

Structures: Beams/Axisymmetric shells

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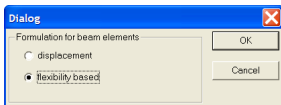
25.08.2009



Structural applications: Examples

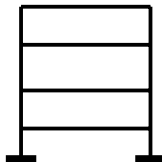
• Example 1

At the material level in group
Main



Next slide

Frame structure (static/pushover/dynamic analysis)

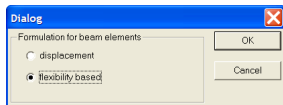


Remark: Each member is discretized by one element (not necessarily for reinforced concrete because of different amount and position of the reinforcement)

Structural applications: Examples

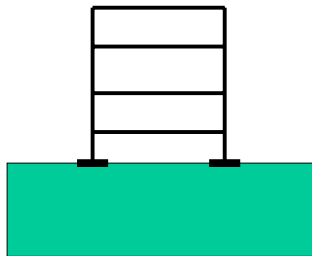
• Example 2

At the material level in group
Main



Next slide

Frame structure resisting on soil (static analysis)



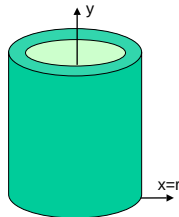
Remark: Each member is discretized by one element (not necessarily for reinforced concrete because of different amount and position of the reinforcement)



Structural applications: Examples

- **Example 3**

Cylindrical water container (axisymmetry)



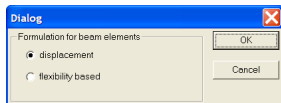
Next slide

Remark: Here standard discretization must be used

Soil-structure interaction: Examples

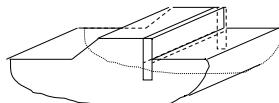
• Example 1

At the material level in group
Main

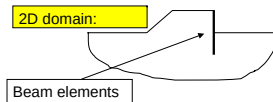


Next slide

Continuum shell



Computational model (Interval between beams $L = 1$ m)

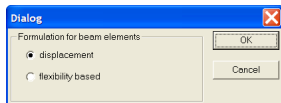


Remark: Each member is discretized with at least few elements; results are given per beam (!)

Soil-structure interaction: Examples

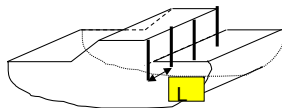
• Example 2

At the material level in group
Main

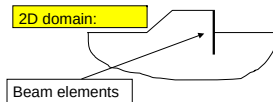


Next slide

Discrete rib system



Computational model (Interval between beams L is user defined)

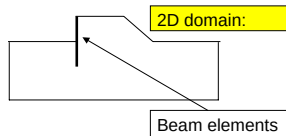
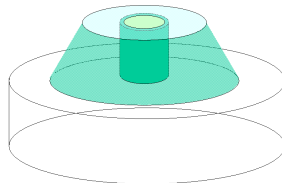


Remark: Each member is discretized with at least few elements; results are given per beam (!)

Soil-structure interaction: Examples

• Example 3

Continuum axisymmetric shell

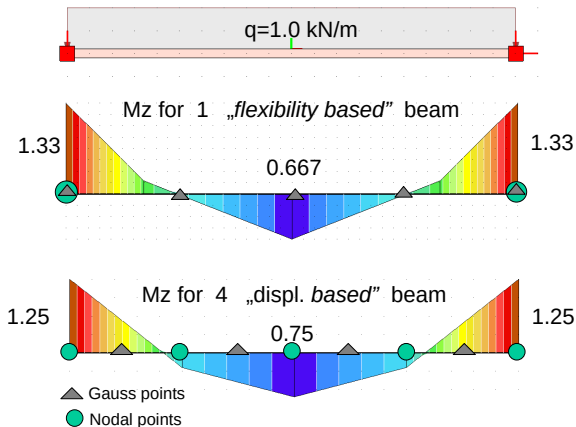


Next slide

Remark: Standard discretization must be used for that case; beam is switched to the axisymmetric shell



Flexibility vs displacement based beam formulation



Note that result for Flexibility based beam (one per member) is exact !



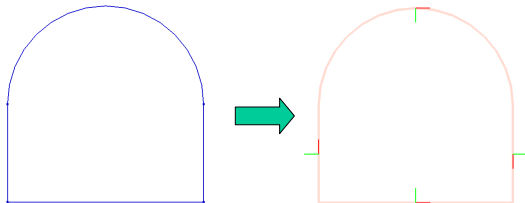
Geometrical model: Macro level

- ① **Create beams on objects**
- ② **Set director (2D)**
- ③ **Set X-axis**
- ④ **Set offsets**

Step:A Select objects:
Macro-model/Objects/Select/....

Step:B Create beams :
Macro-model/Subdomain/Create/Beam(s) on
objects

NB. Split preserves the initial beam geometry

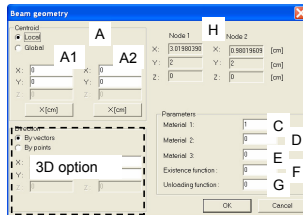


Next slide

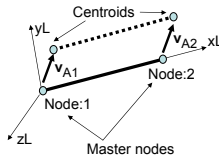


Geometrical model: Macro level

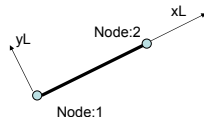
- 1 Create beams on objects
- 2 Set director (2D)
- 3 Set X-axis
- 4 Set offsets



Offset definition by vectors: $\mathbf{v}_{A1}$, $\mathbf{v}_{A2}$



Default local axes x_L , y_L



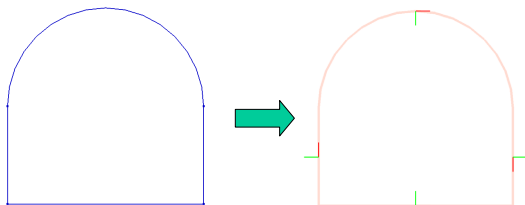
Next slide

- A Use method: Macro-model/Subdomain/Update/Reverse direction to flip y_L axis



Geometrical model: Macro level

- 1 Create beams on objects
- 2 Set director (2D)
- 3 Set X-axis
- 4 Set offsets



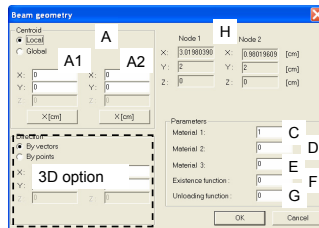
A Use method: Macro-model/Subdomain/Update/Reverse X axis

Next slide

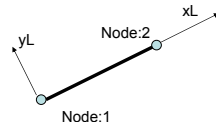


Geometrical model: Macro level

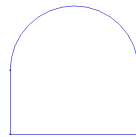
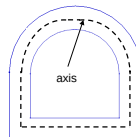
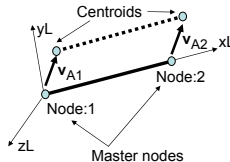
- 1 Create beams on objects
- 2 Set director (2D)
- 3 Set X-axis
- 4 Set offsets



Default local axes x_L , y_L



Offset definition by vectors: $\mathbf{v}_{A1}$, $\mathbf{v}_{A2}$

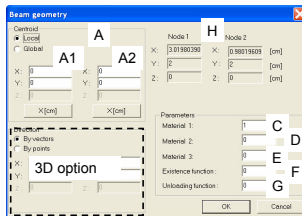


Next slide

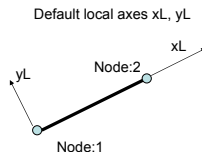
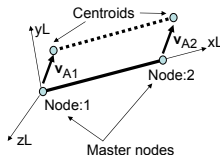


Geometrical model: FE level

- 1 Create beams
- 2 Set director (2D)
- 3 Set X-axis
- 4 Set offsets



Offset definition by vectors: $\mathbf{v}_{A1}$, $\mathbf{v}_{A2}$

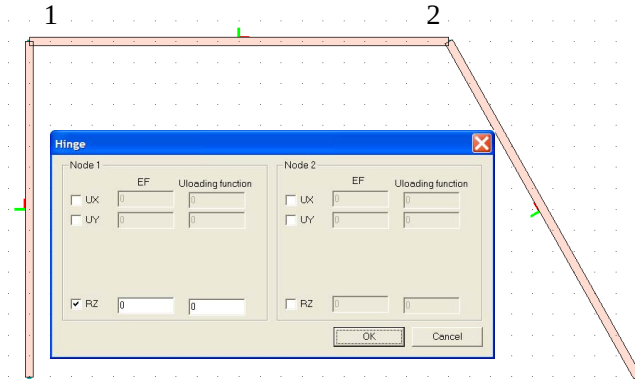


Next slide

- A All methods are similar to the ones designed for Macro-model level but geometry is restricted only to the straight line segment



Geometrical model: FE level: Hinges



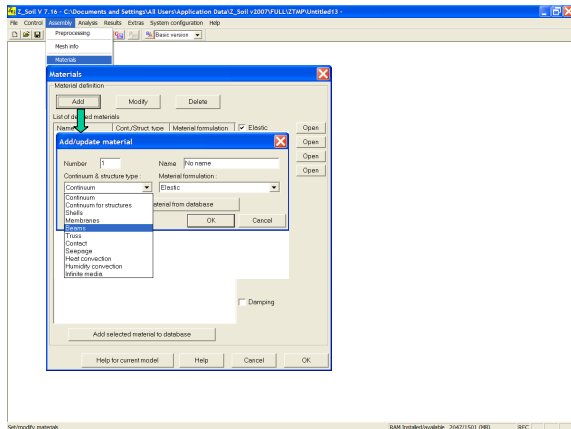
- Hinges are defined in the local $x_L - y_L - z_L$ coordinate system of a selected beam element
- Existence/Unloading functions can be associated with the hinge



Add new linear beam material

- 1 **Add new beam material**
- 2 **Set linear mode**

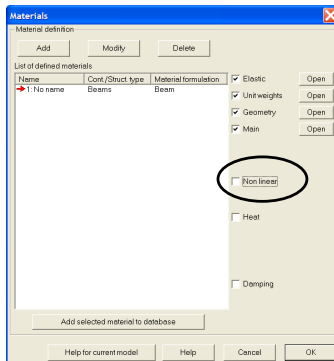
Next slide





Add new linear beam material

- 1 Add new beam material
- 2 Set linear mode



Next slide



Materials for linear beams: data groups

①

Elastic

②

Unit weight

③

Geometry

④

Main

⑤

Heat

⑥

Damping**Obligatory**

Material

Elastic parameters

Young modulus E 100000 [kN/m²]

Poisson ratio v 0.3 []

OK

Cancel

Help

Data mode Standard

Next slide



Materials for linear beams: data groups

Optional

- 1 Elastic
- 2 **Unit weight**
- 3 Geometry
- 4 Main
- 5 Heat
- 6 Damping

Next slide

NB. Mass and body force multipliers visible only if Dynamics is activated in the project preselection



Materials for linear beams: data groups

1

Elastic

2

Unit weight

3

Geometry

4

Main

5

Heat

6

Damping

Obligatory

2D/3D

2D Linear Beam Geometry

Type: User

Section: User

Dimensions:

b: 0.5 [m]

h: 1 [m]

Interval between beams: 1 [m]

Momentum of inertia:

Iz: 0.04166666666 [m⁴]

Area:

Ax: 0.5 [m²]

Ay: 0.41666666666 [m²]

OK Cancel

Axisymmetric case

Geometry

Cross-section thickness: 1 [m]

Shear correction factor: 1

OK Cancel

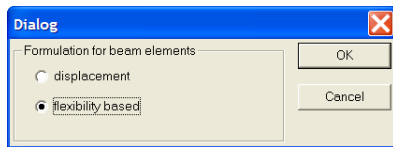
Next slide



Materials for linear beams: data groups

Obligatory

- 1 Elastic
- 2 Unit weight
- 3 Geometry
- 4 **Main**
- 5 Heat
- 6 Damping



NB. Use **Flexibility...** for structural applications and **Displacement...** for soil-structure interaction;

Not meaningful for axisymmetry (!)

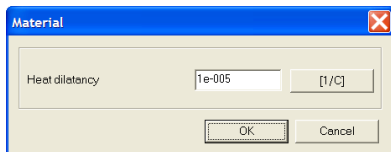
Next slide



Materials for linear beams: data groups

- 1 Elastic
- 2 Unit weight
- 3 Geometry
- 4 Main
- 5 **Heat**
- 6 Damping

Not meaningful for linear beams



NB. Preprocessed thermal strains (by Heat project) are not handled in linear (non-layered) mode (☒ **Nonlinear** mode must be activated for that case)

Next slide



Materials for linear beams: data groups

Optional

- 1 Elastic
- 2 Unit weight
- 3 Geometry
- 4 Main
- 5 Heat
- 6 **Damping**

Damping

α_0 [0] [1/day]

β_0 [0] [day]

☐ Evaluate damping coefficients from imposed values

OK Cancel

Evaluate damping coefficients from imposed values

ω_1 [0] [1/day] ζ_1 [0] [day]

ω_2 [0] [1/day] ζ_2 [0] [day]

Calculate

α_0 [0] [1/day] β_0 [0] [day]

OK Cancel

Next slide

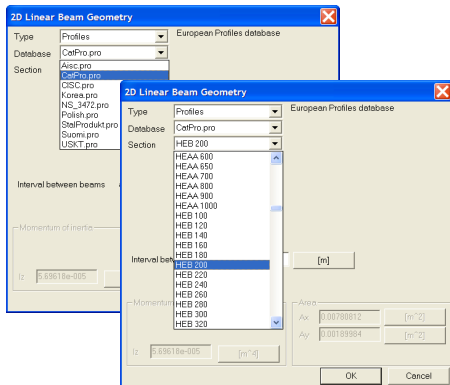
NB. Meaningful only for Dynamics



Cross section definitions

- 1 **Profiles**
- 2 **User**
- 3 **Values**

Next slide

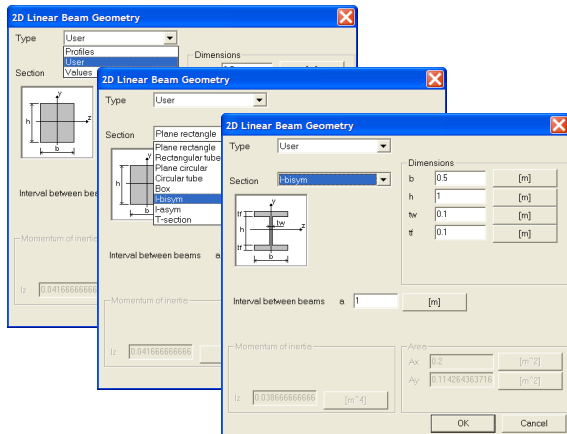


NB. Valid only for 2D (plane-strain) and 3D



Cross section definitions

- 1 Profiles
- 2 **User**
- 3 Values



Next slide

NB. For axisymmetric case only rectabular shape is considered with unit width ($b = 1.0$)



Cross section definitions

- 1 Profiles
- 2 User
- 3 **Values**

Next slide

2D Linear Beam Geometry

Type: Values

Interval between beams: 1 [m]

Momentum of inertia:

Iz: 0.0386666666666 [m⁴]

Area:

Ax: 0.2 [m²]

Ay: 0.114264363716 [m²]

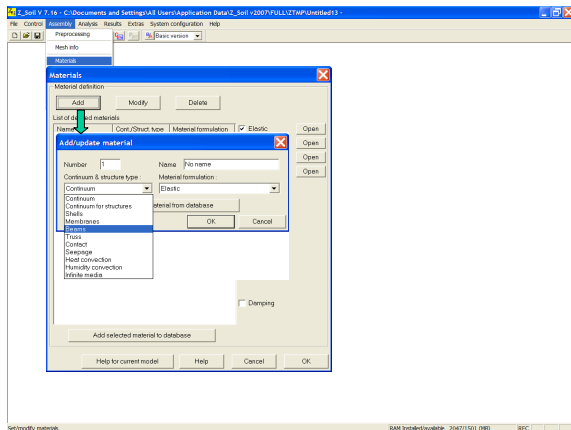
OK Cancel

NB. Valid only for 2D (plane-strain) and 3D

Add new non-linear beam material

- 1 Add new beam material
- 2 Set non-linear mode

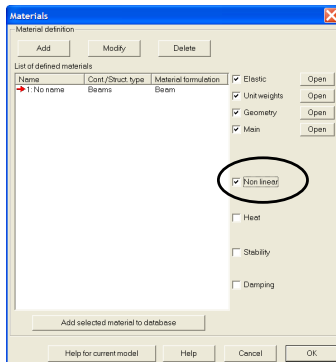
Next slide





Add new non-linear beam material

- 1 Add new beam material
- 2 Set non-linear mode



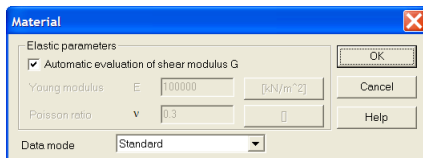
Next slide



Material data groups for non-linear beams:

Obligatory

- 1 **Elastic**
- 2 **Unit weight**
- 3 **Geometry**
- 4 **Main**
- 5 **Heat**
- 6 **Damping**



- These parameters are used only to specify shear modulus G as shear is decoupled from bending
- IF ☒ **Automatic..** mode is OFF $G = \frac{E}{2(1 + \nu)}$
- IF ☒ **Automatic..** mode is ON G will be computed from material data for layers

Next slide



Material data groups for non-linear beams:

- 1 Elastic
- 2 **Unit weight**
- 3 Geometry
- 4 Main
- 5 Heat
- 6 Damping

Optional (same as for linear)

Unit weight/mass

Unit weight/mass

Weight / unit volume

γ 0 [kN/m³]

γ multiplier for body forces 1

Mass / unit volume

ρ 0 [kg/m³]

ρ multiplier for mass matrix 1

Global gravity direction

Data mode Standard

OK Cancel Help

Next slide

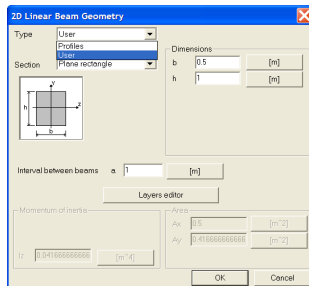
NB. Mass and body force multipliers visible only if Dynamics is activated in the project preselection



Material data groups for non-linear beams:

- 1 Elastic
- 2 Unit weight
- 3 **Geometry**
- 4 Main
- 5 Heat
- 6 Damping

Obligatory



NB. Use **Layers editor** to Add/Delete/Modify material layers:

- Area
- Constitutive model and its properties for layers

For axisymmetry only rectangular cross section is meaningful with $b = 1.0$

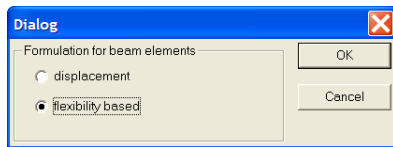
Next slide



Material data groups for non-linear beams:

- 1 Elastic
- 2 Unit weight
- 3 Geometry
- 4 **Main**
- 5 Heat
- 6 Damping

Obligatory (same as for linear)



NB. Use **Flexibility...** for structural applications and **Displacement...** for soil-structure interaction;

Not meaningful for axisymmetry (!)

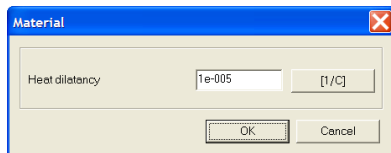
Next slide



Material data groups for non-linear beams:

Optional

- 1 Elastic
- 2 Unit weight
- 3 Geometry
- 4 Main
- 5 **Heat**
- 6 Damping



NB. Preprocessed thermal strains (by Heat project) are computed at each layer as

$$\Delta \varepsilon_{ox} = \Delta \varepsilon_{oy} = \Delta \varepsilon_{oz} = \alpha \Delta T$$

Next slide



Material data groups for non-linear beams:

- 1 Elastic
- 2 Unit weight
- 3 Geometry
- 4 Main
- 5 Heat
- 6 **Damping**

Optional (same as for linear)

Damping

α_0 0 [1/day]

β_0 0 [day]

☐ Evaluate damping coefficients from imposed values

OK Cancel

Evaluate damping coefficients from imposed values

ω_1 0 [1/day] ζ_1 0 []

ω_2 0 [1/day] ζ_2 0 []

Calculate

α_0 0 [1/day] β_0 0 [day]

OK Cancel

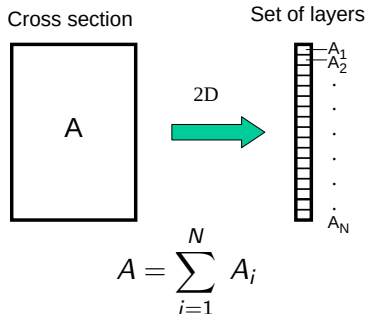
Next slide

NB. Meaningful only for Dynamics



Discretization (2D) of profiles

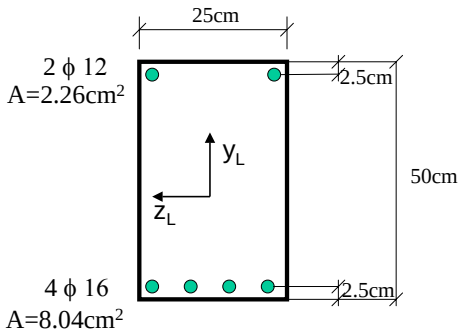
- The **Profile** or **User** predefined cross section is discretized automatically (subdivided to layers)
- By default all created layers are treated as a **Core** material characterized by elastic properties only
- To create a reinforced concrete cross section we can add additional layers of reinforcement





How to edit layered cross section for beam?

Example: Reinforced concrete cross section with elasto-plastic material models for both concrete (Core) and steel

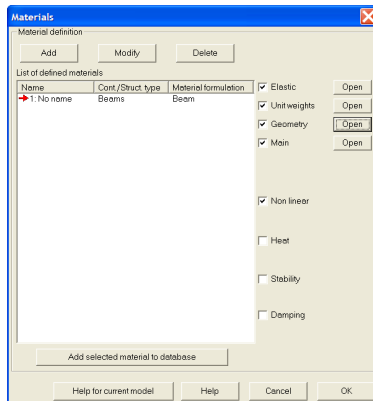


NB. Top fibers are always placed on the positive side of y_L axis !



Setting Core material

1 Set Core cross section type



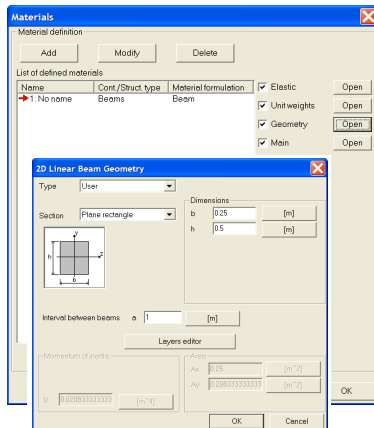
Next slide

• Press **Open** next to the ☒ **Geometry**



Setting Core material

- 1 Set Core cross section type
- 2 Activate layers editor



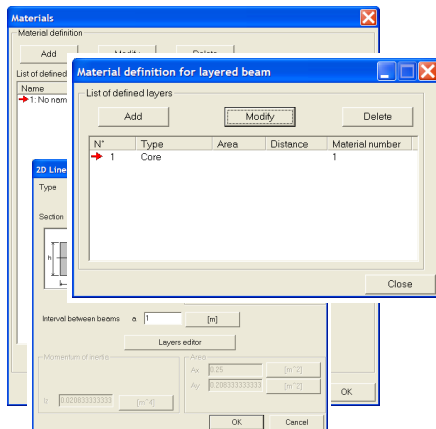
Next slide

- Press button **Layer editor**



Setting Core material

- 1 Set Core cross section type
- 2 Activate layers editor
- 3 **Modify Core properties**



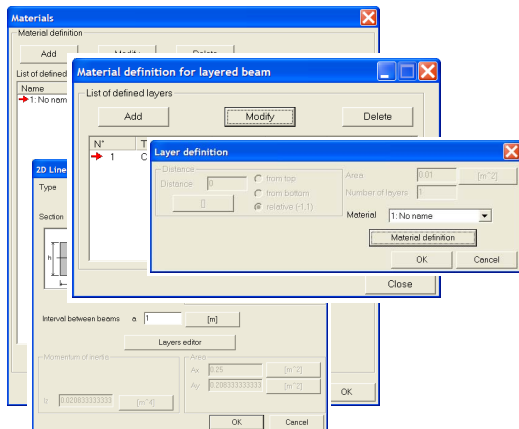
Next slide

- Press button **Modify**



Setting Core material

- 1 Set Core cross section type
- 2 Activate layers editor
- 3 Modify Core properties
- 4 Enter to properties dialog box



Next slide

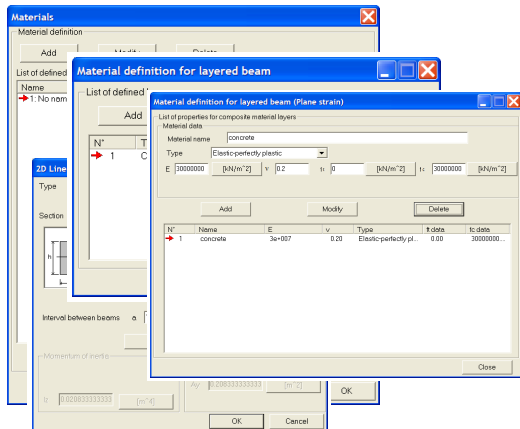
● Press button **Material definition**

● From combo-box select material ID



Setting Core material

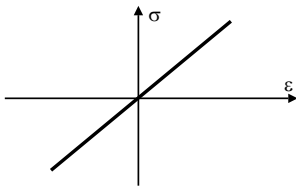
- 1 Set Core cross section type
- 2 Activate layers editor
- 3 Modify Core properties
- 4 Enter to properties dialog box
- 5 Edit properties



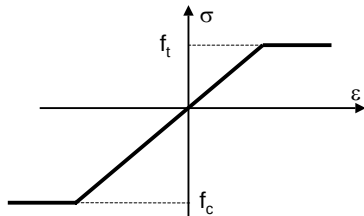
Next slide



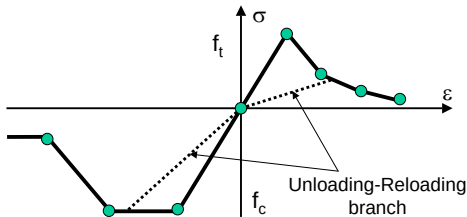
Constitutive models for uniaxial fibers



Elastic



Elastic-perfectly plastic

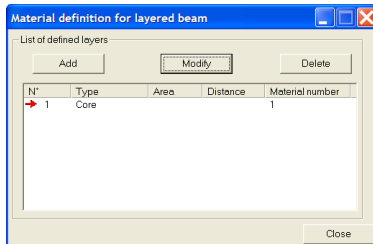


User defined



Adding top reinforcement set

1 Add reinforcement

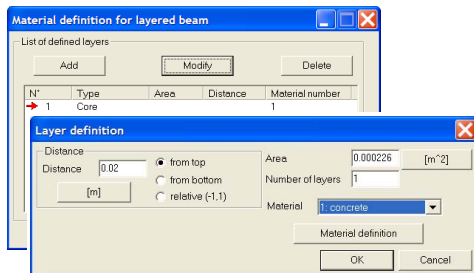


Next slide



Adding top reinforcement set

- 1 Add reinforcement
- 2 Set its area/location and apply proper material ID



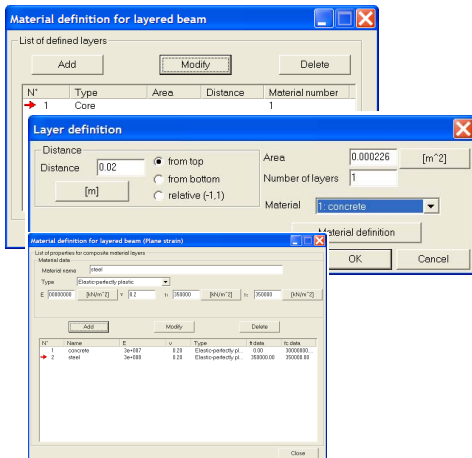
Next slide

- Steel properties are not yet defined so we must add a new property



Adding top reinforcement set

- 1 Add reinforcement
- 2 Set its area/location and apply proper material ID
- 3 Edit properties

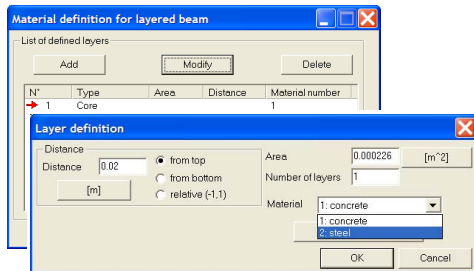


Next slide



Adding top reinforcement set

- 1 Add reinforcement
- 2 Set its area/location and apply proper material ID
- 3 Edit properties
- 4 Apply steel ID to this layer

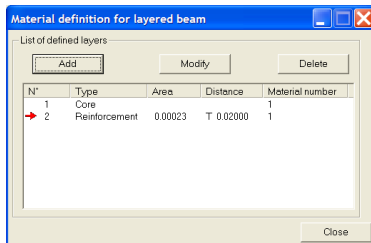


Next slide



Adding bottom reinforcement set

1 Add reinforcement



Next slide



Adding bottom reinforcement set

- 1 Add reinforcement
- 2 Set its area/location and apply proper material ID

Material definition for layered beam

List of defined layers

Add Modify Delete

N°	Type	Area	Distance	Material number
1	Core			1

Layer definition

Distance

Distance 0.02 [m]

☐ from top
☒ from bottom
☐ relative (-1,1)

Area 0.000804 [m²]

Number of layers 1

Material

1: concrete

1: concrete

2: steel

OK Cancel

Next slide



Adding reinforcement in axisymmetric case

- Radial reinforcement (total area or density can be specified)

The 'Layer definition' dialog box is shown with the following settings:

- Distance:** 0.02 [m]
- Orientation:** ☒ Radial
- Type:** ☒ Density
- Area:** 0.01 [m]
- Number of layers:** 1
- Material:** 2: steel
- Buttons:** Material definition, OK, Cancel

- Circumferential reinforcement

The 'Layer definition' dialog box is shown with the following settings:

- Distance:** 0.02 [m]
- Orientation:** ☐ Radial, ☒ Circumferential
- Type:** ☐ Total, ☒ Density
- Area:** 0.01 [m]
- Number of layers:** 1
- Material:** 2: steel
- Buttons:** Material definition, OK, Cancel