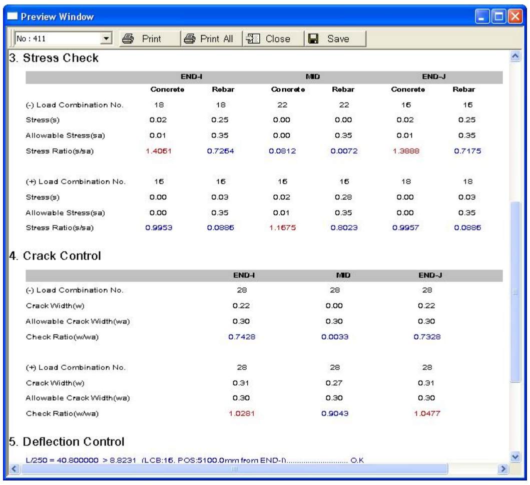
Serviceability Checking (1)

1. *Design > Concrete Code Check > Beam Checking…*
2. *Sorted by: Member*
3. *Results: Serviceability*
4. *Click [>>] to expand the dialog box.*
5. *SEL: select MEMB "1"*



Serviceability Checking (2)

6. *Click* [Graphic…] *button.*



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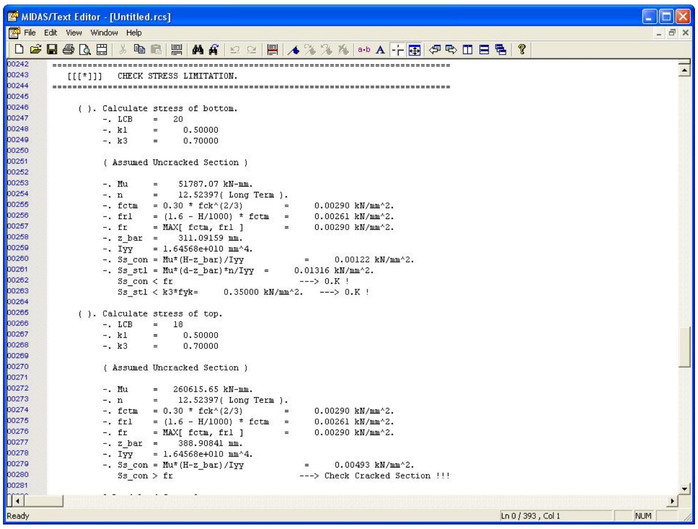
Serviceability Checking (3)

7. Click **[Detail…]** *button.*



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Serviceability Checking (4)

8. Click **[Summary…]** *button.*