Timber Module

Info

Timber Module 6.0

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Datum: 110930

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1 Introduction

1.1 General

With the program **Timber Module** continuous beams and plane frame structures can be designed according to EuroCode EC5. The **Timber Module** is used together with the program **Frame Analysis** in which calculations of section forces is performed.

Design with consideration taken to flexural buckling in the frame plane can be performed for second order theory or for first order theory with help from buckling lengths defined by the user.

Continuous support, as well as support in certain points of the beam as well as transverse stiffeners for open cross-sections can be defined.

The program displays all code prescribed checks depending on type of section and current load.

1.2 Restrictions

Support conditions can be defined as hinged, fixed or free edge with consideration to buckling and lateral instability.

Important! A node defined with the **Member** tool will automatically be considered laterally restrained with respect to flexural buckling out of the frame plane at a possible design. Control of instability out of the frame´s plan is then performed with regard to these defined support conditions.

With the help of the support conditions for each node specified under the option **Support Conditions** equal to one of four Euler buckling cases a reduction factor for flexural buckling, torsional buckling or flexural torsional buckling is calculated and the most dangerous value is chosen. These support conditions are also used for calculating lateral torsional buckling.

The conditions for the program are such that each node is assumed supported out of the plane in such a way that corresponds to one of these buckling cases.

If a larger buckling length with regard to instability out of the plane than what corresponds to one of the above buckling cases can be assumed, the node should instead be defined with the tool **Unsupported joint**.

The node is then only considered to have sufficient torsional stiffness to be assumed as a hinged support with regard to lateral torsional buckling and flexural buckling is calculated for a buckling length assumed to extend between the nearest supported nodes. If with the above procedure it is not possible to adequately model the reality regarding instability out of the plane, the calculation can alternatively be supplemented with a 2-dimensional calculation also perpendicular to the frame plane.

2 Program structure

2.1 Design

When the calculation has been completed the **Design** program mode is enabled, and the appearance of the main menu changes as seen below. The **Design** option in the main menu makes it possible to define any additional information that may occur for a design check as well as study the results of the calculation.

Note! This mode is only available if **Timber Module** has been installed.
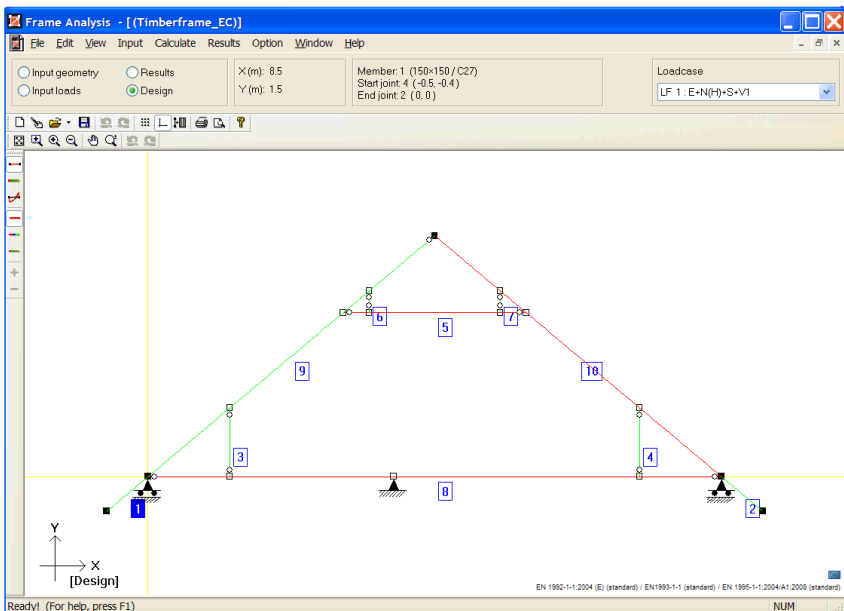
2.2 Input
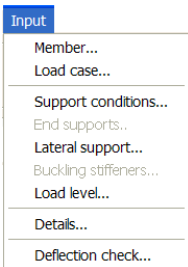
The **Input** menu option makes it possible to define possible additional information for a design. Under **Input** the **Member**, **Load case**, **Support conditions**, **Lateral support**, **Load level**, **Details** and **Deflection check** options are situated.

2.2.1 Member
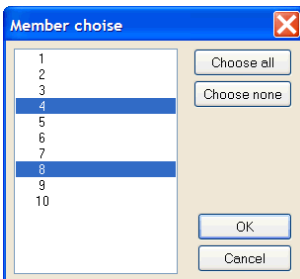
The **Member** option displays a dialog-box in which you can select requested members.

2.2.2 Load case
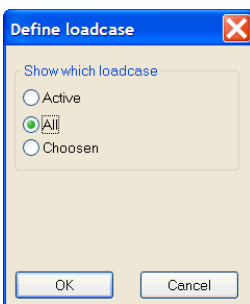
In **Load case** the load cases to be calculated for design check can be chosen.

2.2.3 Support conditions

In the **Support conditions** dialog buckling lengths are defined regarding buckling in the frame plane if the analysis has been performed according to 1st order theory. Here is also support conditions regarding buckling out of frame plane defined. Initially all members defined with the tool **Member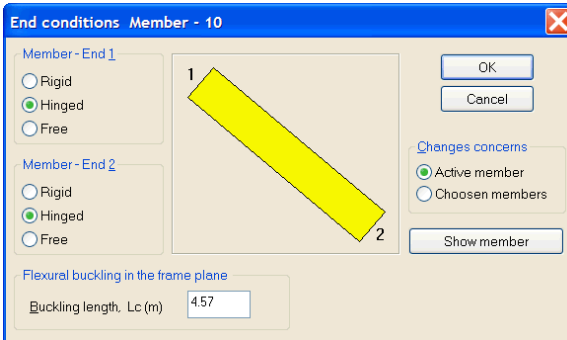** in **Frame Analysis** is supposed to have hinged support conditions at both ends. This means that the buckling length is equal to the member length.

Note! A joint that has been defined with the tool **Member** will automatically be regarded as supported with regard to buckling out of the frame plane. If no lateral support with regard to flexural buckling is expected the tool **Unsupported joint** should be used instead.
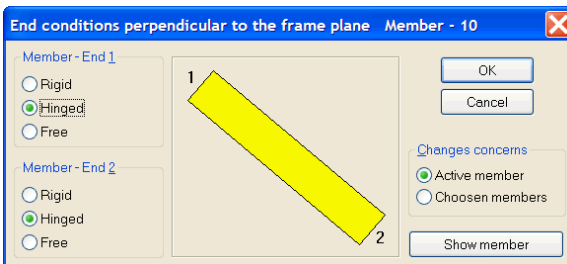
If design is performed according to 2nd order theory only support conditions regarding buckling out of frame plane should be defined.

When defining, only the active member or selected members are affected depending on what is defined above. In the above picture only 1 member is selected which is seen in the title row of the dialog. In order to make it possible to define support conditions at least one member must be selected. To make it possible to define a free end the other end must be fixed.

2.2.4 Lateral supports

In the **Lateral supports** dialog the user can define lateral support to reduce instability out of the frame plane. **Lateral supports** are defined as continuous or single supports. When a lateral support has been defined it will prevent the member to bend sideways in the support point. This requires the side supporting structure to have enough strength to be able to prevent the lateral movement.

Max number of lateral point supports allowed are **10**. The single supports may not be defined closer to each other or to a member end than **L/10**.

Lateral support cannot be defined for circular sections.

2.2.4.1 Continuous supports
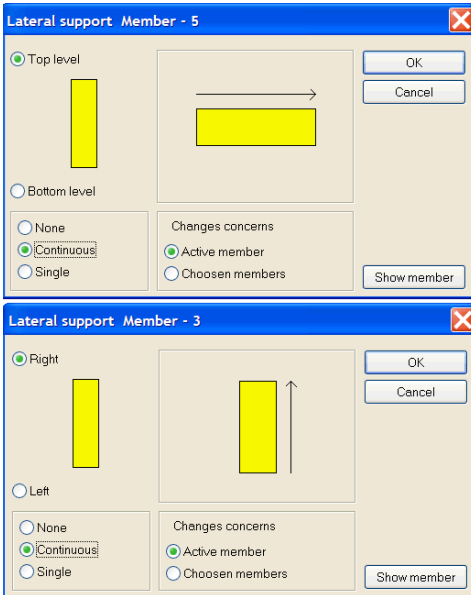
Continuous supports can be defined for one or both edges of the section.

In the above dialogs the top edge of a beam member (member 5) and the right side of a column member (member 3) are defined continuously supported in the weak direction.

What is defined will only affect the active member or the chosen members depending on the above choice.

2.2.4.2 Single supports

Single supports can be defined for one or both edges of the section. Maximum number of supports is **10**. The supports must not be situated closer to each other or to a member end than **L/10**.
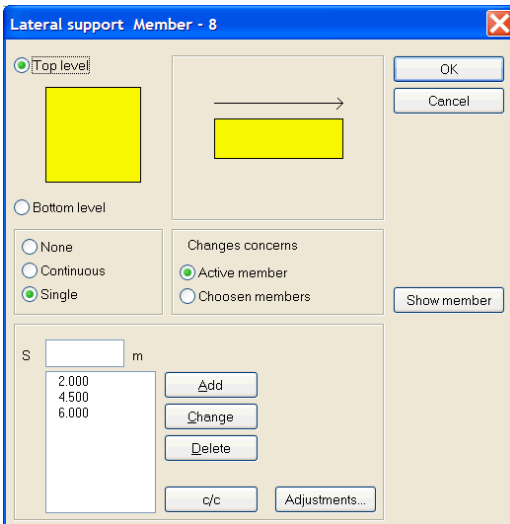
In the above dialog the upper edge of a beam element is supported at four points situated 1,0 m, 2,0 m 3,0 and 4.0 m from the left member end.

2.2.5   Load level
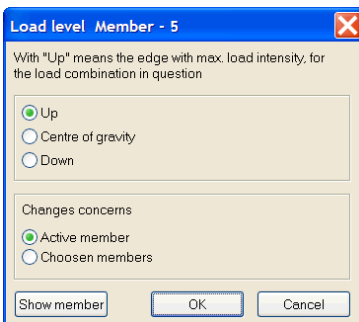
For members sensitive to lateral torsional buckling the capacity depends on the level where the loads are situated.

In the dialog is shown how the load level is defined. The program knows in what direction the loads act and can place the load accordingly.

2.2.6 Details

When the option **Details** is chosen a window showing the current member is presented as a beam or a column.
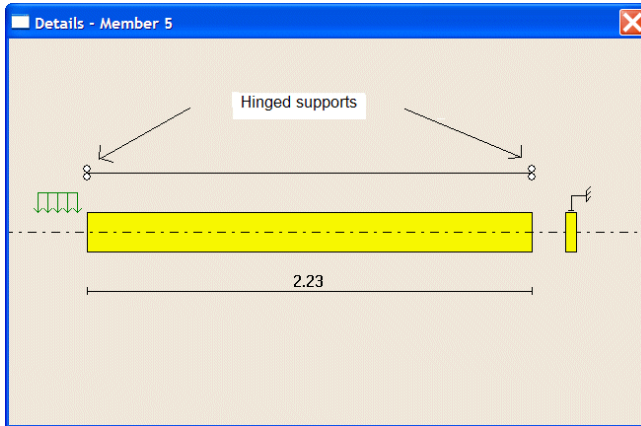
Details can only be defined if the member's stiff direction is in the frame plane. From the picture above the current support conditions can be seen.
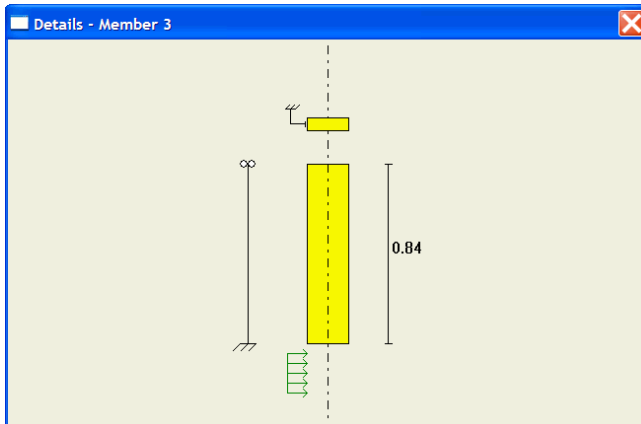
The picture above shows a column member where the left edge is defined continuously supported. For a continuously supported edge the supports are as-

sumed to be situated so closely along the whole member that no instability can occur between the supports.

If both edges are continuously supported, no flexural buckling in the weak direction, flexural-torsional buckling or lateral torsional buckling can occur. If only one edge is supported flexural-torsional buckling can occur.

For lateral torsional buckling the capacity depends on how large part of the supported edge that is in compression. If an edge is in compression along the entire member and continuously supported no lateral torsional buckling is possible but if the supported edge is in tension the capacity is calculated with regard to this. The connection between the supports and the member is assumed to be hinged.

The picture above shows single supports at the top edge for a beam member. or single supports instability between these supports can occur. When calculatin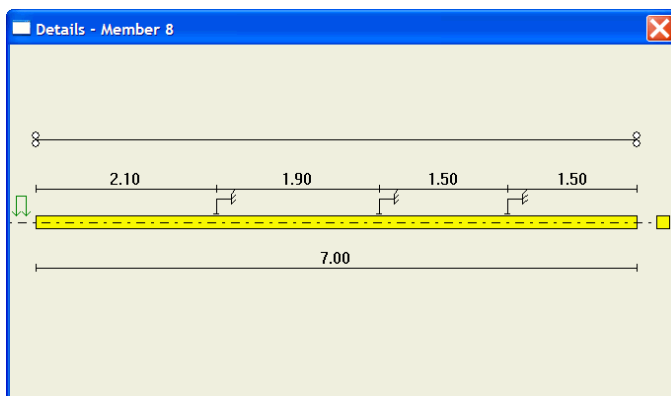g the capacity due to pure flexural buckling in the weak direction the buckling length is calculated with regard to all single supports regardless which edge these are situated on. For flexural-torsional buckling the buckling length is calculated with regard to single supports situated at the same edge and the maximum length from the two edges will be decisive.

The capacity due to lateral torsional buckling is only dependent of single supports defined at an edge in compression for the current load case. No consideration to possible supports defined at an edge in tension.

Simple supports at the top edge of a beam member
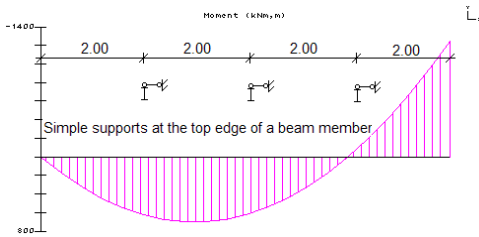
For a beam member with moment distribution and lateral support as above no consideration is made to the rightmost support concerning lateral torsional buckling as the top edge is in tension at this point. The calculation will thus be made for three areas with length 2,0 m, 2,0 m and 4,0 m. If single supports are defined at an edge which is totally or partly in compression no consideration is made to a possible continuous support at the other edge.

The calculation of the elastic critical lateral torsional buckling moment assumes a linearly varying moment distribution between the supports. A check is therefore made if the supports are situated close enough for such an assumption.
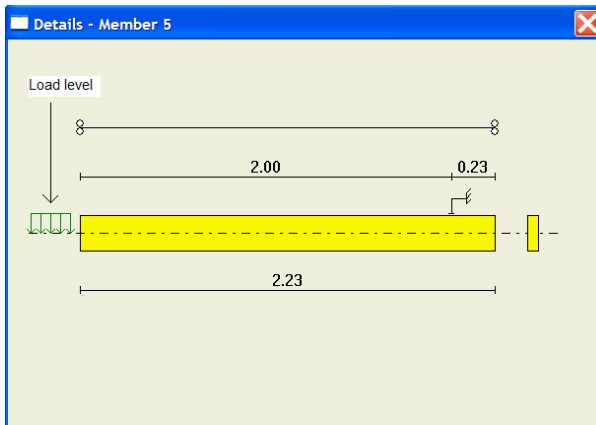
The picture shows how buckling stiffeners are displayed for a beam member.

2.2.7 Deflection check
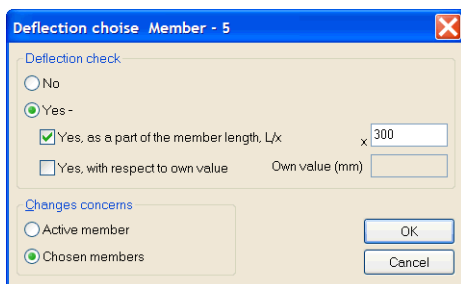
In the **Deflection check** dialog a deflection check for active or selected members are defined. The deflection check can then be performed with respect to a factor of current span length or a stated value.

In the latter case the same criterion will be used for all selected members.

2.3 Results
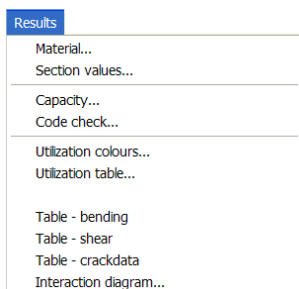
The **Results** menu option makes it possible to study the results generated by the calculation. Under **Results** the following options can be found: **Material**, **Section values**, **Capacity**, **Code check**, **Utilization colours and Utilization table**. The remaining options are only relevant for concrete members.

2.3.1 Material

Material design strengths are shown in the **Material** dialog box.

2.3.2 Section values

The **Section values** option displays a graphic picture of the current profile with associated geometrical properties and the calculated section classes.
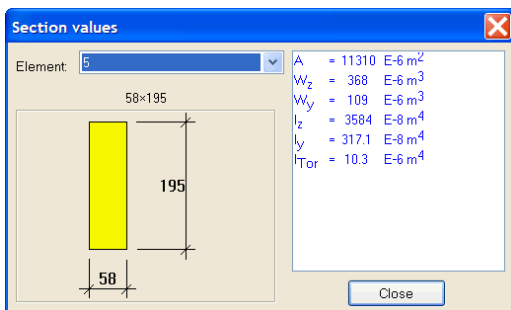
In the above picture a section with section values is shown.

2.3.3 Capacity

The **Capacity** option displays a dialog box where the capacity of the active member with regard to instability corresponding to the current section forces is displayed. What is shown depends on section type, loading and possible lateral bracing. Below the appearance of the capacity dialog box for some cases are shown:

Moment and shear force in stiff direction. Unsupported member. Rectangular section.
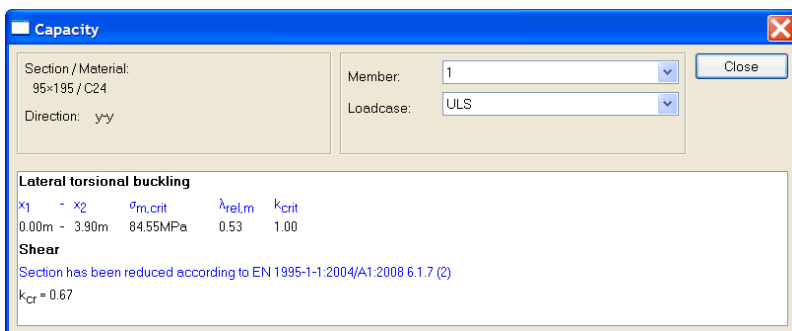
In the above picture the critical lateral torsional buckling moment and the reduction factor with regard to lateral torsional buckling are shown together with the value of the reduction factor with regard to shear.

Axial force and moment in stiff direction. Unsupported member. Rectangular section.
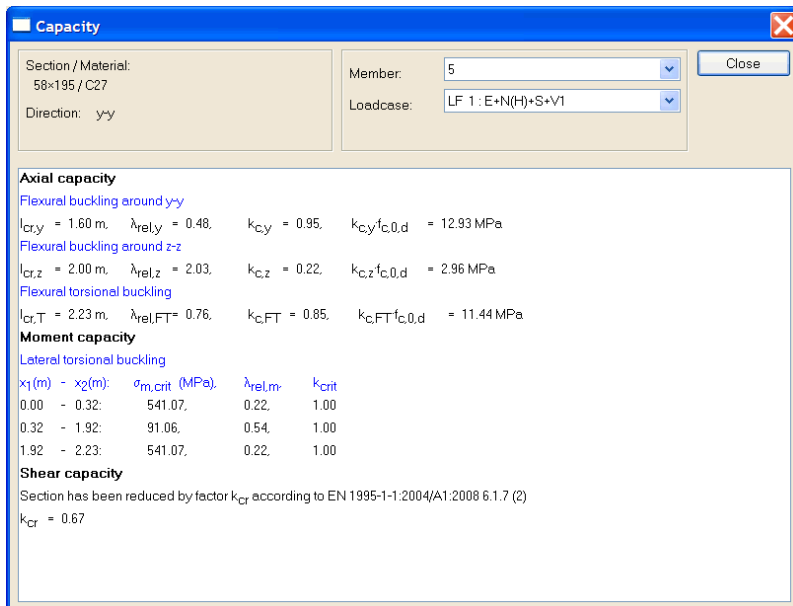
Above is shown the capacity window for a 1th order design. $l_{cr,y}/l_{cr,z}/l_{cr,T}$ are the buckling lengths and $k_{c,y}/k_{c,z}/k_{c,T}$ are the reduction factor for flexural and torsional buckling respectively.

2.3.4   Code Check

The **Code Check** option displays for the active member at Ultimate Limit State all capacity checks according to EC5 as well as a possible deflection check for the Serviceability Limit State. It is also shown where the most critical section is

located, and if upper or lower edge is critical. For vertical members the right side corresponds to the upper edge. What is displayed depends on section type, loading and possible lateral bracing. Checks that might indicate that the load-bearing capacity is insufficient are shown with red text. The sum of the interaction formula displayed is the maximum value along the member length for the current load case.

If more than one load case is defined the maximum utilization with regard to all load cases are displayed for each code check and also which load case that is decisive.

Moment and shear force in stiff direction. Unsupported member. Rectangular section.
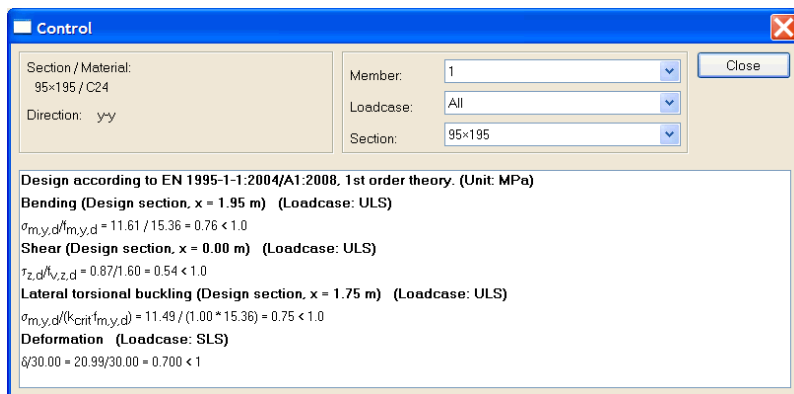
Axial force, moment and shear force in stiff direction. Unsupported member. Rectangular section. 1th order design.

Control

Section / Material:
250x500 / GL 32h

Direction: y-y

Member: 1
Loadcase: All
Section: 250x500

Close

Design according to EN 1995-1-1:2004/A1:2008, 1st order theory. (Unit: MPa)

Maximum stress check (Design section, x = 5.00 m) (Loadcase: ULS2)

$(\sigma_{c,0,d}/f_{c,0,d})^2 + \sigma_{m,y,d}/f_{m,y,d} = (0.08/20.88)^2 + 10.87/25.15 = 0.43 < 1.0$

Shear (Design section, x = 0.00 m) (Loadcase: ULS2)

$\tau_{z,d}/f_{v,z,d} = 0.67/2.74 = 0.25 < 1.0$

Flexural buckling around y-y (Design section, x = 5.00 m) (Loadcase: ULS2)

$\sigma_{c,0,d}/(k_{c,y} \cdot f_{c,0,d}) + \sigma_{m,y,d}/f_{m,y,d} = 0.08/(0.96 \cdot 20.88) + 10.87/25.15 = 0.44 < 1.0$

Flexural buckling around z-z (Design section, x = 5.00 m) (Loadcase: ULS2)

$\sigma_{c,0,d}/(k_{c,z} \cdot f_{c,0,d}) + k_m \cdot \sigma_{m,y,d}/f_{m,y,d} = 0.08/(0.66 \cdot 20.88) + 0.70 \cdot 10.87/25.15 = 0.31 < 1.0$

Flexural and lateral torsional buckling (Design section, x = 4.75 m) (Loadcase: ULS2)

$(\sigma_{m,y,d}/(k_{crit} \cdot f_{m,y,d}))^2 + \sigma_{c,0,d}/(k_{c,z} \cdot f_{c,0,d}) = (10.67/(1.00 \cdot 25.15))^2 + 0.08/(0.66 \cdot 20.88) = 0.19 < 1.0$

Axial force, moment and shear force in stiff direction. Unsupported member. Rectangular section. 2nd order design.

Control

Section / Material:
250x500 / GL 32h

Direction: y-y

Member: 1
Loadcase: All
Section: 250x500

Close

Design according to EN 1995-1-1:2004/A1:2008, 2nd order theory. (Unit: MPa)

Maximum stress check (Design section, x = 5.00 m) (Loadcase: ULS2)

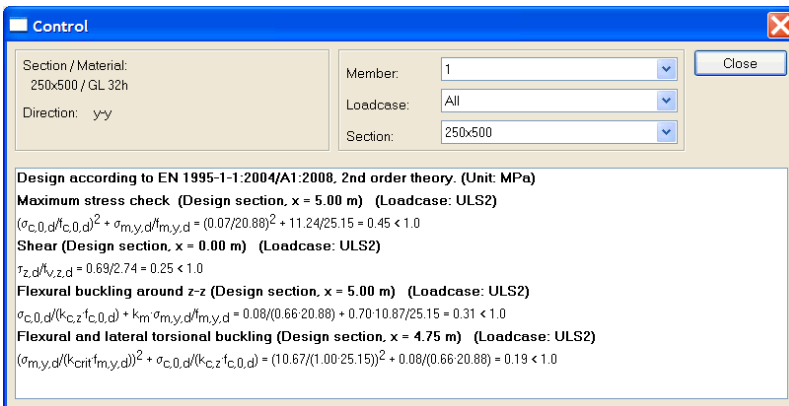$(\sigma_{c,0,d}/f_{c,0,d})^2 + \sigma_{m,y,d}/f_{m,y,d} = (0.07/20.88)^2 + 11.24/25.15 = 0.45 < 1.0$

Shear (Design section, x = 0.00 m) (Loadcase: ULS2)

$\tau_{z,d}/f_{v,z,d} = 0.69/2.74 = 0.25 < 1.0$

Flexural buckling around z-z (Design section, x = 5.00 m) (Loadcase: ULS2)

$\sigma_{c,0,d}/(k_{c,z} \cdot f_{c,0,d}) + k_m \cdot \sigma_{m,y,d}/f_{m,y,d} = 0.08/(0.66 \cdot 20.88) + 0.70 \cdot 10.87/25.15 = 0.31 < 1.0$

Flexural and lateral torsional buckling (Design section, x = 4.75 m) (Loadcase: ULS2)

$(\sigma_{m,y,d}/(k_{crit} \cdot f_{m,y,d}))^2 + \sigma_{c,0,d}/(k_{c,z} \cdot f_{c,0,d}) = (10.67/(1.00 \cdot 25.15))^2 + 0.08/(0.66 \cdot 20.88) = 0.19 < 1.0$

In this case no flexural buckling check in the plane of the frame is made as the stress check is also a buckling check as the stress is calculated with regard to 2nd order moments.

2.3.5 Quick way to change section

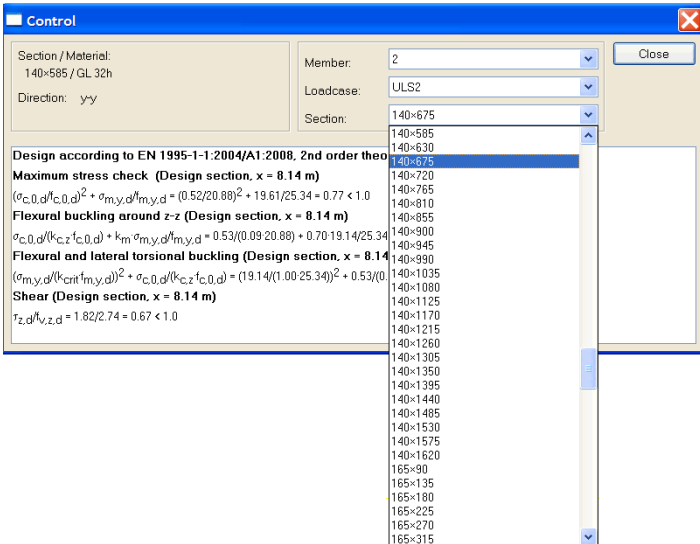In the **Code check** dialog box it is also possible to change section temporarily. This is very useful if the capacity is inadequate in order to quickly find a section with sufficient capacity.
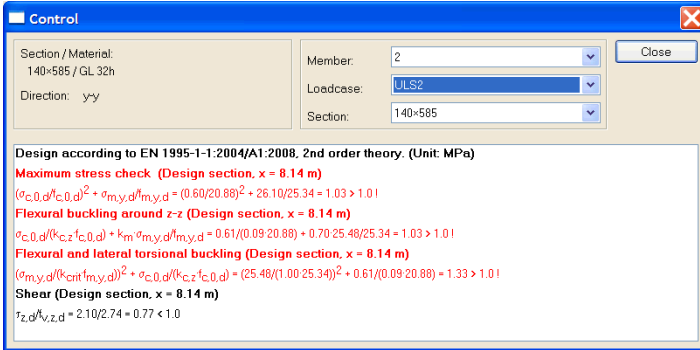
Above the current section 140 x 585 is inadequate.

It is possible to change section within the same section type.

By changing to a 140 x 675 the capacity is sufficient for the current load case.

Warning!

Changing the section in the code check window means that a new design is made but the analysis is the same although the stiffness distribution in the structure has changed. The ability of section change has been created for the user to quickly find an appropriate section but then a new analysis has to be performed with the new sections. The program will therefore change back to the original section when the code check dialog window is closed.

2.3.6   Utilization colours

When the design has been completed the included members will get different colours depending on how the result turns out. The members that pass all checks will get a green colour and the others will get a red colour as default.

Members can also be coloured blue according to the **Utilization ratio-colours** option. The purpose with this can e.g. be to swiftly survey, not only which members will pass but also to see which members are being utilized over a user-given limit.
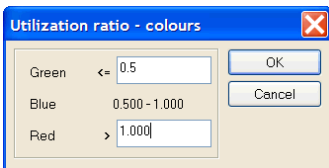
In the picture above an example is shown where all members that are being utilized less than 50% are being green coloured, those that are being utilized 50-100% are being blue coloured, and those that don't have enough capacity are being red coloured.

2.3.7   Utilization table
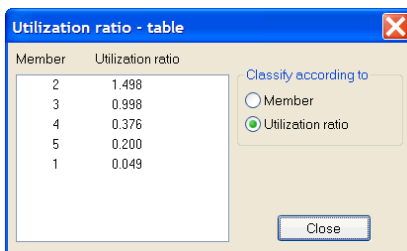
In order to quickly get an opinion of the utilization in different parts of the structure the **Utilization ratio-table** option can be used. A table is displayed, showing the utilization value for all members. The table can be sorted according to utilization or member number.

2.4 Option
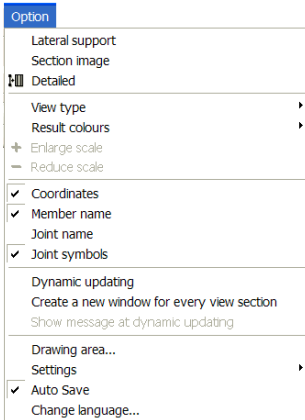
2.4.1 Lateral supports

It is possible to support the members laterally continuously or with simple supports. If the option **Lateral support** in the menu **Option** is activated this lateral bracing is displayed as shown below:
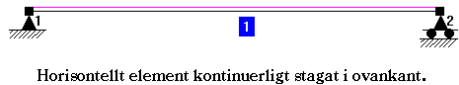
If a number of members are supported simultaneously the top edge for a horizontal member corresponds to the right edge for a vertical member.

Horisontellt element kontinuerligt stagat i ovankant.

Horisontellt element med punktvis stagning i ovankant.

2.4.2 Section image

If the option **Section image** in the menu **Option** is activated the section for each member will be displayed as for the figure.

Timber Module - Program structure
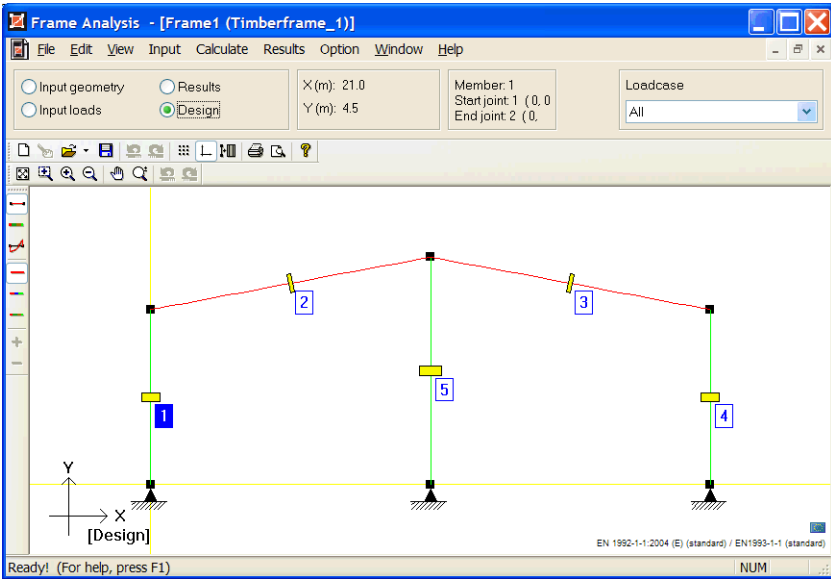
3 Methods of calculation

3.1 Design methods with regard to buckling

The design is being performed according to [1] along with all code prescribed checks depending on section type, section class and loading. Flexural buckling in the frame plane can be performed according to 1th or 2nd order theory. For buckling out of the plane frame 1th order theory is used. The user decide desired method in **Frame Analysis**.

3.1.1 First Order Theory

The following are valid when designing according to the first order theory:

The capacity with regard to flexural buckling is calculated according to [1] 6.3.2. In the frame plane the buckling length is defined by the user and out of the plane the buckling length is calculated from support conditions defined by the user. The effect of initial bow imperfection is already considered and has not to be defined separately but the effect of possible deviation has to be considered by horizontal loads.

3.1.2 Second Order Theory

The second order theory considers the influence of deflection on force and moment distribution within the frame. There is no need to define buckling lengths in the frame plane when using this method since the buckling effect will be considered with the second order moments in the members. The capacity with regard to flexural buckling in the frame plane is shown with the maximum stress check in the code check window with regard to 2nd order moments. When all members pass the code checks there will be enough buckling safety within the frame plane for each member as well as for the frame as a whole.

Calculations according to the second order theory must have been selected in **Frame Analysis** in order to perform the design in this way in **Timber Module**. When using this method the following demands must be fulfilled:

Consideration shall be taken to initial bow imperfections. Use the tool "Initial bow imperfection" in **Frame Analysis** to state which members shall have initial curvature due to imperfection. It is particularly important for hinged members loaded with axial force only otherwise there will be no effect from 2nd order moments. Therefore no design is allowed for compression members if the 1th order moment does not correspond to the initial bow imperfection moment.

When working with sway-frames (or isolated columns) consideration must also be taken to initial deviation from the vertical loads of the frame. **Frame Analysis** will not automatically consider this, so the user must choose another method in order to include effect of initial deviation. A suitable method is to add fictive horizontal loads corresponding to the effect of the deviation.

With regard to instability out of the frame plane, also a flexural and a flexural and lateral torsional buckling check is made unless the member is prevented from lateral movement by lateral bracing.

Instability out of the frame plane is also affected from the support conditions defined by the user under the option **Support conditions**. As default it is presumed that all members are hinged at both ends.

3.2   Axial force capacity

The capacity for members in tension and compression is calculated according to [1] 6.1.2-5.

The capacity for compressed members is calculated with regard to flexural buckling and possible torsional buckling.

The member can be laterally supported continuously or at certain points in order to increase the capacity with regard to instability out of the frame plane.

3.3   Moment capacity

The capacity is calculated according to [1] 6.3.3.

3.3.1 Lateral torsional buckling

Lateral torsional buckling is calulated for rectangular massive sections, **I**-sections, rectangular hollow sections and **U**-sections if the height > width.

The reduction factor with regard to lateral torsional buckling is calculated according to [1] 6.3.3.

The elastic critical moment for lateral torsional buckling M_{cr} is calculated as described below.

Elastic critical moment for lateral-torsional buckling M_{cr}

When calculating lateral-torsional buckling it is required to find the critical moment M_{cr} for arbitrary sections, where the moment distribution and support conditions greatly influences the result. A theoretical solution could be written as:

$$M_{cr} = m \,/\, L \, (E_{0,05} \, I_z \, G_{0,05} \, I_{Tor})^{0,5}$$

Where **m** is a coefficient depending on the section type, loading, support conditions and load level and κ is depending on the support conditions.

I_{Tor} is the torsional constant.

It is however in most cases not possible to find a theoretical solution for the critical moment M_{cr} for arbitrary sections, loading situations and support conditions.

Present solution

In the timber design module routines to calculate the critical moment is used where a method to transfer the current case to a case with a known theoretical solution is the so called "Deflection analogy" where the deflection for the member as simply supported with the current load situation is compared to deflection for a standard load in this case a uniform load. To consider different moment distributions, support conditions and load levels [4] and [5] are used. As the centre of gravity of the load action along the member is important especially when the support conditions differ between the edges, this point is calculated and the critical moment is influenced accordingly.

The following moment types will be used in the calculation:

| Momenttyp 1 | Momenttyp 2 | Momenttyp 3 |
| Momenttyp 4 | Momenttyp 5 | Momenttyp 6 |
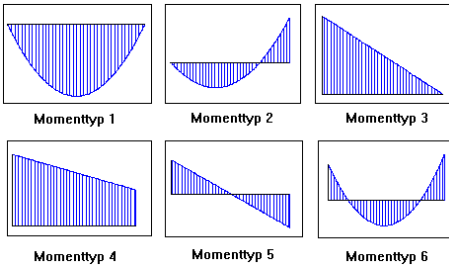
No consideration is taken to an increased critical moment due to the continuity between members but each member is treated as simply supported, however with regard to the actual moment distribution. Defining fixed support conditions can also increase the critical moment.

Moment types 1,2 and 6

The current load case is transferred to the case uniform distributed load by the deflection analogy. The load level in this case influences the critical moment. The capacity could be increased by fixed support conditions in the weak direction at one or both ends. If only one end is fixed the calculation will also consider the position of the centre of gravity for the current load case with regard to the fixed end.

For moment type 2, if only one end is fixed the critical moment will differ depending on if the support moment is situated at the fixed end or not.

For moment type 2 and 6 the critical moment is influenced by the relation between the magnitudes of the positive and the negative moments.

Moment types 3,4 and 5

For these types the calculation is made for a linear moment distribution, where the relation between the magnitudes of the end moments highly influences the result. The critical moment could be increased by fixed support conditions in the weak direction at one or both ends. If only one end is fixed the capacity will differ depending on if the largest moment is situated at the fixed end or not.

For a cantilever the current load case is transferred for moment type 3 to the case uniform distributed load by the deflection analogy. The load level will in this case influence the critical moment.

For moment type 4 the calculation for a cantilever will be performed as for a member hinged at both ends with double length.

3.4 Shear capacity

The capacity is calculated according to [1] 6.1.7. An effective width $b_{ef} = 0,67\ b$ is used but can be adjusted if the user not want to follow the code in this respect.

Timber Module - Methods of calculation

4 References

1.   *EN 1995-1-1 Design of timber structures – Part 1-1: General rules and rules for buildings*.

2.   *Structural Timber Design to Eurocode 5*. Porteous and Kermani. 2007.

3.   *Limträhandboken*, Svenskt Limträ, 2008.

4.   *Handboken Bygg, Allmänna grunder*, Avsnitt A30, Stockholm, 1985.

5.   *Knäckning Vippning Buckling*, StBK-K2, Statens Stålbyggnadskommitte, 1973.