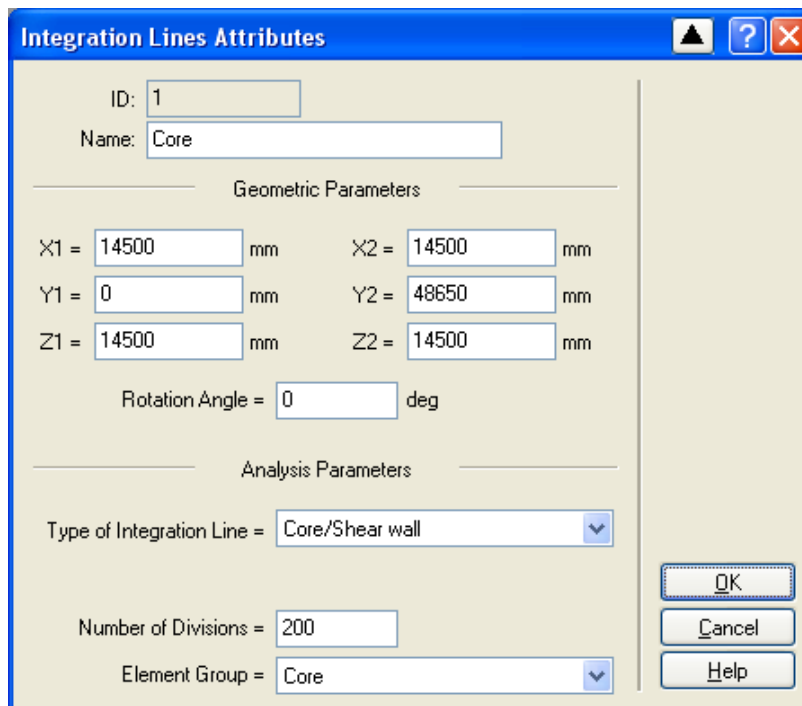


INTEGRATION LINES FOR CORES AND SLABS

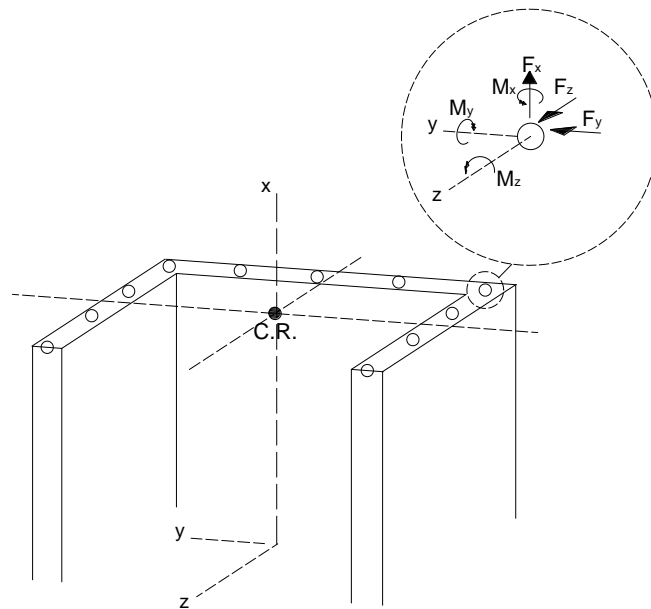
1. THE INTEGRATION LINE

The integration line command allows associating a group of plates and/or members to a reference axis system called an integration line. To define the line, we must specify two points which create the axis passing at the center of gravity of the core. At each division along this line, the total forces on the cutting plane are calculated by considering the lever arm when calculating the moments. The force distribution on each cutting plane may also be obtained.

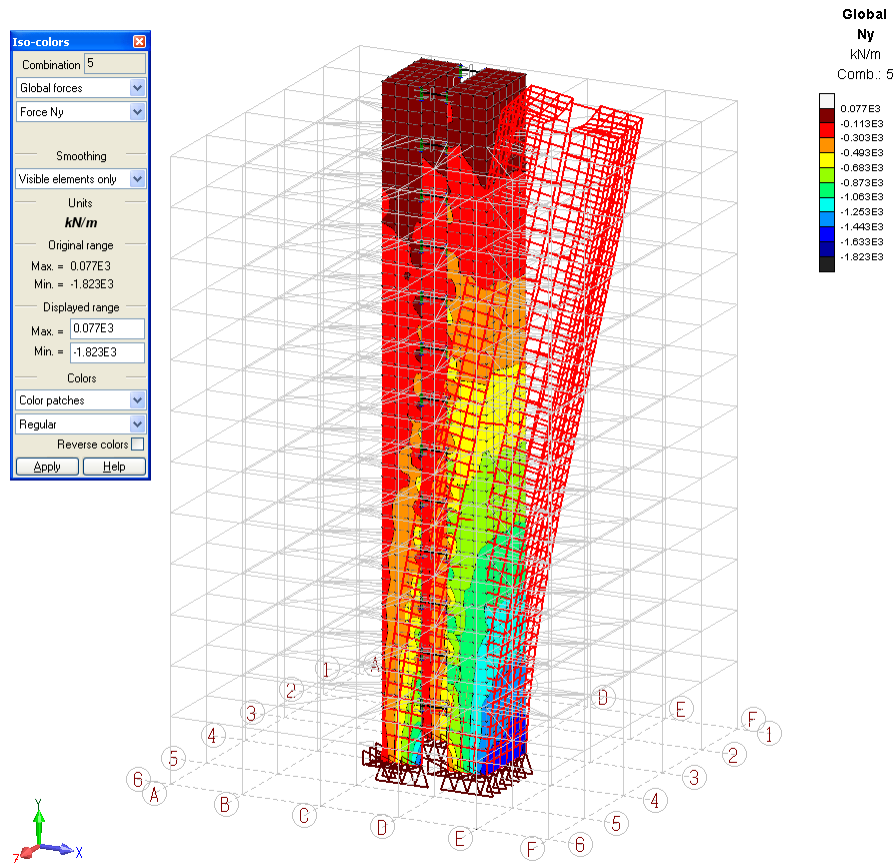


The dialog box titled "Integration Lines Attributes" contains the following fields and controls:

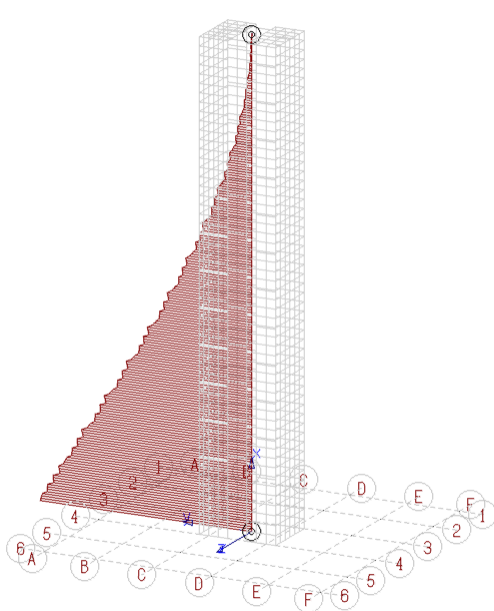
- ID:** 1
- Name:** Core
- Geometric Parameters:**
 - X1 = 14500 mm, X2 = 14500 mm
 - Y1 = 0 mm, Y2 = 48650 mm
 - Z1 = 14500 mm, Z2 = 14500 mm
 - Rotation Angle = 0 deg
- Analysis Parameters:**
 - Type of Integration Line = Core/Shear wall (dropdown menu)
 - Number of Divisions = 200
 - Element Group = Core (dropdown menu)
- Buttons:** OK, Cancel, Help



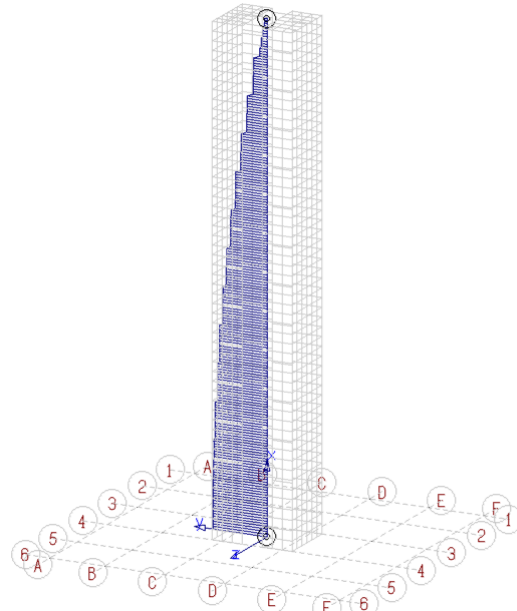
The analysis of the iso-stresses may be activated by using the **Contours** button from the **Results** toolbar. The core below is submitted to a lateral seismic load along the X direction. In the figure below, we can see the deflection of the core. We also see the axial forces in the concrete walls by means of iso-colors.



The total forces in the integration line at each division are available by means of spreadsheets or graphically. These results may be visualized graphically through the same command used to display member results. The results for bending moments and shear forces in the core are presented below. Note that in this example, the total bending moment M_z is mainly produced by the integration of the axial forces in the core plates.

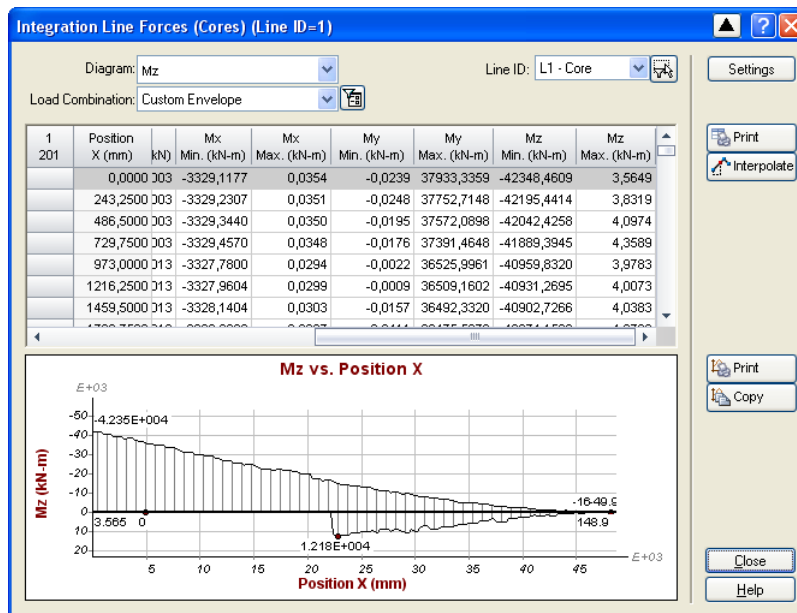


BENDING MOMENT M_z (AROUND Z)



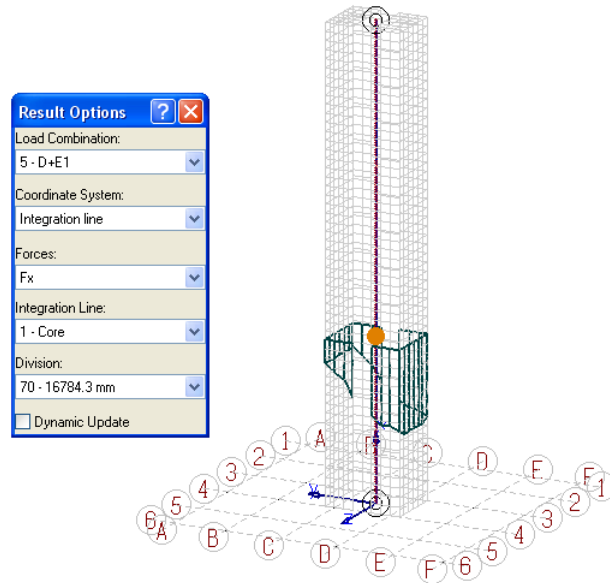
SHEAR FORCE (F_y)

These results are also available through spreadsheets or graphically by the means of the **Integration Line Forces (Cores)** command.



INTEGRATION LINES FOR CORES AND SLABS

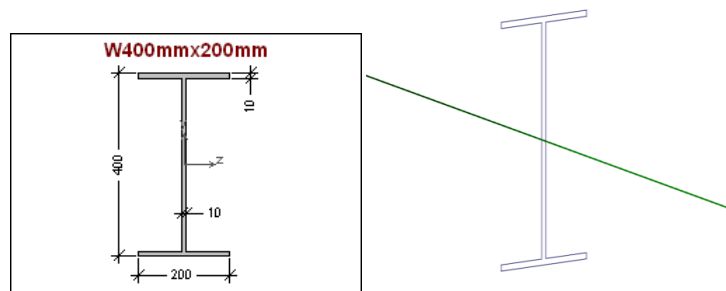
At each division along the integration line, the force distribution is available by means of spreadsheets or graphically using the **Integration line unit transverse forces**. In the example below, the axial forces in the core are presented for the cutting plane located at 16784.3 mm for a seismic load combination.



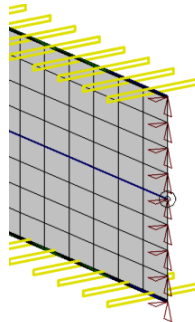
2. INTEGRATION LINES FOR THE ANALYSIS OF A PLATE AND/OR MEMBER GROUP

In the example below, three identical beams are modeled in three different ways. Note that the beam has a fixed support at one end and a pinned support at the other end.

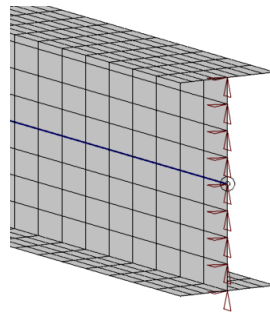
The first model is a member element with the section shape shown below.



The second model uses plate elements to model the web and member elements to model the top and bottom flanges. Note in this case that the section shape assigned to the member elements is 200 mm x 10 mm rectangular section.

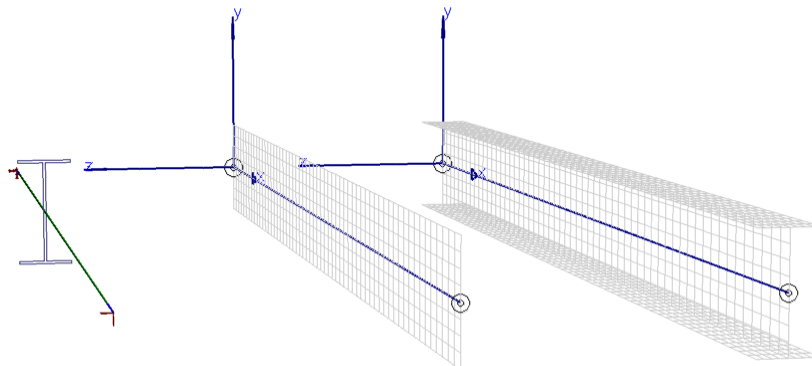


The third model is made entirely with plate elements for the web and both flanges.

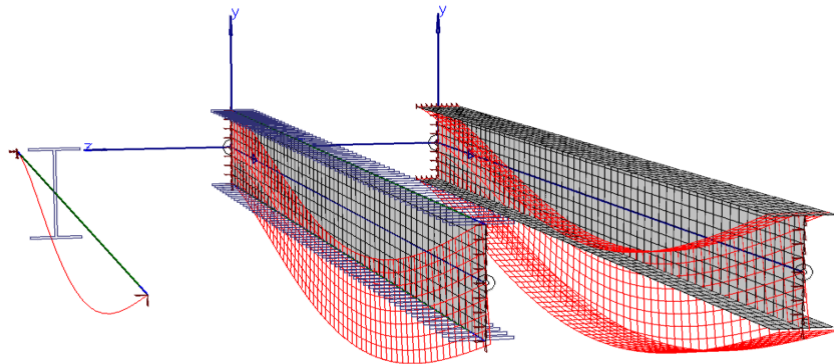


It is possible to integrate the forces of the second and third model by associating an integration line to each.

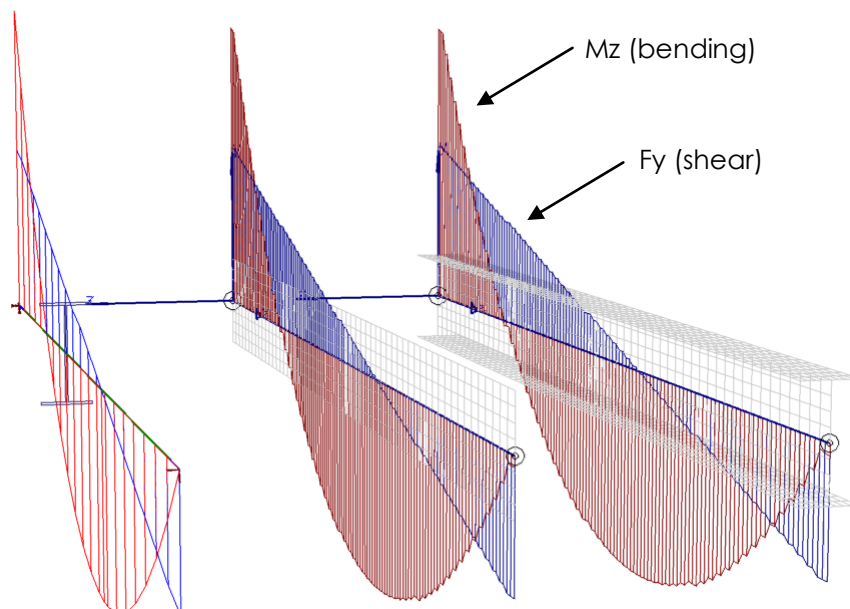
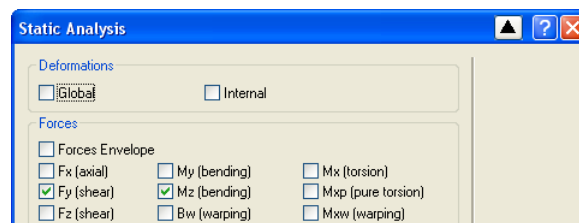
By associating an integration line to these models, it is possible to view the cumulated forces and the forces distribution graphically or by means of tables.



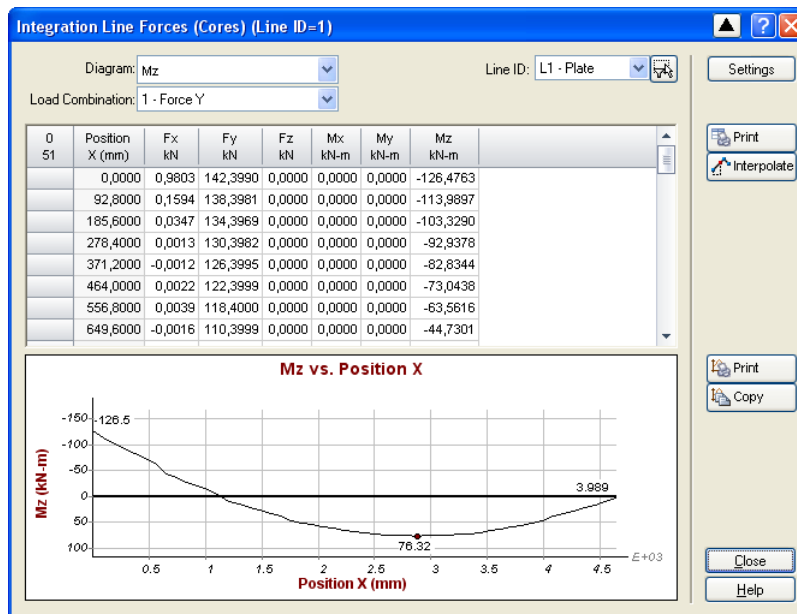
The figure below presents the deformation for the three models.



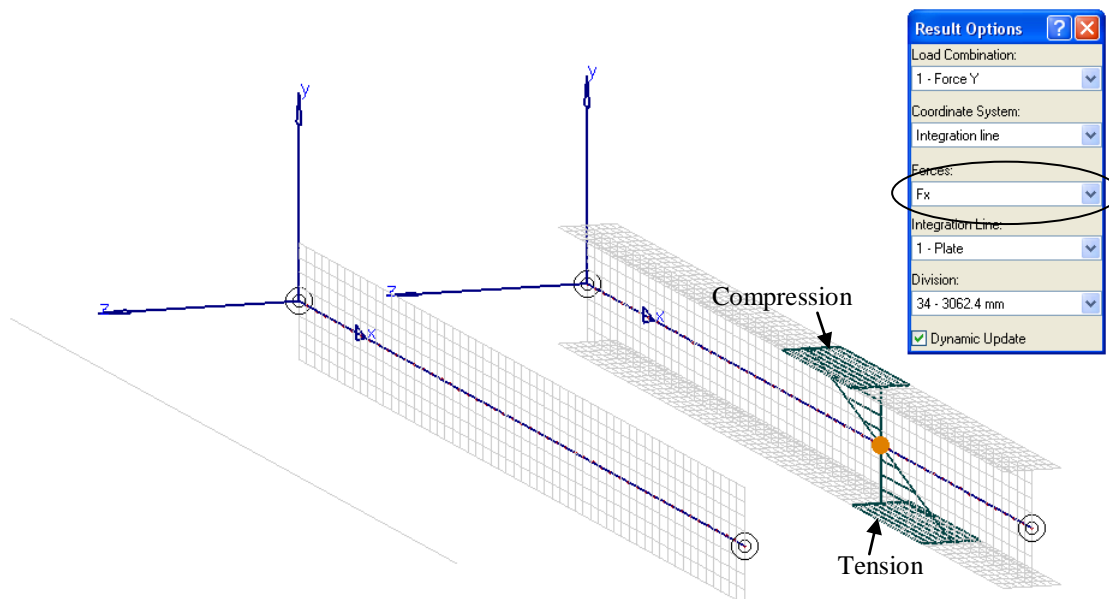
By using the same command used to display member results, it is possible to view the forces and moments curves on the integration lines.



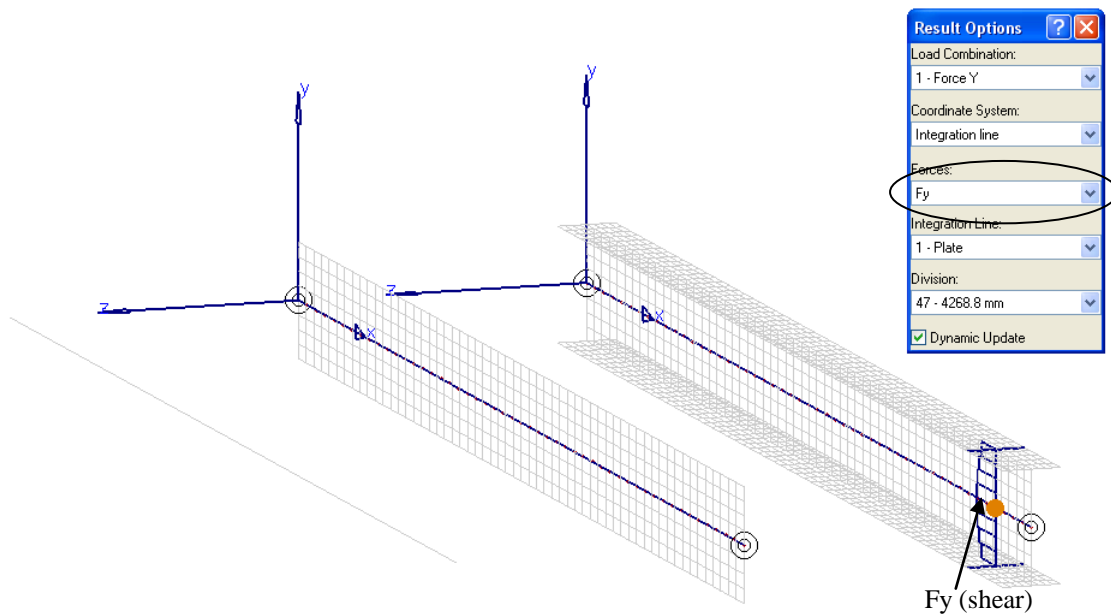
These results are also available by using the **Integration Lines Forces (Cores)** command.



At each division along an integration line, the forces distribution is available either graphically or through tables by the means of the **Integration Lines Unit Transverse Forces** command. In the example below, the force distribution for the third model is presented for a cutting plane located at 3093.33 mm.



In the figure below, the shear force in the third model is presented for a cutting plane located at 4292 mm.



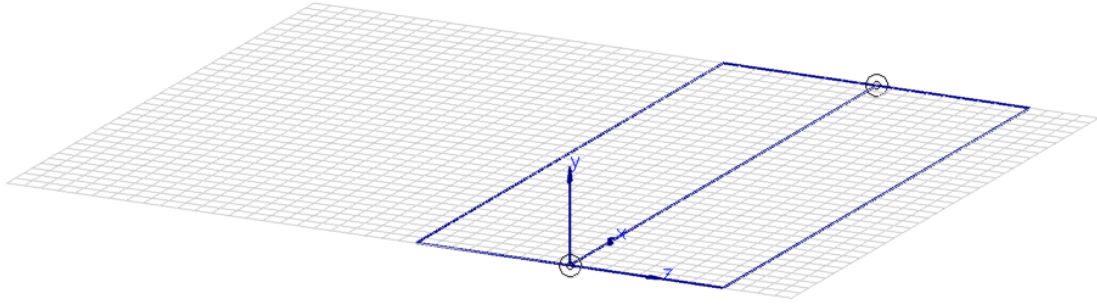
3. INTEGRATION LINE FOR THE ANALYSIS OF A SLAB

The **Integration Line** command allows to associate a group of plates and/or members to a reference axis system called an integration line. To define the line, we must specify two points which create the axis passing at the center of gravity of the core. At each division along this line, the forces distribution and the total forces on the cutting plane are calculated. The figure below presents an integration line for a strip of a two-way slab.

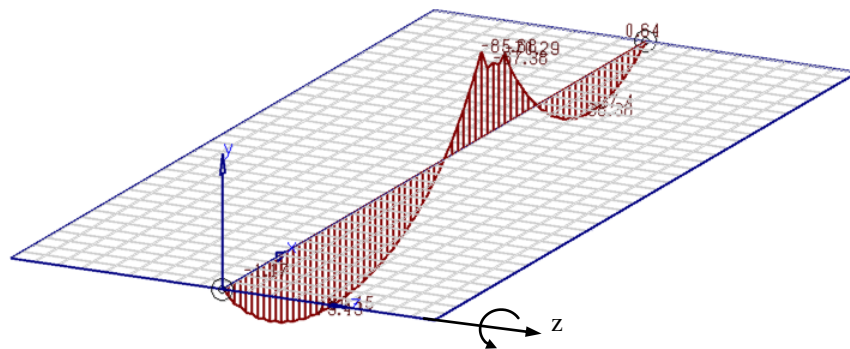
The 'Integration Lines Attributes' dialog box is shown with the following settings:

- ID: 3
- Name: Strip
- Geometric Parameters:
 - X1 = 8250 mm, X2 = 8250 mm
 - Y1 = 0 mm, Y2 = 0 mm
 - Z1 = 9000 mm, Z2 = 0 mm
 - Rotation Angle = 0 deg
- Analysis Parameters:
 - Type of Integration Line = Slab
 - Width of Strip = 4500 mm
 - Number of Divisions = 72
 - Element Group = Floor

Buttons: OK, Cancel, Help



The figure below shows the curve of the total bending moment at each cutting plane on the integration line. Note that the moment displayed is the M_z moment (moment around z) in the member convention.

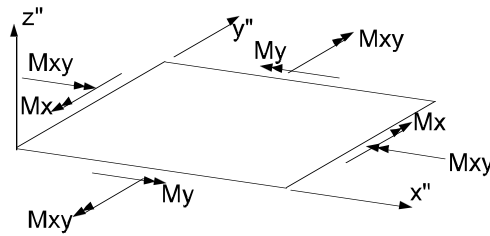


When designing a reinforced concrete slab, certain conditions must be fulfilled in order to uniformly distribute the reinforcement along the "x" direction across the width of the strip.

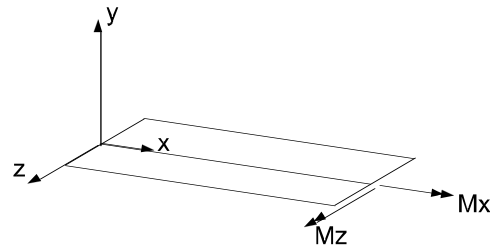
1. The total reinforcement provided within a band shall be sufficient to resist the total factored moment computed for that band (see **Mzdes Mean**).
2. The moment resistance per unit width within the band shall be at least two-thirds of the maximum factored moment intensity within the band.

In order to simplify this verification, the values of **Mzdes Unif** corresponding to the maximum of **Mzdes Mean** and $2/3$ of **Mzdes Ext** may be used.

The *Wood-Armer* method is a combination of the M_x moments and the M_{xy} moments in the plate (in plate convention). This method allows to obtain the design moments used to orthogonally reinforce a slab for which the orientation of the bars does not correspond to the orientation of the principal moments. In this situation, the value of m_{xy} is different than zero.



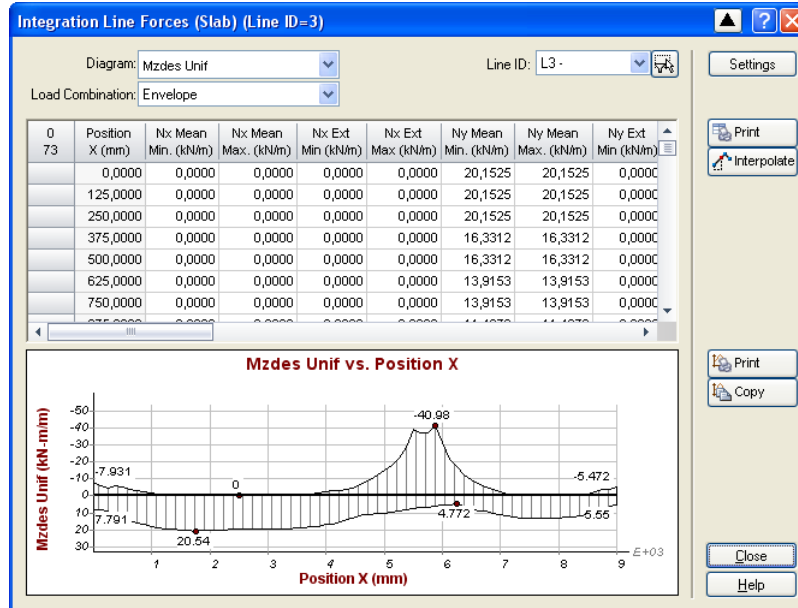
$$\mathbf{Mxdes} = \mathbf{Mx} \pm \mathbf{|Mxy|} \quad (\text{Plate convention})$$



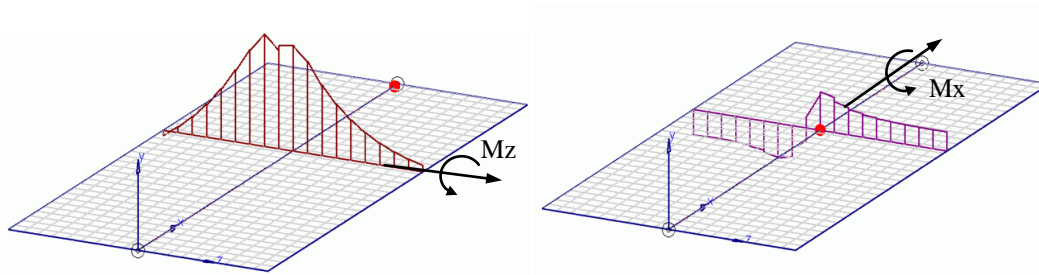
$$\mathbf{Mzdes} = \mathbf{Mz} \pm \mathbf{|Mx|} \quad (\text{Member convention})$$

The **mxdes** (plate convention) is equivalent to the **Mzdes** (member convention). The torsional moment **Mxy** (plate convention) becomes in the member convention the moment **Mx** for a disposition of reinforcement in the x direction.

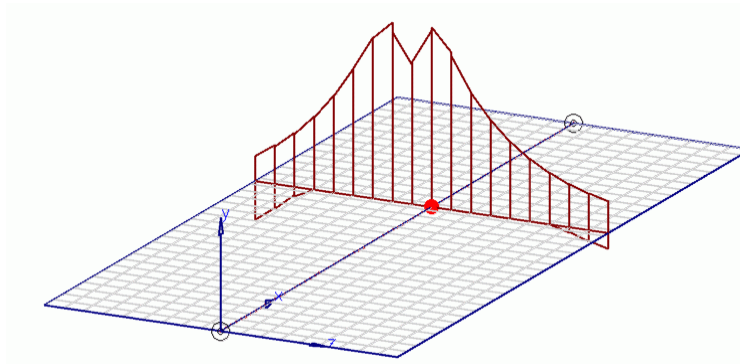
In short, the **Mzdes Unif** bending moment curve shown below can be used to determine the uniform distribution of the reinforcement across the width of the strip.



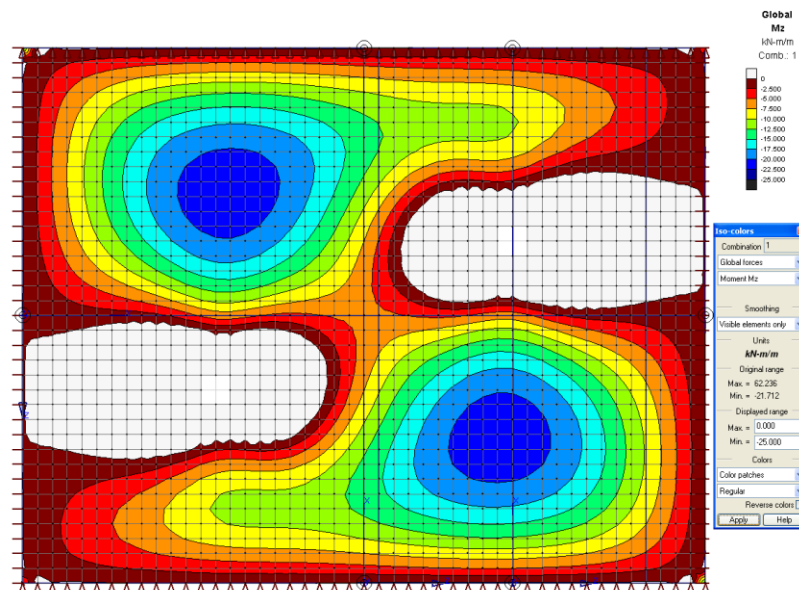
At a specific cutting plane, it is possible to view the distribution of the bending moments across the width of the cutting plane by using the **Integration line unit transverse forces** command. Below are presented the **Mz** (bending) and **Mx** (torsion) moments distributions.



The design bending moment M_{zdes} shown below is obtained by combining the two curves above.

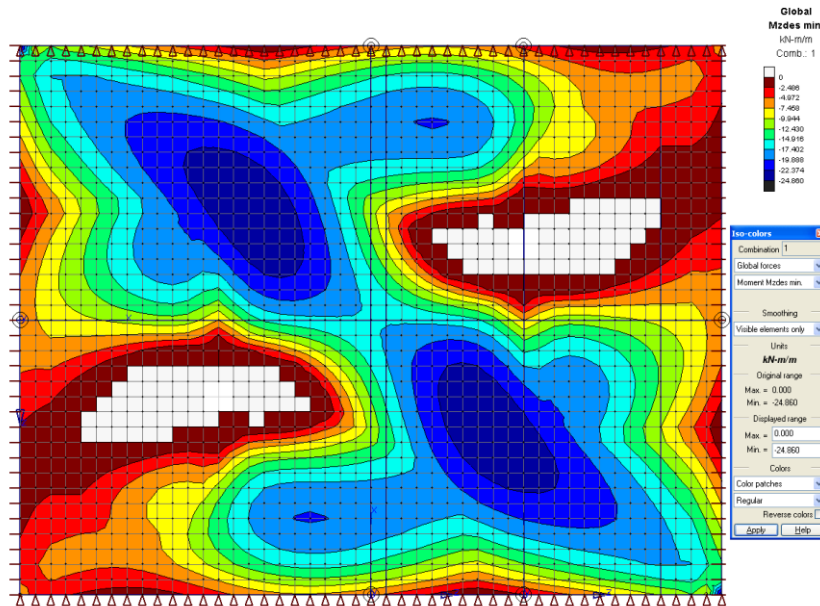


It is important to note that the results regarding moments on finite elements use a different convention than for members. In the example below, the iso-colors are presented for the M_z plate (in global coordinates) for the whole slab. In the plate convention, these moments are useful to determine the reinforcement placed along the Z direction. In fact, the M_z moment is a moment acting around the X axis for this slab lying in the XZ plane.



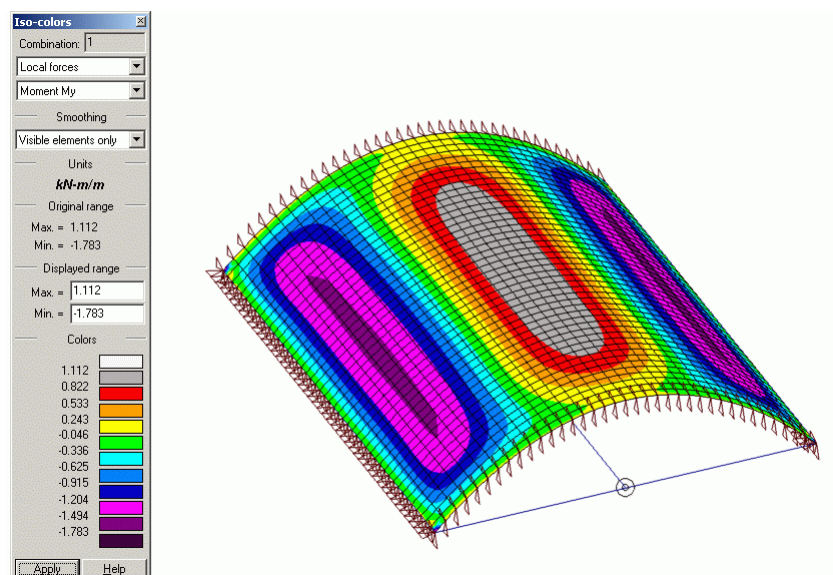
INTEGRATION LINES FOR CORES AND SLABS

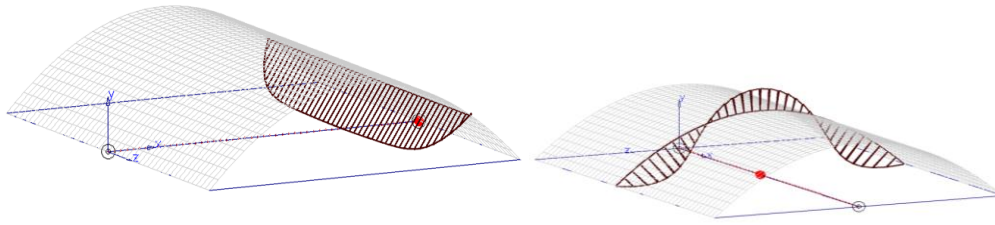
Note that it is also possible to view the design moments M_{xdes} , M_{ydes} , M_{zdes} by means of iso-colors. By comparing the results in the figure below with those shown above, we see the influence of the torsional moments in the slab on the design moments.



4. INTEGRATION LINE FOR THE ANALYSIS OF A CURVED SHELL

The results of curved shells may be analyzed by the means of iso-colors and integration lines.





The results on integration lines may be displayed according to two different coordinate systems. The line coordinate system corresponds to the integration line internal axes. In this coordinate system, the results follow the member convention (an M_x moment acts around the internal x axis).

The normal coordinate system varies from one element to the other according to the plate normal "z" axis. The normal coordinate system is useful to interpret the results on curved surfaces.

