

Structural glass

Development of a Straus7's API based application

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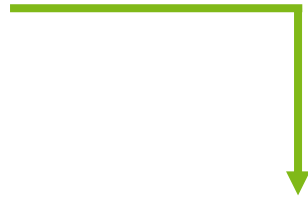


General design rules

Structural glass

General design rules

- Structural hierarchy
- Robustness
- Structural redundancy



- Class of consequence (CC)
- Laminated glass
- Post-failure verification



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General design rules

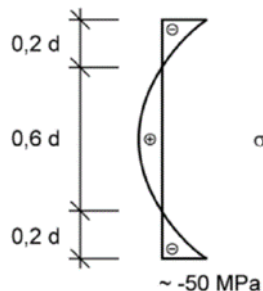
Strength dependencies:

- Load duration
- Concentration of stresses
- Presence of defects

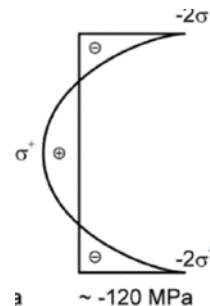


- Detail design accuracy
- Strengthening process

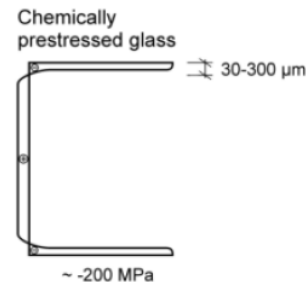
heat
strengthened glass
HSG



thermally
toughened glass
TTG



chemically
strengthened glass
HSG



Structural glass

General design rules

CNR- DT 210/2013 design value of bending strength

$$f_{g;d} = \frac{k_{mod} \cdot k_{ed} \cdot k_{sf} \cdot \lambda_{gA} \cdot \lambda_{gl} f_{g;k}}{R_M \gamma_M} + \frac{k'_{ed} k_v \cdot (f_{b;k} - f_{g;k})}{R_{M;v} \gamma_{M;v}}$$

- k_{mod} load duration
- k_{ed}, k'_{ed} finishing of edge affected by tensile stresses
- k_{sf} surface profile
- $\lambda_{gA}, \lambda_{gl}$ pane area / edge length affected by tensile stresses
- k_v manufacturing toughening process
- $f_{g;k}$ characteristic value of the bending strength for annealed glass (45 MPa)
- $f_{b;k}$ characteristic value of the bending strength of prestressed glass
- $\gamma_M, \gamma_{M;v}$ material partial factor for annealed / prestressed glass
- $R_M, R_{M;v}$ factor for class of consequence (CC1) o (CC2)

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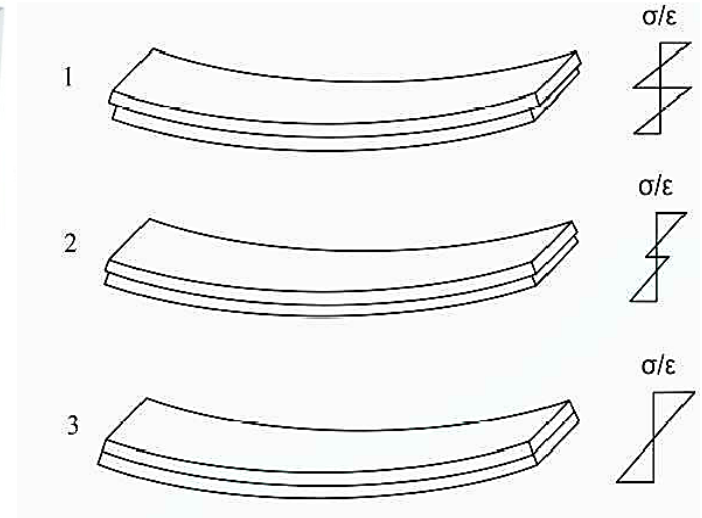
General design rules

Dependencies of interlayer mechanical properties:

- Load duration
- Temperature



Behaviour of laminated panel



Case studies

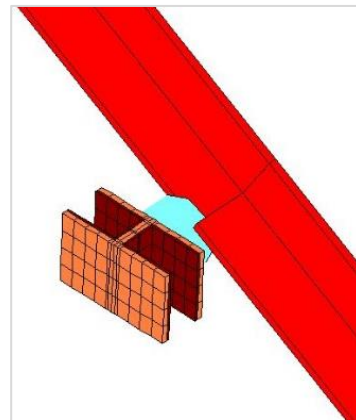
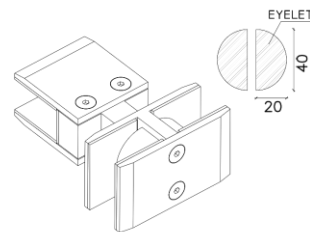
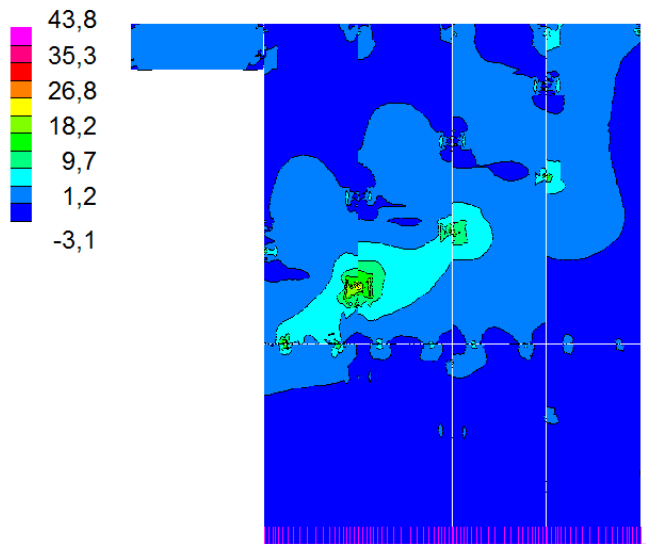
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Case studies

Refurbished Margherita Theatre in Livorno



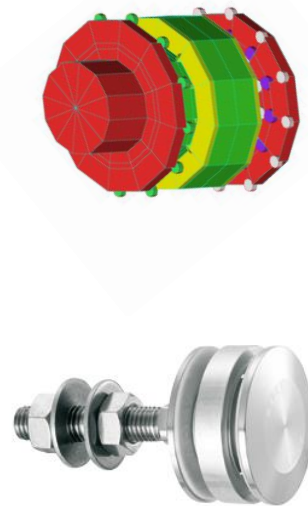
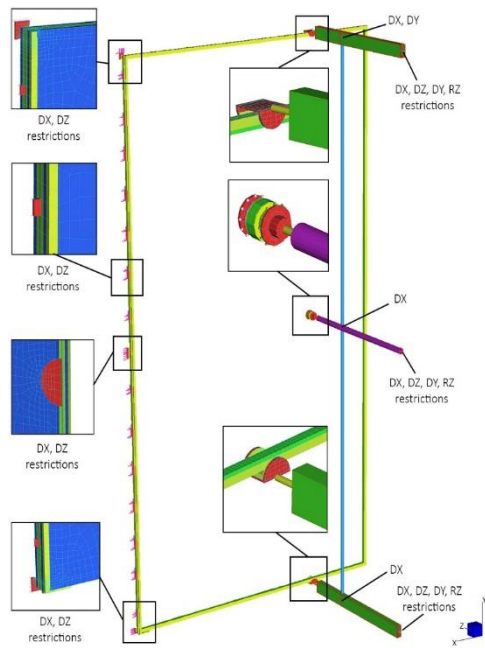
Brick Stress:11 (MPa)



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Case studies

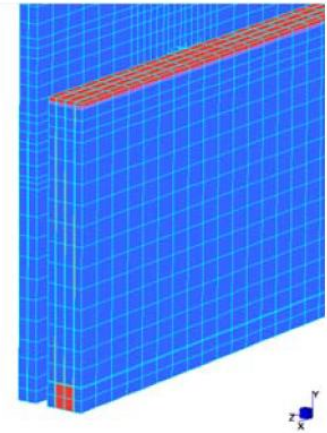
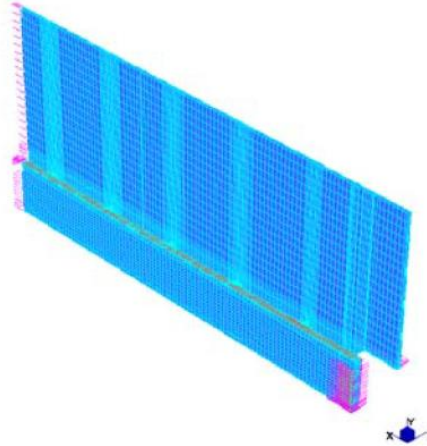
Tour Trinity façade in Paris



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Case studies

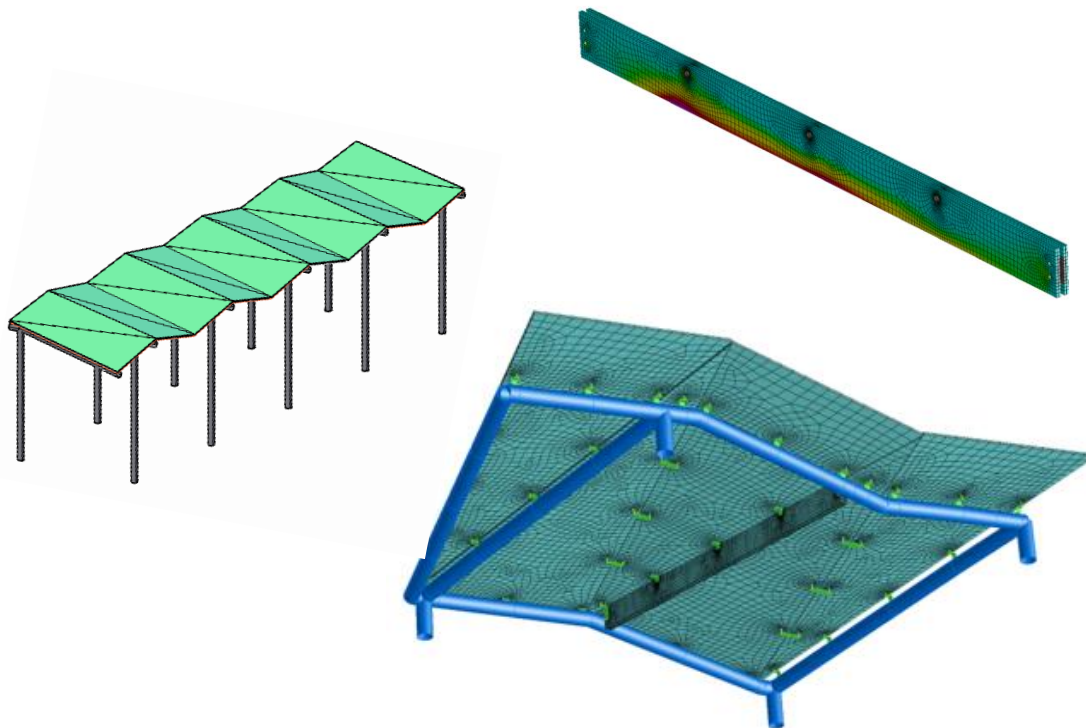
Refurbishment historical slaughterhouse in Pisa



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Case studies

Point-supported glass roof for "San Rossore clinic" in Pisa



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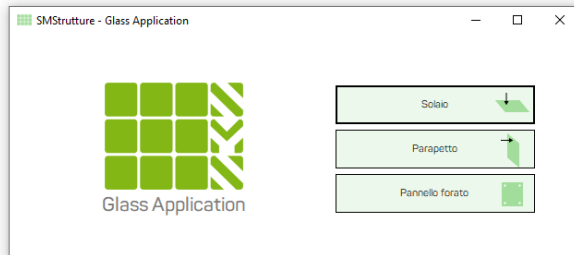
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Goals

Accurate modeling
Short modeling times
Verification according to CNR DT 210

Tools

Visual Studio – Windows Forms .NET
C# programming language
St7API.dll



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Case studies

- 1 - Floor
- 2 - Parapet
- 3 – Panel with holes

Workflow

- a - Modeling
- b – Load definition
- c – Material definition
- d - Verification

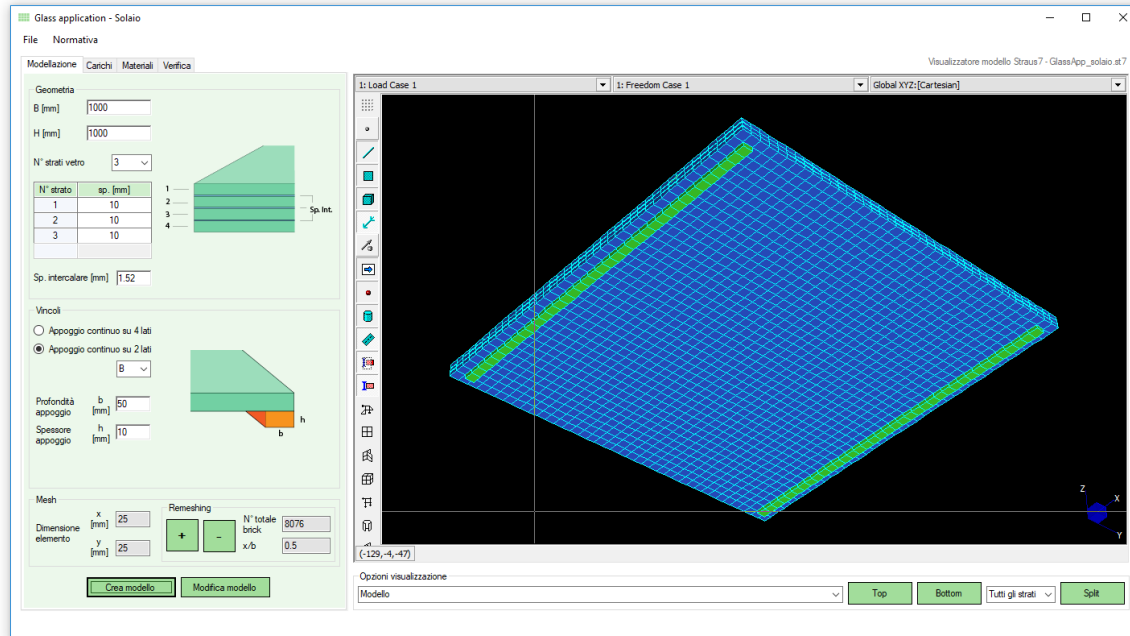
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1 - FLOOR a - Modeling

Definitions:

- Panel dimension
- Number and thickness of layer
- Interlayer thickness
- Boundary condition



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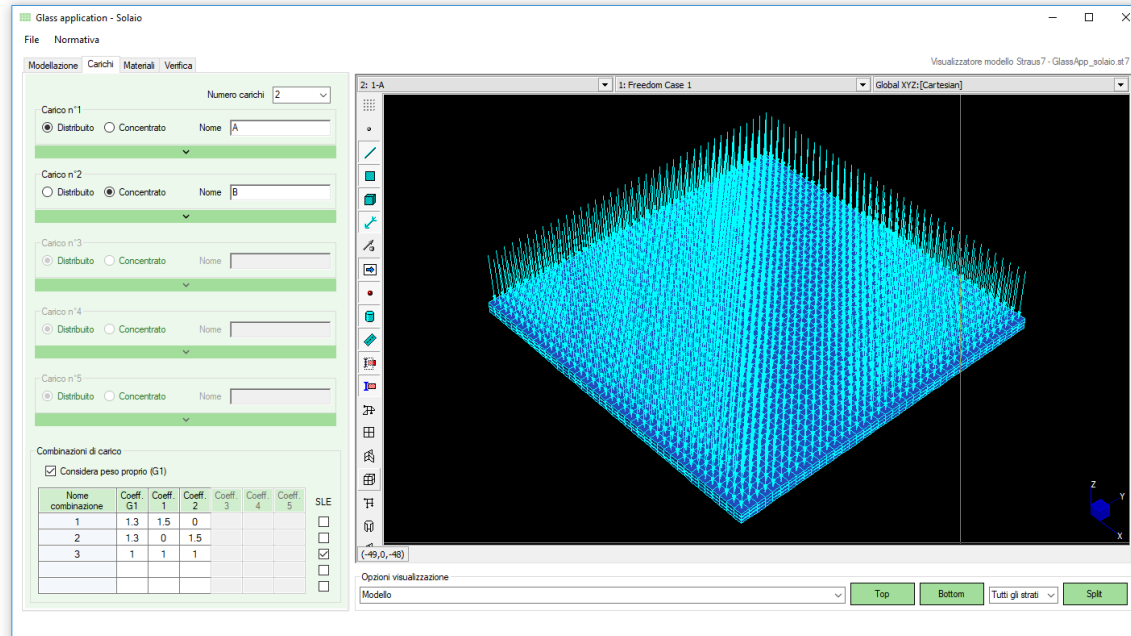
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1 - FLOOR

b – Load definition

Definitions :

- Number of loads
- Value, position and duration of load
- Combination



Structural glass

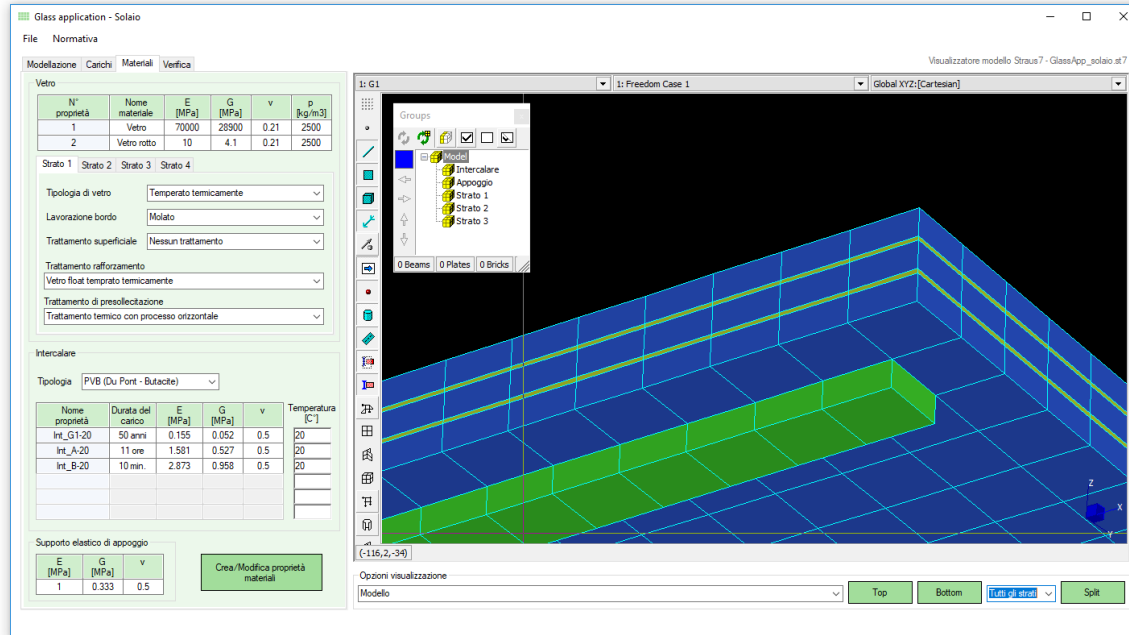
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1 - FLOOR

c – Material definition

Definitions :

- Glass material
- Glass strength
- Interlayer material
- Support material



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1 - FLOOR d - Verification

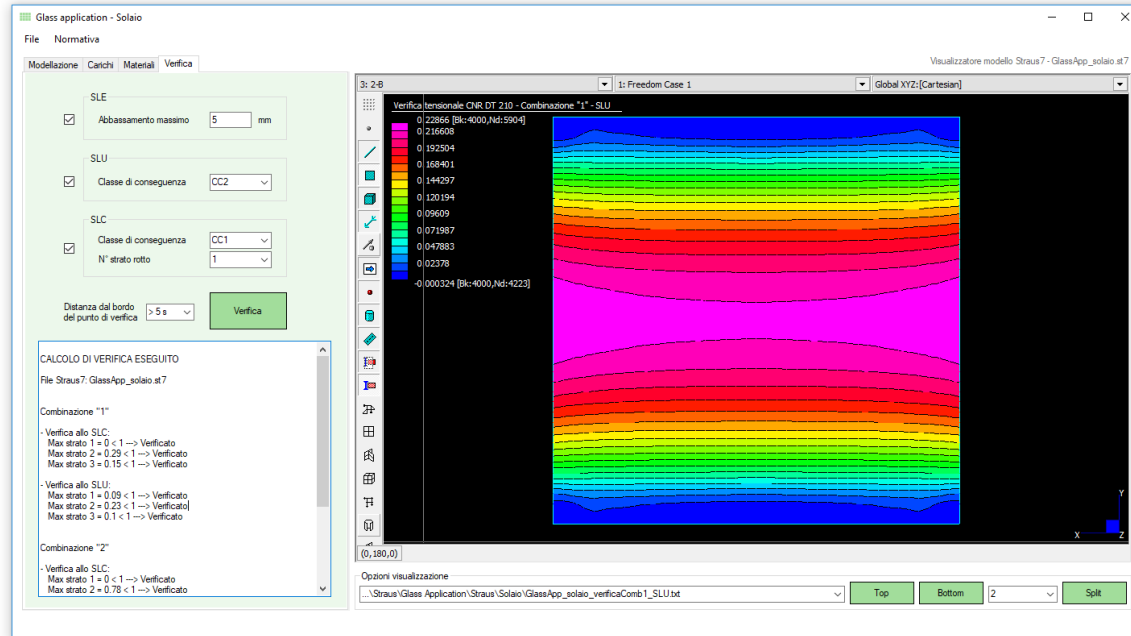
Definitions :

- Max displacement
- ULS and NC CC
- Cracked layer
- Point of verification

Verification :

- One LSA for each load case and limit state
- superposition

$$\frac{\sigma_{\max}^G}{f_{g,d}^G} + \frac{\sigma_{\max}^q}{f_{g,d}^q} \leq 1$$

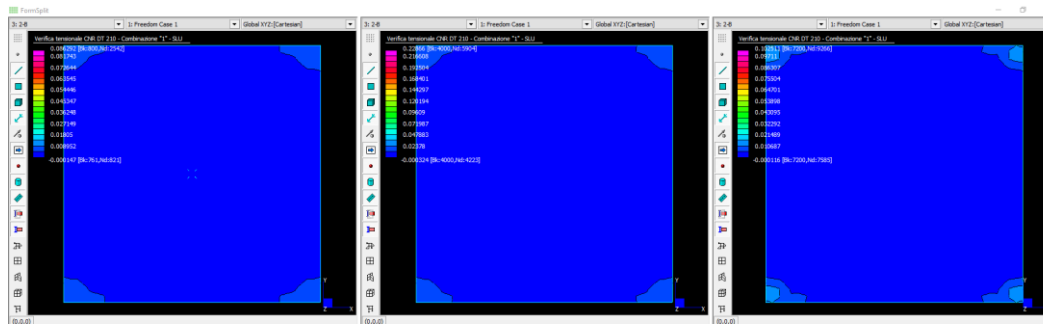


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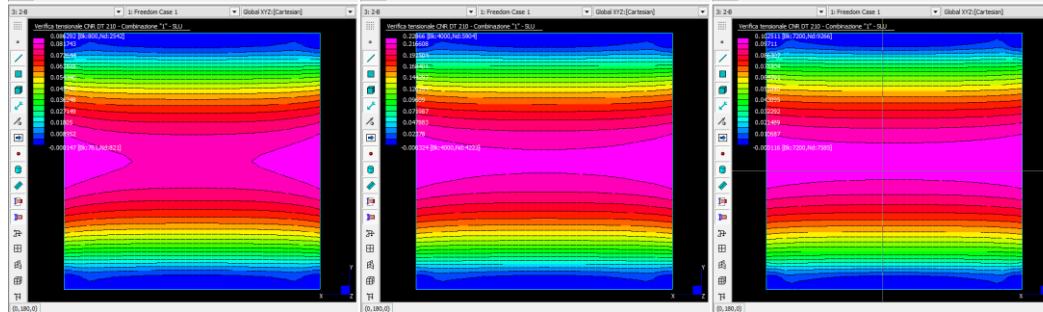
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1 - FLOOR Split

Top



Bottom



Layer 1

Layer 2

Layer 3

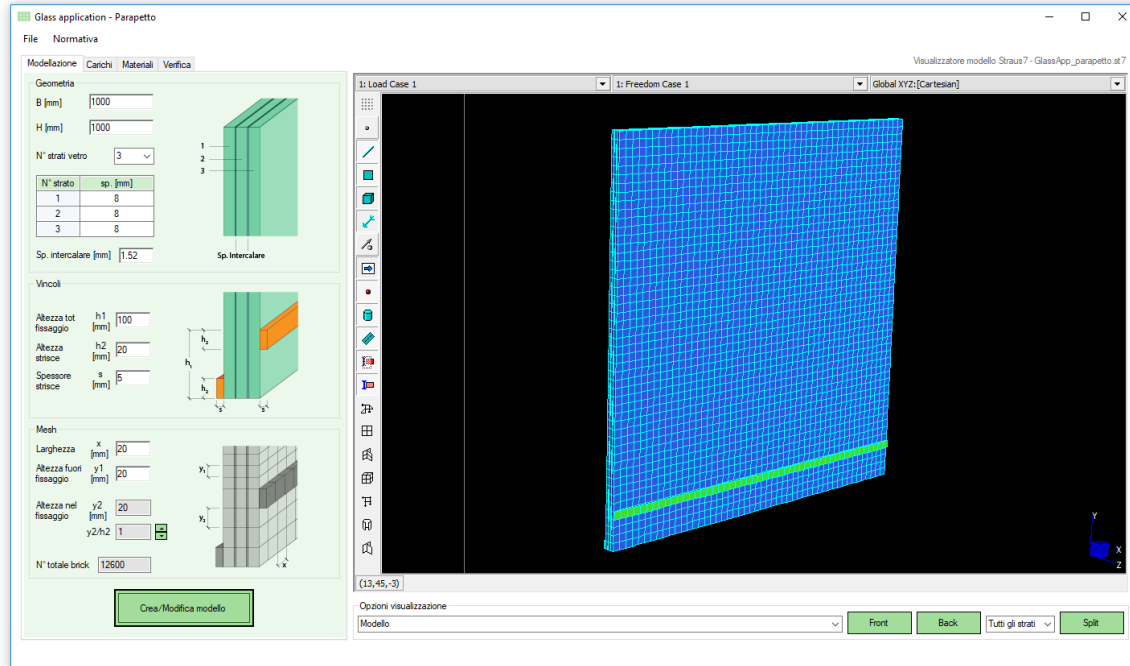
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2 - PARAPET a - Modeling

Definitions:

- Panel dimension
- Number and thickness of layer
- Interlayer thickness
- Boundary condition



Structural glass

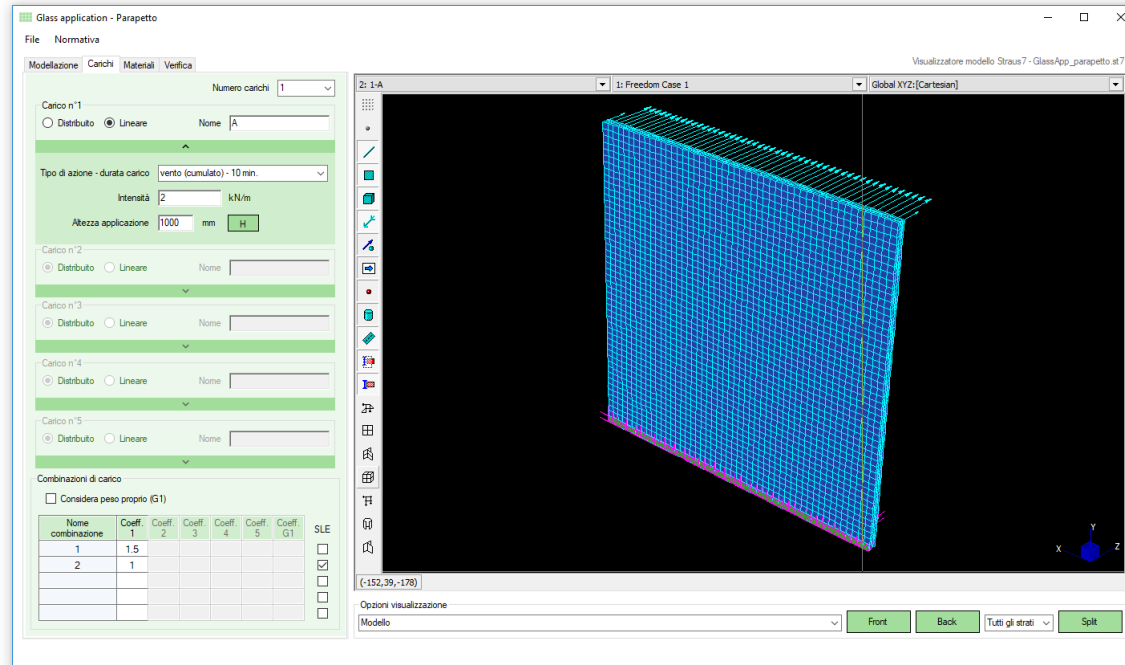
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2 - PARAPET

b - Loads definition

Definitions :

- Number of loads
- Value, position and duration of load
- Combination



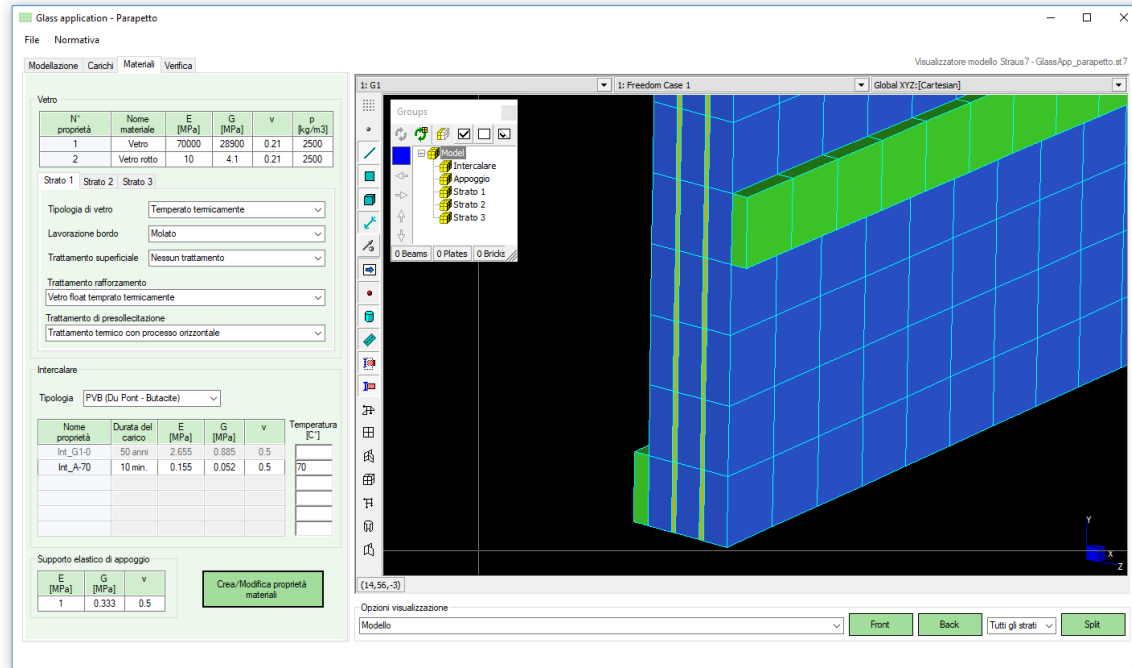
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2 - PARAPET c – Material definition

Definitions :

- Glass material
- Glass strength
- Interlayer material
- Support material



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2 - PARAPET d - Verification

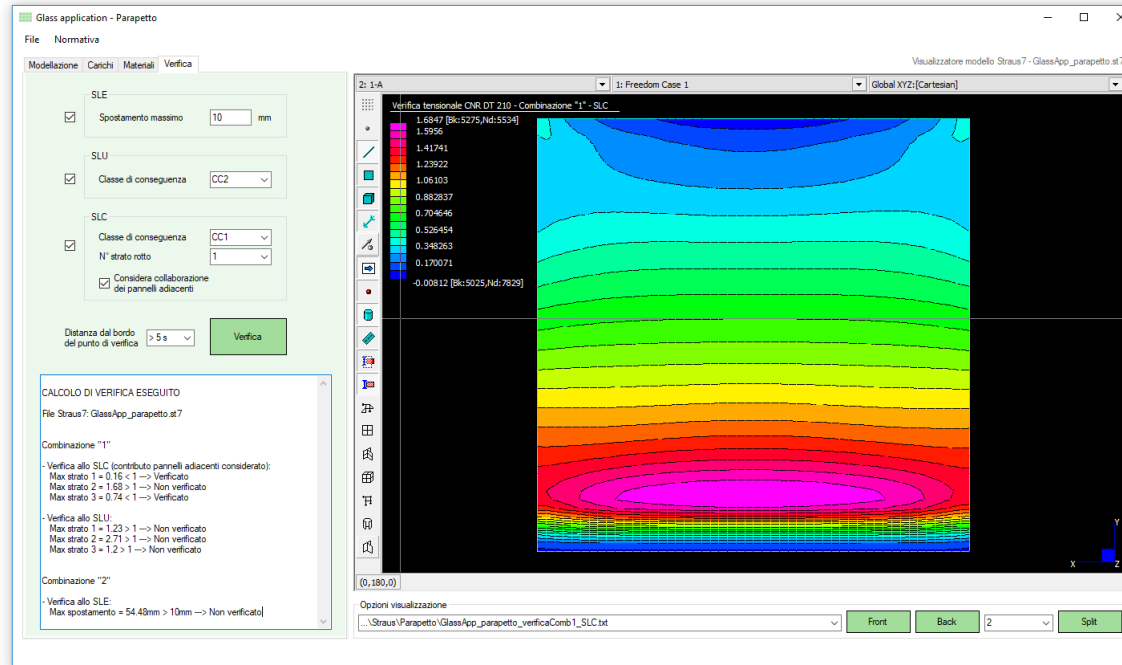
Definitions :

- Max displacement
- ULS and NC CC
- Cracked layer
- Point of verification

Verification :

- One LSA for each load case and limit state
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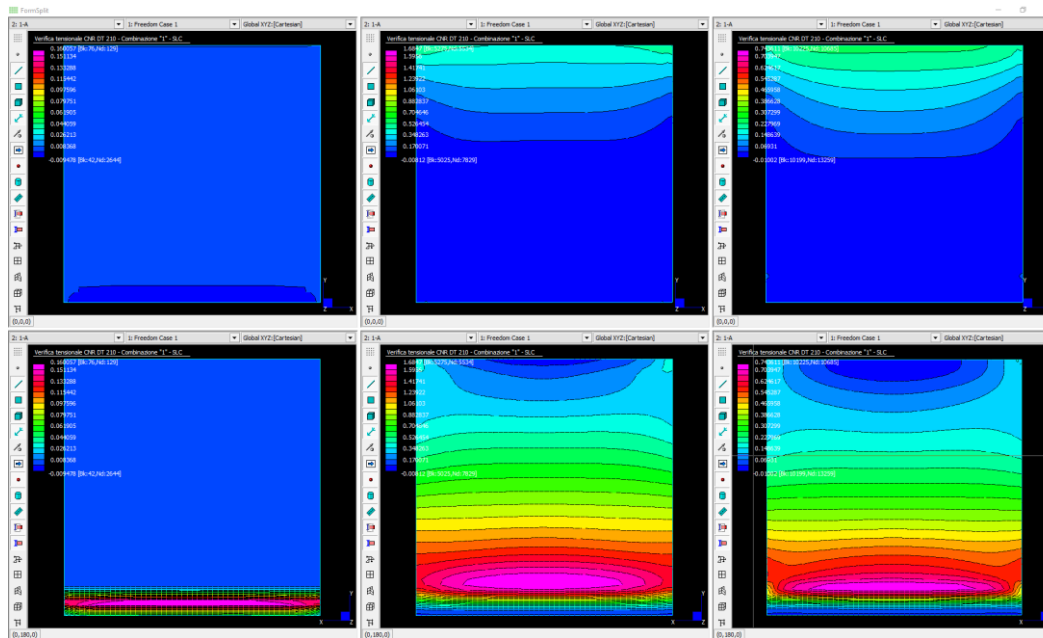


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2 - PARAPET Split

Front



Back

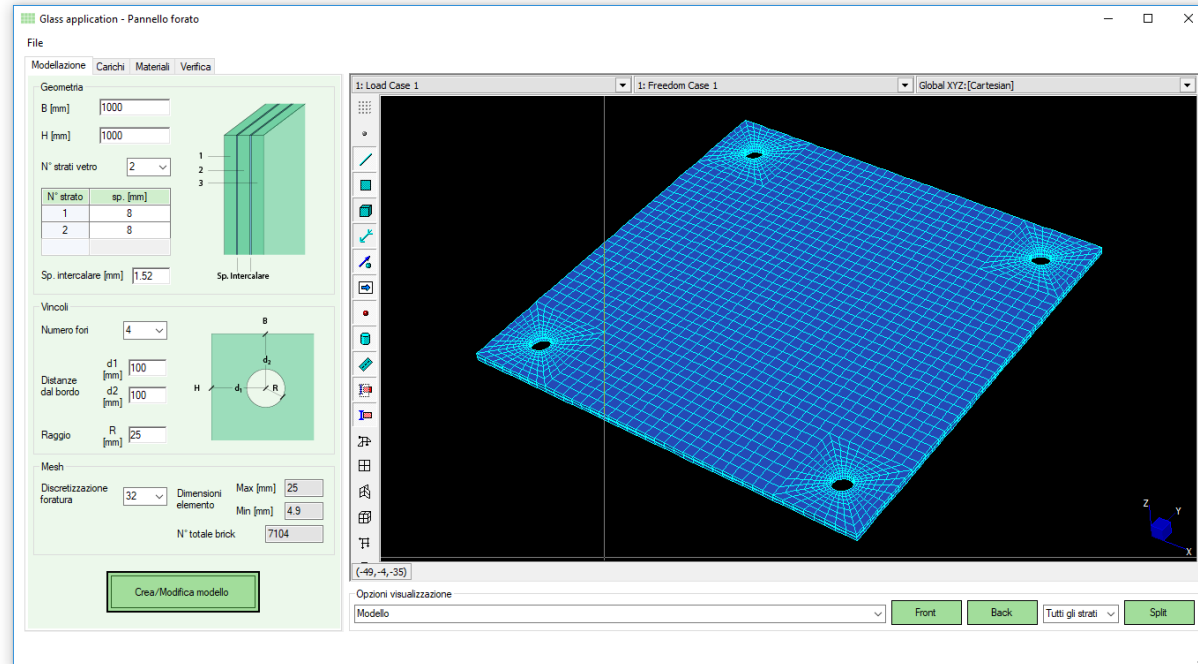
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3 - PARAPET a - Modeling

Definitions:

- Panel dimension
- Number and thickness of layer
- Interlayer thickness
- Number, position and diameter of holes



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Outlook

Tensional verification of puntual joints

Impact verification

DGU verification

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Thank you for your attention!