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ACCOUNTING FOR IMPERFECTIONS AS PER EUROCODE 2 AND EUROCODE 3 IN ETABS 2016 AND SAP2000 V19

I. Overview

Eurocode 2 and Eurocode 3 requires frame and member imperfections (global and local) be accounted for either in the analysis stage or in the design stage.

Accounting global and local imperfections in the analysis stage of a numerical model can be done by either:

- Modeling the global and/or local imperfections explicitly in the model
- Applying horizontal UDL along vertical member length for local imperfection (applicable for EC3 only)
- Applying Equivalent Horizontal Force (EHF) at each stories for global imperfection.
- Using the buckling mode shapes as initial geometry (applicable for EC3 only)

Accounting global and/or local imperfections in the analysis stage by modelling the frames and members unstraight or crooked, although can be done, will be impractical and time consuming. Similarly, applying horizontal UDL on vertical members to account for local imperfection is only practical when checking the effect on a single vertical element. These methods will not be discussed here.

In EC2 and EC3, global imperfections can be accounted for in the design stage as ECC (eccentricity) on isolated vertical members. Local imperfections in EC3 are accounted for in the design stage by using the relevant buckling shape factors in member buckling check.

This technical note discusses on how to account for imperfections in ETABS 2016 and SAP2000 v19 models.

II. Accounting for Global Imperfection in Design Stage as ECC

The most convenient way to account for global imperfections is to consider it as an ECC in design of isolated vertical members. This method is available in ETABS 2016 and SAP2000 v19 for EC2 design, but not currently available for EC3 design. This will be included for EC3 design in the future software release/updates.

The inclination value will be calculated as:

 $\theta_i = \theta_0 \alpha_h \alpha_m$

where

 θ_0 = is the basic value given as 0.005 (= 1/200) ; [Please check your NDP value] α_m = 1

 $\alpha_h = 2 \div \sqrt{1}$; $2/3 \le \alpha_h \le 1$



I = actual length of the vertical member

The eccentricity due to imperfection will be calculated as:

$$e_i = \theta_i I_0/2$$

The eccentricity e_i shall be equal or bigger than code specified minimum eccentricity:

 $e_{min} = h/30 \ge 20 \text{ mm}$

The resulting geometric imperfection moments, M_{i2} and M_{i3} , will be added to analysis first order moments in a single direction at a time:

 $M_{i2} = e_{i2} N_{Ed}$

 $M_{i3} = e_{i3} N_{Ed}$

Setting **Concrete Frame Design Preference** to account for global imperfection in ETABS 2016 and SAP2000 v19 for EC2 column design:

Go to **Design>Concrete Frame Design>View/Revise Preferences...** and specify Theta0 value.

| | | | item Description |
|---------------|------------------------------------|--|---|
| | Item | Value | The stress ratio limit to be used for acceptability. Stress ratios that are |
| 01 | Design Code | Eurocode 2-2004 | less than or equal to this value are |
| 02 | Country | Singapore | considered acceptable. |
| 03 | Combinations Equation | Eq. 6.10 | |
| 04 | Reliability Class | Class 2 | |
| 05 | Second Order Method | Nominal Curvature | |
| 06 | Multi-Response Case Design | Step-by-Step - All | |
| 07 | Number of Interaction Curves | 24 | |
| 08 | Number of Interaction Points | 11 | |
| 09 | Consider Minimum Eccentricity? | Yes | |
| 10 | Theta0 (ratio) | 0.005 | |
| 11 | GammaS (steel) | 1.15 | |
| 12 | GammaC (concrete) | 1.5 | |
| 13 | AlphaCC (compression) | 0.85 | |
| 14 | AlphaCT (tension) | 1 | |
| 15 | AlphaLCC (lightweight compression) | 0.85 | |
| 16 | AlphaLCT (lightweight tension) | 0.85 | |
| 17 | Pattern Live Load Factor | 0.75 | Explanation of Color Coding for Values |
| ▶ 18 | Utilization Factor Limit | 1 | Blue: Default Value |
| t To D All | efault Values Reset To | Previous Values tems Selected Items | Black: Not a Default Value Red: Value that has changed during the current session |



Setting **Shear Wall Design Preference** to account for global imperfection in ETABS 2016 and SAP2000 v19 for EC2 wall design:

Go to Design>Shear Wall Design>View/Revise Preferences... and specify Theta0 value.

| | ltem | Value | ^ | The selected design code. Subsequent design is based on this |
|----------------|---|-------------------|----|--|
| 01 | Design Code | Eurocode 2-2004 | | selected code. |
| 02 | Multi-Response Case Design | Envelopes - All | | |
| 03 | Rebar Material | H500 | | |
| 04 | Rebar Shear Material | H500 | | |
| 05 | Country | Singapore | | |
| 06 | Combinations Equation | Eq. 6.10 | | |
| 07 | Reliability Class | Class 2 | | |
| 08 | Second Order Method | Nominal Curvature | | |
| 09 | Consider Minimum Eccentricity? | Yes | | |
| 10 | Theta0 (ratio) | 0.005 | | |
| 11 | Force Modification Factor for Shear Design | 2 | | |
| 12 | Curvature Ductility Factor | 2 | | |
| 13 | Gamma (Steel) | 1.15 | | |
| 14 | Gamma (Concrete) | 1.5 | | |
| 15 | Gamma (Shear) | 1.25 | | |
| 16 | AlphaCC | 0.85 | | |
| 17 | AlphaLCC | 0.85 | | Explanation of Color Coding for Values |
| 18 | Number of Curves | 24 | ~ | Blue: Default Value |
| To De All I | fault Values Reset To tems Selected Items Al | Previous Values | ns | Black: Not a Default Value Red: Value that has changed durin the current session |

III. Accounting for Global Imperfection in Analysis Stage as EHF

Global imperfection can be accounted for in analysis stage as EHF defined as notional loads in ETABS 2016 and SAP2000 v19.

This is done by defining notional load patterns for all dead load and live load pattern in both x and y directions.

Click on Define>Load Patterns...

Add a new notional load pattern for each dead and live load patterns for x and y directions. Specify the Load Ratio as the value of calculated θ_i , or conservatively use 0.0005.



| Loads | | | | | | Click To: |
|---|--|----------------|--|--|-----|--|
| | | - | Self Weight | Auto | | Add New Load |
| Load | N. r | lype | Multiplier | Lateral Load | | 70011017 2000 |
| Dead | INOTION: | ai | V 0 | Auto | ~ | Modify Load |
| Live | Live | | o | | | Modify Lateral Load |
| RoofLive GlxDead | Roof L Notion | ive al | 0 | Auto | | |
| GlyDead GlyLive | Notion | al | 0 | Auto | | Delete Load |
| GlyLive | Notion | al | ŏ | Auto | | |
| GlyRoofLive | Notion | al | 0 | Auto | | 04 |
| | | | | | | Cance |
| | Auto Notional | Load Generatio | n | × | | |
| | Notional Load | Value 🗸 | | | | |
| | Base Load | Pattern | Dead | ~ | | |
| | Load Ratio | | (0.0 | 05 | - 0 | $= \theta_0 \cdot \alpha_h \cdot \alpha_m$ |
| | Netterellent | Disenting | C. | | | |
| | Notional Load | Direction | 0.5 | | | |
| | Global | X | Global Y | | | |
| | | | | | | |
| | | | | | | |
| | | OK | Cancel | | | |
| ine Load Patter | ns | OK | Cancel | | | |
| ine Load Patter | ns | ОК | Cancel | | | Click To: |
| ine Load Patter pads Load | ns | ОК | Self Weight Multiplier | Auto Lateral Load | | Click To: Add New Load |
| ine Load Patter pads Load SiyRoofLive | ns | Туре | Self Weight Multiplier | Auto Lateral Load | ~ | Click To: Add New Load |
| ine Load Patter pads Load SiyRoofLive Dead | ns Notiona | Туре | Self Weight Multiplier | Auto Lateral Load | v | Click To: Add New Load Modify Load |
| ine Load Patter bads Load GlyRoofLive Dead Live RoofLive | ns Notiona | OK Type | Self Weight Multiplier | Auto Lateral Load | × | Click To: Add New Load Modify Load Modify Lateral Load |
| ine Load Patter bads Load 3hyRoofLive Dead Live RoofLive GkDead GhDead | ns Notiona | OK Type | Self Weight Multiplier | Auto Lateral Load Auto Auto | × | Click To: Add New Load Modify Load Modify Lateral Load Delete Load |
| ine Load Patter Load StyRoofLive Dead Live RoofLive SkDead SkUive SkUive | ns Notiona | OK Type | Self Weight Multiplier | Auto Auto Auto Auto Auto Auto Auto Auto | | Click To: Add New Load Modify Load Modify Lateral Load Delete Load |
| ine Load Patter Load Load SiyRoofLive Dead Live RoofLive SixDead SixLive SixUead SixLive SixUead SixLive SixLive SixLive SixLive SixLive | ns Notiona Dead Live Roof Li Notiona Notiona Notiona | OK Type | Self Weight Multiplier V 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 | Auto Auto Auto Auto Auto Auto Auto Auto | ~ | Click To: Add New Load Modify Load Modify Lateral Load Delete Load |
| ine Load Patter bads Load BiyRoofLive Dead Live RoofLive SixDead SixLive SixDead SixLive SixRoofLive SixRoofLive | INS | OK Type | Cancel Self Weight Multiplier V 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | Auto Auto Auto Auto Auto Auto Auto Auto | ~ | Click To: Add New Load Modify Load Modify Lateral Load Delete Load |
| ine Load Patter bads Load Dead Live RoofLive SkDead SkDead SkUead SkUive SkRoofLive SkRoofLive SkRoofLive SkRoofLive | ns Notiona Dead Uve Roof Li Ve Ro | OK Type | Self Weight Multiplier V 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 | Auto Lateral Load Auto Auto Auto Auto Auto Auto Auto Auto | ~ | Click To: Add New Load Modify Load Modify Lateral Load Delete Load |
| ine Load Patter bads Load Dead Live RoofLive SixDead SiyDead SiyDead SiyLive SixRoofLive SixRoofLive SixRoofLive ClyRoofLive | Ins Notiona Dead Live Roof Li Vitiona Notiona Notiona Notiona Notiona | OK Type | Self Weight Multiplier 0 1 0 0 0 0 0 0 0 0 0 0 0 | Auto Lateral Load Auto Auto Auto Auto Auto Auto Auto Auto | ~ | Click To: Add New Load Modify Load Delete Load OK Cance |
| ine Load Patter bads Load Dead Live RoofLive SkDead SkDead SkUive SkRoofLive SkRoofLive SkRoofLive SkRoofLive SkRoofLive Notiona | ns Notiona Dead Live Roof Li Ve R | OK Type | Self Weight Multiplier 0 0 0 0 0 0 0 0 0 0 0 0 0 | Auto Lateral Load Auto Auto Auto Auto Auto Auto Auto Auto | | Click To: Add New Load Modify Load Modify Lateral Load Delete Load |
| ine Load Patter bads Load Dead Live RoofLive SkDead SkDead SkDead SkLive SkRoofLive SkRo | ns Notiona Dead Live Roof Li Ve Load Generat Load Value Load Pattem | OK Type | Self Weight Multiplier 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 | Auto Lateral Load Auto Auto Auto Auto Auto Auto Auto Auto | | Click To: Add New Load Modify Load Modify Lateral Load Delete Load |
| ine Load Patter Dads Load Dead Live Bod Live SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkUive SkDead SkLive SkDead SkDead SkLive SkDead SkLive SkDead SkLive SkDead | INS Notional Dead Live Notional Notional Notional Notional Notional Notional Notional Notional Load Generat | OK Type | Cancel Self Weight Multiplier ✓ 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | Auto Lateral Load Auto Auto Auto Auto Auto Auto Auto | | Click To: Add New Load Modify Load Modify Lateral Load Delete Load OK Cance |
| ine Load Patter bads Load SiyRoofLive Dead Live RoofLive SixDead SiyLoed SiyLoed SiyLive SixRoofLive S | INS Notiona Dead Live Roof Liv Notiona | OK Type | Cancel Self Weight Multiplier | Auto Lateral Load Auto Auto Auto Auto Auto Auto Auto Xuto | | Click To: Add New Load Modify Load Modify Lateral Load Delete Load OK Cance |

The value of Load Ratio to be used in defining the EHFs is equal to inclination θ_i from equation below:

 $\theta_i = \theta_0 \alpha_h \alpha_m$

where

 $\begin{array}{l} \theta_0 &= \text{ is the basic value given as } 0.005 \ (= 1/200) \ ; \ [Please check your NDP value] \\ \alpha_m &= \text{number of vertical members contributing to the horizontal force} \\ \alpha_h &= 2 \div \text{VI} \ ; \ 2/3 \leq \alpha_h \leq 1 \\ \text{I} &= \text{height of building} \end{array}$

Cancel

OK



If designing for EC2, set the Theta0 value in the concrete frame and shear wall design preferences with very small value (i.e., 0.000001). This is done so that the effect of global imperfection will not be accounted twice. This step is not required if designing for EC3.

| | | | Item Description |
|----------------|--|---|---|
| | tem | Value | The stress ratio limit to be used for acceptability. Stress ratios that are |
| 01 | Design Code | Eurocode 2-2004 | less than or equal to this value are |
| 02 | Country | Singapore | considered acceptable. |
| 03 | Combinations Equation | Eq. 6.10 | |
| 04 | Reliability Class | Class 2 | |
| 05 | Second Order Method | Nominal Curvature | |
| 06 | Multi-Response Case Design | Step-by-Step - All | |
| 07 | Number of Interaction Curves | 24 | |
| 08 | Number of Interaction Points | 11 | set to small value |
| 09 | Consider Minimum Eccentricity? | Yes | if geometric |
| 10 | Theta0 (ratio) | 0.000001 | imperfection is |
| 11 | GammaS (steel) | 1.15 | accounted for in |
| 12 | GammaC (concrete) | 1.5 | the englycic |
| 13 | AlphaCC (compression) | 0.85 | |
| 14 | AlphaCT (tension) | 1 | stage as EHF. |
| 15 | AlphaLCC (lightweight compression) | 0.85 | |
| 16 | AlphaLCT (lightweight tension) | 0.85 | |
| 17 | Pattern Live Load Factor | 0.75 | Explanation of Color Coding for Values |
| ▶ 18 | Utilization Factor Limit | 1 | Blue: Default Value |
| et To D All | efault Values Reset To Items Selected Items All | Previous Values Items Selected Items | Black: Not a Default Value Red: Value that has changed during the current session |

| | ton | Value | <u>^</u> | The minimum ratio of reinforcing |
|--------------|--|-------------------------------------|----------|--|
| 01 | Design Code | a Code Europode 2-2004 | | considered in the design of a pier with a Uniform/Section Designer section |
| 02 | Multi-Response Case Design | Envelopes - All | - 1 | a onnonivocción ocaigner acción. |
| 03 | Rebar Material | H500 | | |
| 04 | Rebar Shear Material | H500 | | |
| 05 | Country | Singapore | | |
| 06 | Combinations Equation | Eq. 6.10 | | |
| 07 | Reliability Class | Class 2 | | |
| 08 | Second Order Method | Nominal Curvature | | |
| 09 | Consider Minimum Eccentricity? | Yes | | |
| 10 | Theta0 (ratio) | 0.000001 | | |
| 11 | Force Modification Factor for Shear Design | 2 | | |
| 12 | Curvature Ductility Factor | 2 | | |
| 13 | Gamma (Steel) | 1.15 | | |
| 14 | Gamma (Concrete) | 1.5 | | |
| 15 | Gamma (Shear) | 1.25 | | |
| 16 | AlphaCC | 0.85 | | |
| 17 | AlphaLCC | 0.85 | | Explanation of Color Coding for Values |
| 18 | Number of Curves | 24 | ~ | Blue: Default Value |
| To De All | efault Values Reset To Items Selected Items All | Previous Values Items Selected Iter | ns | Black: Not a Default Value Red: Value that has changed durin the current session |



The design load combinations should also be updated to include these effects.

Click on **Define>Load Combinations...** and modify/create design load combinations to include the generated EHF load cases with the appropriate load factors. Use positive and negative values for opposing directions.

| ieneral Data | UDCoo2 |
|---|--|
| Combination Type | Linear Add |
| Netes | |
| Notes | Modify/Show Notes |
| Auto Combination | No |
| Define Combination of Load Case | /Combo Results |
| Load Name | Scale Factor |
| Dead | 1.35 Add |
| Live | 1.5 Delete |
| GlyDead | 1.5 |
| GlxLive | 1.5 |
| GlxRoofLive | 1.5 |
| ad Combination Data | OK Cancel |
| ad Combination Data General Data Load Combination Name | DK Cancel - UDCon2-1 |
| ad Combination Data General Data Load Combination Name Combination Type | OK Cancel - UDCon2-1 Linear Add |
| ad Combination Data General Data Load Combination Name Combination Type Notes | DK Cancel |
| ad Combination Data General Data Load Combination Name Combination Type Notes Auto Combination | OK Cancel |
| ad Combination Data General Data Load Combination Name Combination Type Notes Auto Combination Define Combination of Load Case | OK Cancel |
| ad Combination Data General Data Load Combination Name Combination Type Notes Auto Combination Define Combination of Load Case | DK Cancel |
| ad Combination Data General Data Load Combination Name Combination Type Notes Auto Combination Define Combination of Load Case Load Name Dead | OK Cancel Cancel UDCon2-1 Linear Add Modify/Show Notes No s/Combo Results Scale Factor 1.35 Add |
| ad Combination Data General Data Load Combination Name Combination Type Notes Auto Combination Define Combination of Load Case Load Name Dead Live | DK Cancel Cancel Cancel Combo Results Combo Results Combo Results Add Delete Add Delete Combo Results Combo Results |
| ad Combination Data General Data Load Combination Name Combination Type Notes Auto Combination Define Combination of Load Case Load Name Dead Live RoofLive | DK Cancel |
| ad Combination Data General Data Load Combination Name Combination Type Notes Auto Combination Define Combination of Load Case Load Name Dead Live RoofLive GixDead | DK Cancel |
| ad Combination Data General Data Load Combination Name Combination Type Notes Auto Combination Define Combination of Load Case Load Name Dead Live RoofLive GixDead GixLive CirdBeaffing | DK Cancel Cancel Cancel Combo Results Combo Results Combo Results Combo Results Add Delete 1.5 -1.35 -1.5 1.5 -1.5 1.5 -1.5 -1.5 |

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IV. Accounting for Local Imperfection in Design Stage

ETABS 2016 and SAP2000 v19 automatically accounted for local imperfection effect by the relevant buckling and imperfection factors as per EC3 in the design for buckling resistance of vertical steel members. This is done automatically and no additional input is required.

$$\frac{\frac{N_{Ed}}{\chi_{y}N_{Rk}}}{\gamma_{Ml}} + k_{yy}\frac{\frac{M_{y,Ed} + \Delta M_{y,Ed}}{\chi_{LT}}}{\frac{M_{y,Rk}}{\gamma_{Ml}}} + k_{yz}\frac{\frac{M_{z,Ed} + \Delta M_{z,Ed}}{\frac{M_{z,Rk}}{\gamma_{Ml}}} \le 1$$

$$\frac{\frac{N_{Ed}}{\chi_{z}N_{Rk}}}{\frac{\chi_{Rk}}{\gamma_{Ml}}} + k_{zy}\frac{\frac{M_{y,Ed} + \Delta M_{y,Ed}}{\chi_{LT}}}{\frac{M_{y,Rk}}{\gamma_{Ml}}} + k_{zz}\frac{\frac{M_{z,Ed} + \Delta M_{z,Ed}}{\frac{M_{z,Rk}}{\gamma_{Ml}}} \le 1$$

$$(6.61)$$

γ_{MI}

The reduction factor, χ for the relevant buckling mode is taken as:

$$\left(\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \overline{\lambda}^2}} \le 1.0\right)$$
(EC3 6.3.1.2(1))

where the factor, Φ and the non-dimensional slenderness, $\overline{\lambda}$ are taken as:

$$\Phi = 0.5 \left[1 + \alpha (\overline{\lambda} - 0.2) + \overline{\lambda}^2 \right]$$
(EC3 6.3.1.2(1))
$$\overline{\lambda} = \sqrt{\frac{Af_y}{N_{cr}}} = \frac{L_{cr}}{i} \frac{1}{\lambda_1}, \text{ for Class 1, 2 and 3 cross-sections (EC3 6.3.1.3(1))}$$
$$\overline{\lambda} = \sqrt{\frac{A_{eff}f_y}{N_{cr}}} = \frac{L_{cr}}{i} \frac{\sqrt{A_{eff}/A}}{\lambda}, \text{ for Class 4 cross-sections (EC3 6.3.1.2(1))}$$

The reduction factor χ_{LT} is taken as:

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \overline{\lambda}_{LT}^2}} \le 1.0$$
(EC3 6.3.2.2(1))

where the factor, Φ , and the non-dimensional slenderness, $\overline{\lambda}_{LT}$ are taken as:

$$\Phi_{LT} = 0.5 \left[1 + \alpha_{LT} \left(\overline{\lambda}_{LT} - 0.2 \right) + \overline{\lambda}_{LT}^2 \right]$$
(EC3 6.3.2.2(1))
$$\overline{\lambda}_{LT} = \sqrt{\frac{W_y f_y}{M_{cr}}}$$
(EC3 6.3.2.2(1))

γ_{MI}



ETABS 2015 Steel Frame Design

Eurocode 3-2005 Steel Section Check (Strength Summary)

SAMPLE EC3 CALCULATION SUMMARY



Element Details (Part 1 of 2)

| Level | Element | Unique Name | Length (mm) | Location (mm) | Combo | Design Type | Element Type |
|--------|---------|-------------|-------------|---------------|------------|-------------|--------------|
| Story3 | C7 | 19 | 4000 | 3596.8 | UDStIS10-1 | Column | DCL MRF |

Element Details (Part 2 of 2)

| Section | Classification | Rolled |
|---------------|----------------|--------|
| UKC305X305X97 | Class 3 | Yes |

Design Parameters

| National Annex | Combination Equation | Analysis Type | Reliability |
|----------------|----------------------|--------------------|-------------|
| Singapore | Eq. 6.10 | Method 2 (Annex B) | Class 2 |

Design Code Parameters

| ¥ мо | ¥м | ¥ M2 | A _n /A _g | LLRF | PLLF | Stress ratio Limit |
|------|----|------|--------------------------------|------|------|--------------------|
| 1 | 1 | 1.1 | 1 | 1 | 0.75 | 0.95 |

Section Properties

| A (cm | 1²) | l ₁₇ (c | m*) | i _w (m | m) | W _{*kyy} (cm ³) | | ') | A _{xy} (cm ²) | | W _{play} (cm ³) | | | I _{ye} (cm*) | | I _t (cr | m*) | |
|-------|------------|----------------------|-----|--------------------|----------------|--------------------------------------|--------|-----------------|------------------------------------|--------------------------------|--------------------------------------|--------------------|---|-----------------------|------|--------------------|-----|--|
| 123 | | 222 | 49 | 134. | 5 | 144 | | 1445.2 | | 30.5 159 | | 592 | | 0 | | 91. | 2 | |
| | I == (cm*) | |) i | _{=z} (mm) | V | N _{si,zz} (cm | "(cm³) | | _{v,z} (cr | z (cm²) W _{pl,zz} (cn | | n²) l _w | | I., (cm*) | | ım) | | |
| - | | 7308 77.1 478.7 95.6 | | 726 15 | | 15 | 62218 | 307 | 7.9 | | | | | | | | | |
| | | | A. | (cm²) | e _N | , (mm) | e, | ي (m | m) | W | el.yy | (cm³) | W | el.22 | cm³) | | | |
| | | _ | 1 | 23 | | 0 | | 0 | | | 144 | 5.2 | | 478 | .7 | | | |

Material Properties

| E (MPa) | f _y (MPa) | f _u (MPa) |
|---------|----------------------|----------------------|
| 210000 | 275 | 430 |

Stress Check Forces and Moments

| Location (mm) | N Ed (kN) | M Ed.yy (kN-m) | M Ed,zz (kN-m) | V Ed,z (kN) | V Ed.y (kN) | T Ed (kN-m) |
|---------------|-----------|----------------|----------------|-------------|-------------|-------------|
| 3596.8 | -121 | -71 | 35 | 36 | -17 | 0 |

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| SAN | | | | D/ | C Ratio = | N _{Ed} /N _{Rd} + M _{z,Ed} /M _{z,Rd} | M _{y,Ed} /M | _{y,Rd} + | | |
|-----|-------|--------------|-----------|-----------------------------|-----------|--|----------------------|--------------------------------|-------------------|---------------------------------|
| CAL | CUL | AII | OIA | | 0.477 | - 0.032 + 0 | 0.263 | | | |
| SL | JMM | AR' | Y | | Bas | ic Factors | | | | |
| | | | Buckl | ing Mode | K Factor | L Factor | L Ler | ngth (mm) | L _a /i | - |
| | | | Ма | (or (y-y) | 1.834 | 0.899 | 3 | 3596.8 | 49.035 | _ |
| | | | Majo | or Braced | 1 | 0.899 | 3 | 3596.8 | 26.743 | _ |
| | | | Min | 10r (z-z) | 1.327 | 0.899 | : | 3596.8 | 61.899 | - |
| | | | Mino | or Braced | 1 | 0.899 | 3 | 3596.8 | 46.663 | _ |
| | | | | LTB | 1.327 | 0.899 | 3 | 3596.8 | 61.899 | _ |
| | | | | | Axial F | orce Desi | gn | | | - |
| | | N ≊a F ki | orce N | N _{c,Rd} Cap kN | pacity | N _{t,Rd} Capa kN | acity | N _{byy.Rd} M kN | ajor | N _{bez,Rd} Minor kN |
| | Axial | -12 | 21 | 338 | 3 | 3383 | | 2890 | | 2424 |
| | | | | N pl.Rd | NuRd | N _{cr,T} | N _{G,TF} | A _n /A _g | | |

Demand/Capacity (D/C) Ratio 6.2.1(7), 6.2.9.2(1)

 kn
 kn
 kn
 kn
 Unitless

 3383
 4327
 8984
 8984
 1

 Design Parameters for Axial Design
 Composition
 Composition

| | Curve | α | N _{cr} (kN) | <u>∧</u> | Φ | X | N bd.Rd (kN) |
|--------------|-------|------|----------------------|----------|-------|-------|--------------|
| Major (y-y) | D | 0.34 | 10602 | 0.565 | 0.722 | 0.854 | 2890 |
| MajorB (y-y) | D | 0.34 | 35645 | 0.308 | 0.566 | 0.961 | 2890 |
| Minor (z-z) | c | 0.49 | 6654 | 0.713 | 0.88 | 0.717 | 2424 |
| MinorB (z-z) | c | 0.49 | 11708 | 0.537 | 0.727 | 0.822 | 2424 |
| Torsional TF | c | 0.49 | 8984 | 0.614 | 0.79 | 0.777 | 2629 |

Moment Designs

| | | | - | | | |
|-------------|--------------------|-------------------------------------|------------------------------------|---------------------------|---------------------------|------------------------------------|
| | M ≝dMoment kN-m | M _{Ed,apan} Moment kN-m | M _{∈,R⊌} Capacity kN-m | M _{v,Rd} kN-m | M _{n,Rd} kN-m | M _{b,Rd} Capacity kN-m |
| Major (y-y) | -71 | -71 | 397 | 397 | 397 | 384 |
| Minor (z-z) | 35 | 35 | 132 | 132 | 132 | |

| | | | | Moment D | esigns | | | | | | |
|-------------|---------|---------------|---------|-----------------|-----------------|-----|-----|-------|-----|------|------------------------|
| | Section | Flange | Web | ε (U | nitless) | | a | (Unit | les | 5) | ψ (Unitless) |
| Compactness | Class 3 | Class 3 | Class 1 | 0 | .924 | | | 0.5 | 8 | | -0.928 |
| | Curve | α_{LT} | | λ _{LT} | Ф _{LT} | | X | LT | (| C1 | M _{cr} (kN-m) |
| LTB | a | 0.21 | | 0.35 | 0.577 | | 0.9 | 65 | (| 2.7 | 3236 |
| | | C my | C ma | CmLT | k _w | k, | yz. | k, | y | k, | z |
| | Factors | 0.4 | 0.4 | 0.4 | 0.403 | 0.4 | 06 | 0.99 | 12 | 0.40 | 06 |

| | | | • | | |
|-----------|-----------------|---------------------------------|---------------------------------|--------------|--------------|
| | V Ed Force (kN) | V _{c,Rd} Capacity (kN) | T _{Ed} /Torsion (kN-m) | Stress Ratio | Status Check |
| Major (z) | 36 | 484 | 0 | 0.075 | OK |
| Minor (y) | 17 | 1517 | 0 | 0.011 | ок |

Shear Design

V. Using Buckling Mode Shape as Modified Geometry to Account for Global and/or Local Imperfection in Analysis Stage

As per EC3, the assumed shape of global imperfections and local imperfections may also be derived from the elastic buckling mode of a structure in the plane of buckling considered.

The deformed geometry of any Buckling Analysis load case can then be used as modified geometry of the structure to account for global and/or local imperfections.



This method is useful for modelling non-building structures (e.g., domes, etc.) wherein modelling global imperfection as EHF may not be applicable anymore.

This method requires engineering judgment and experience in selecting which buckling load case and mode to use. This may also mean that a single structure will have to be saved in multiple models with different deformed geometry for analysis and design.

After running the buckling analysis load cases, click on Analyze>Modify Undeformed Geometry...

Select the buckling load case and one of its mode shape to be used to modify the initial geometry.

| Current Undeformed Geometry | Modification Type | | | |
|---|----------------------------|----------------------|----------------------|---------------------------------|
| None | | | | |
| Undeformed Geometry Modific | ation Options | | | |
| O Target Displacement Re | vise Original Joint Coordi | nates by Subtracting | Displacements Obtain | ned From this Case |
| Load Case | | | | |
| Scale Factor for Disp | placements | | | |
| Scaled mode Shape mod | aity Original Geometry Ba | sed on the Shape of | this Mode | |
| Load Case Mode Maximum Displaceme | any Original Geometry Ba | sed on the Shape of | Buck1-1 | 1000 mm |
| Load Case Mode Maximum Displaceme Direction | ent | sed on the Shape of | Buck1-1 | 1 v 1000 mm (i) Resultant |
| Load Case Mode Maximum Displaceme Direction Reinstate Original Undeform | ent O X | sed on the Shape of | Buck1-1 | 1 v 1000 mm @ Resultant |