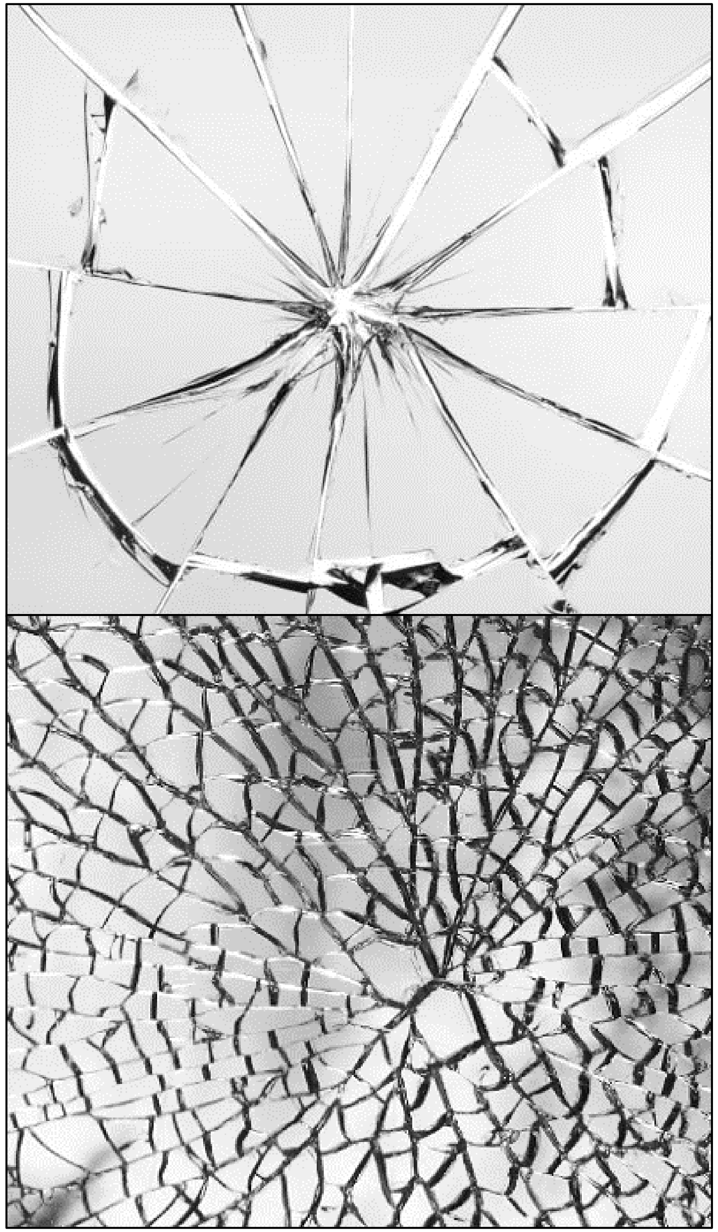
Computational Modeling and Experimental Verification of Soft-body Impact on Glass Structures

Ernest Björklund

Axel Christoffersson

Glass as an Engineering Material



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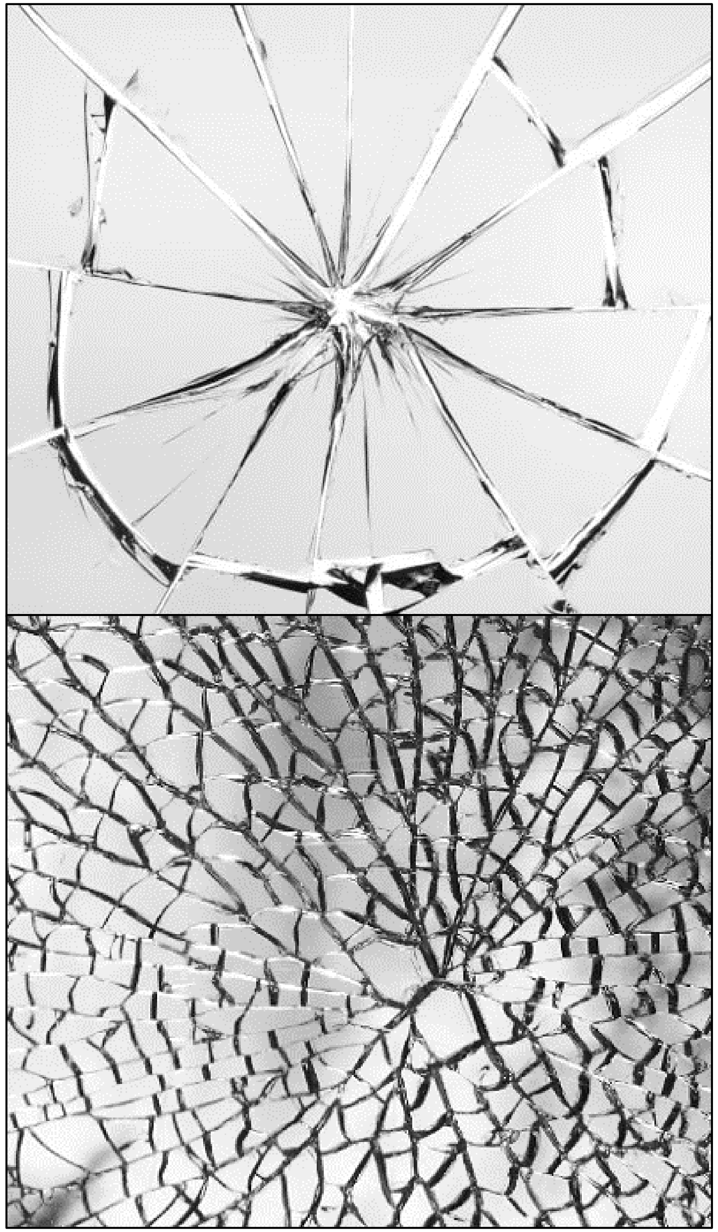

- High theoretical strength: ~20 GPa*
- Surface flaws
  → practical strength: ~0.1 GPa
- This, combined with glass having no plastic capacity:
  → Principal stress governing
  → Sensitivity to high-stress load events

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Area of Interest: High Stress, Short Duration Loading, i.e. Impact Loading

- Material strength lost as soon as cracks appear
  - → Sensitive to impact

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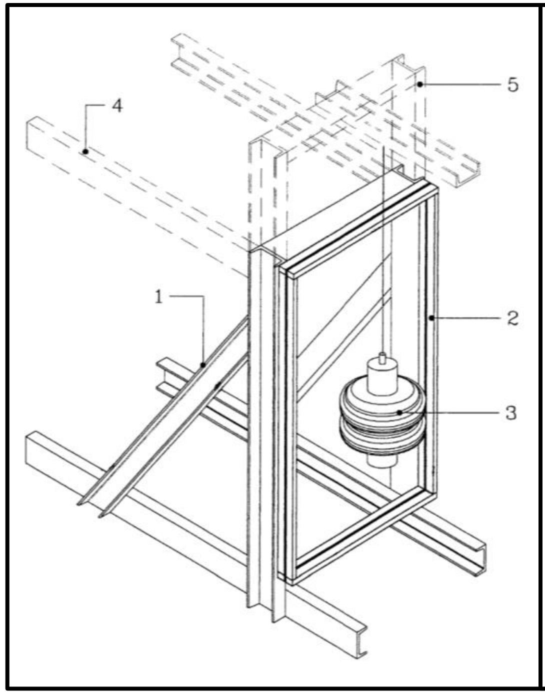

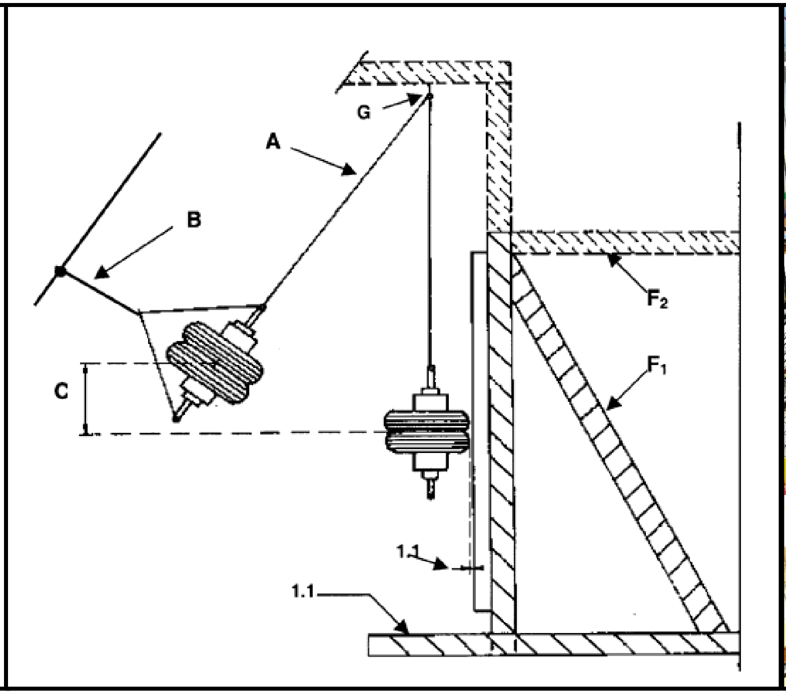

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  → 50 kg pendulum mass, glass panel supported on all sides

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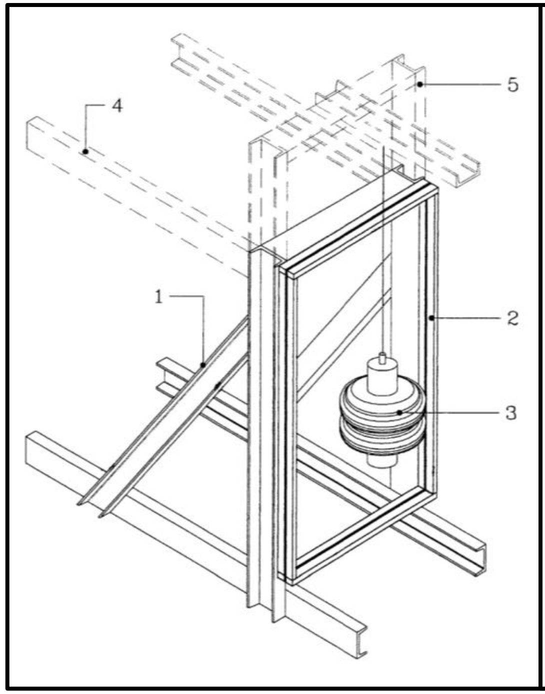

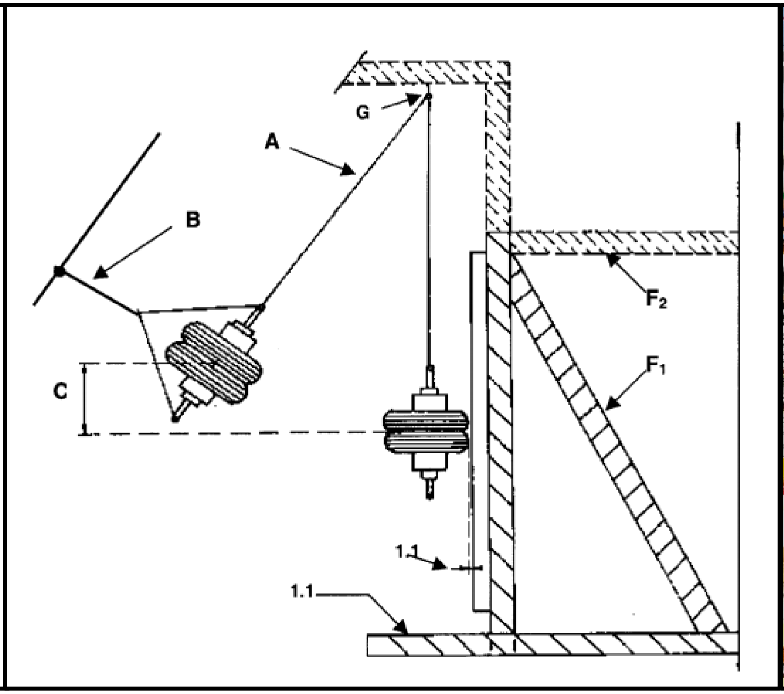

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- Experimental method (SS-EN 12600) used for classifying glass with respect to resistance against soft-body impact
  → 50 kg pendulum mass, glass panel supported on all sides
  → Expensive, time-consuming, only one connection type

Experimental Setups

Purpose: investigate the viability of
a numerical method for verifying
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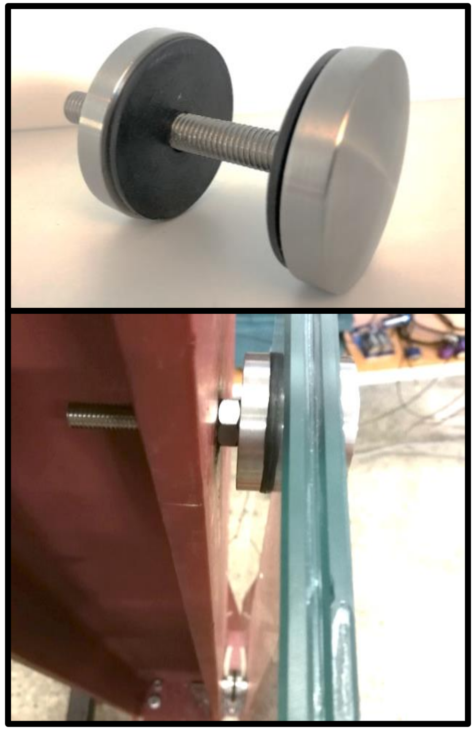

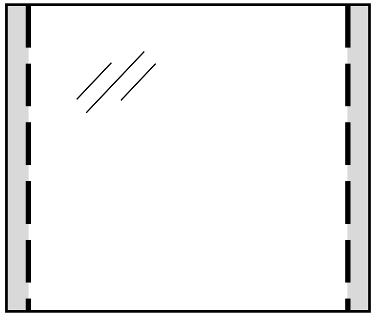
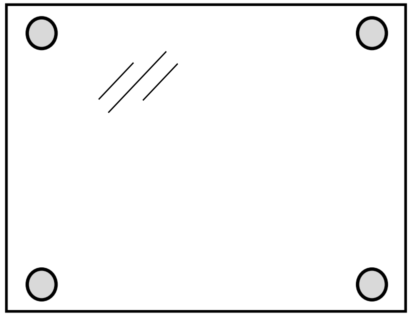
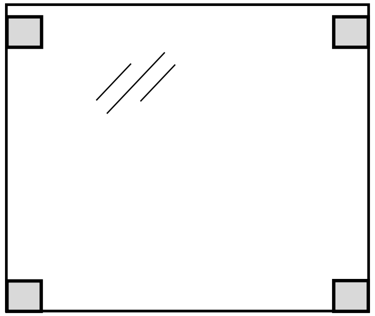

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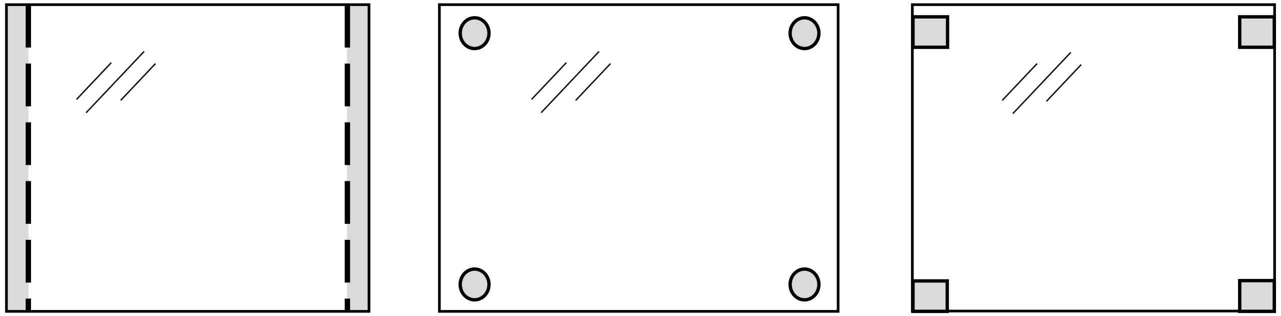
Purpose: investigate the viability of a numerical method for verifying the resistance of an arbitrary glass panel to soft-body impact.

Extensive experimental data

- Multiple glass types; monolithic and laminated
- 3 Setups: Simply-Supported, Point-fixed at corners, Clamp-fixed at corners
- Five different drop heights



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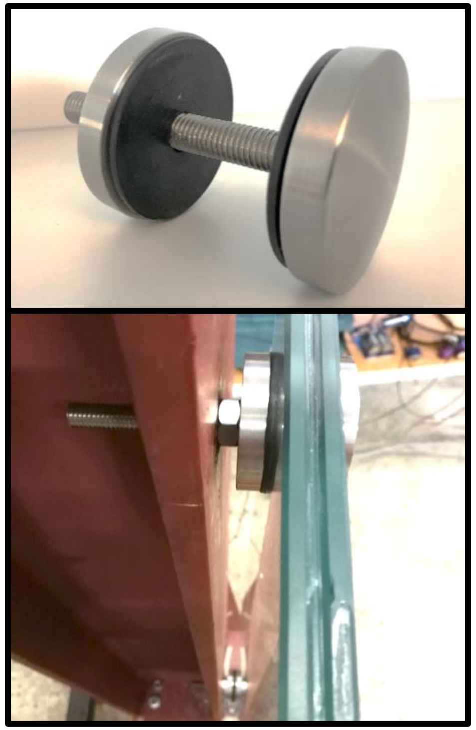
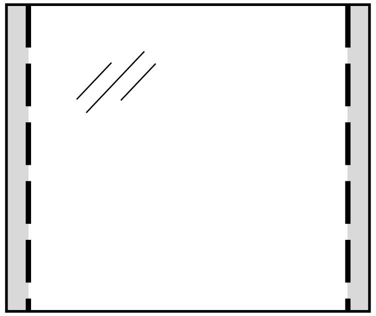
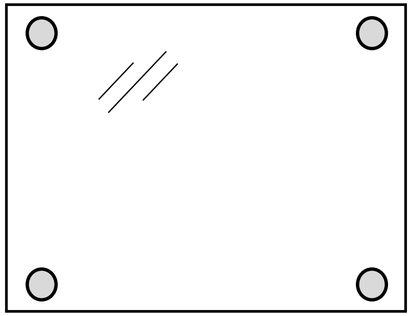
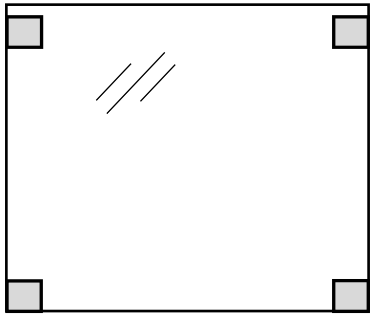




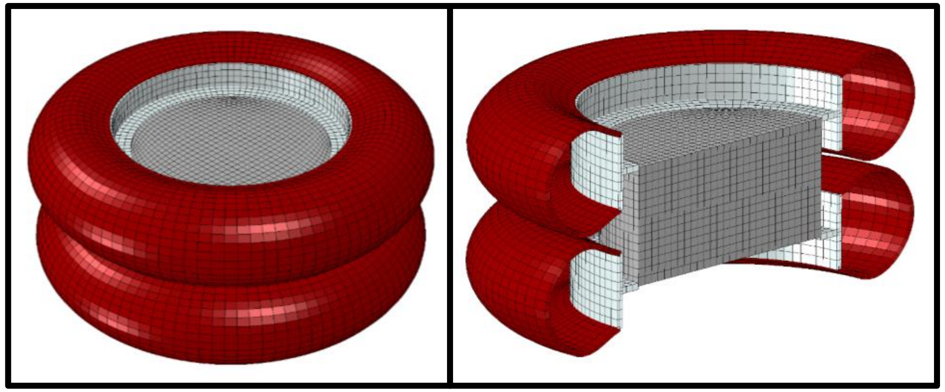


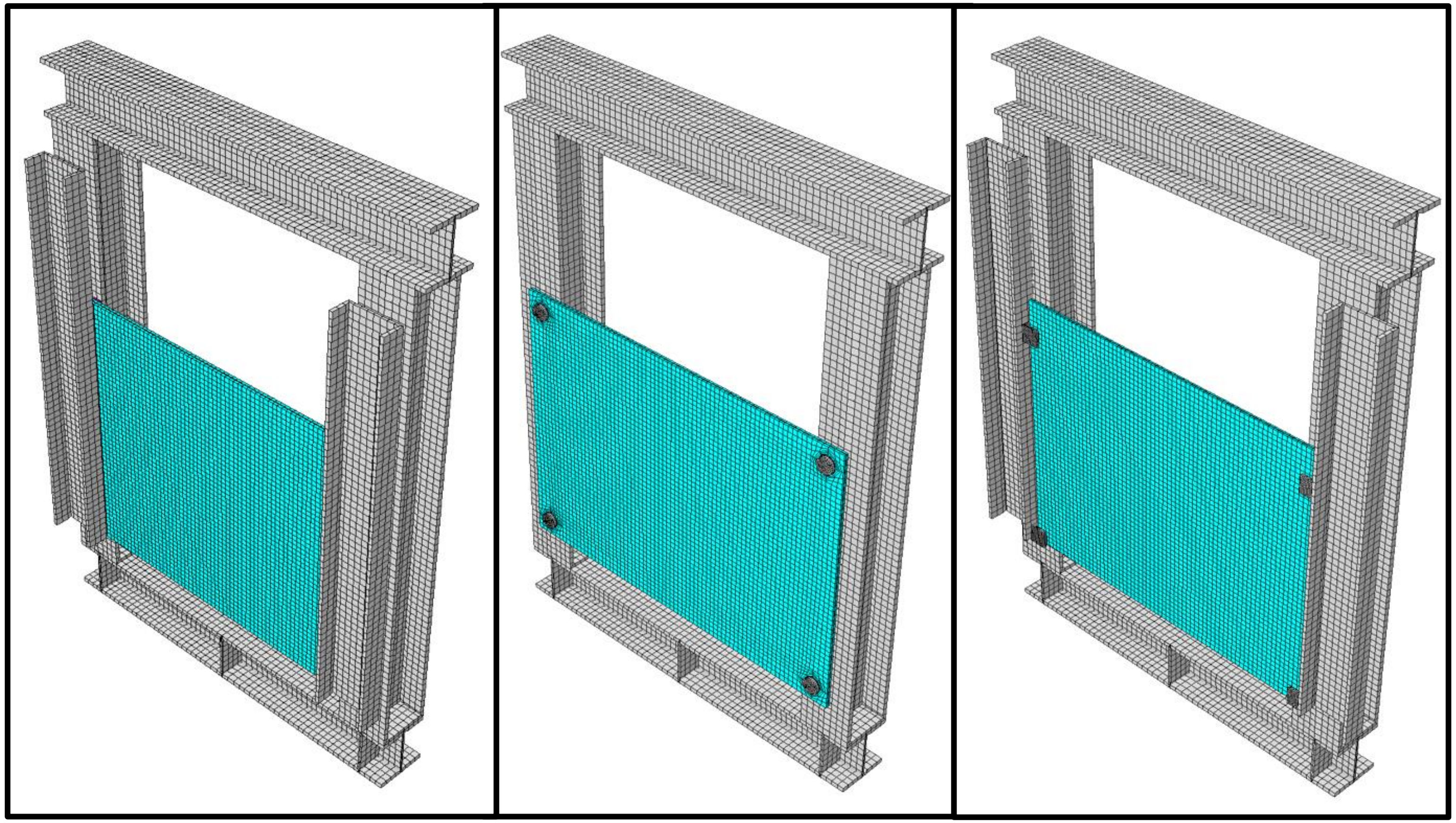


Finite Element Models

- Developed in Abaqus

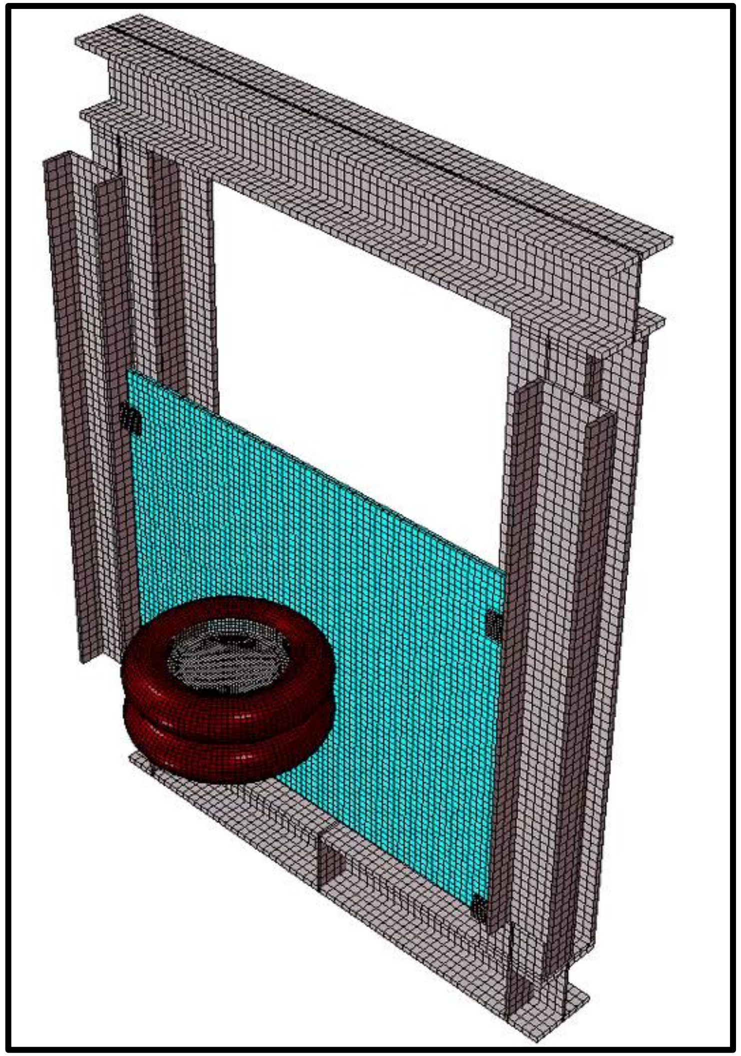
- Impactor
- Main frame
- Clamping frame
- Glass specimen

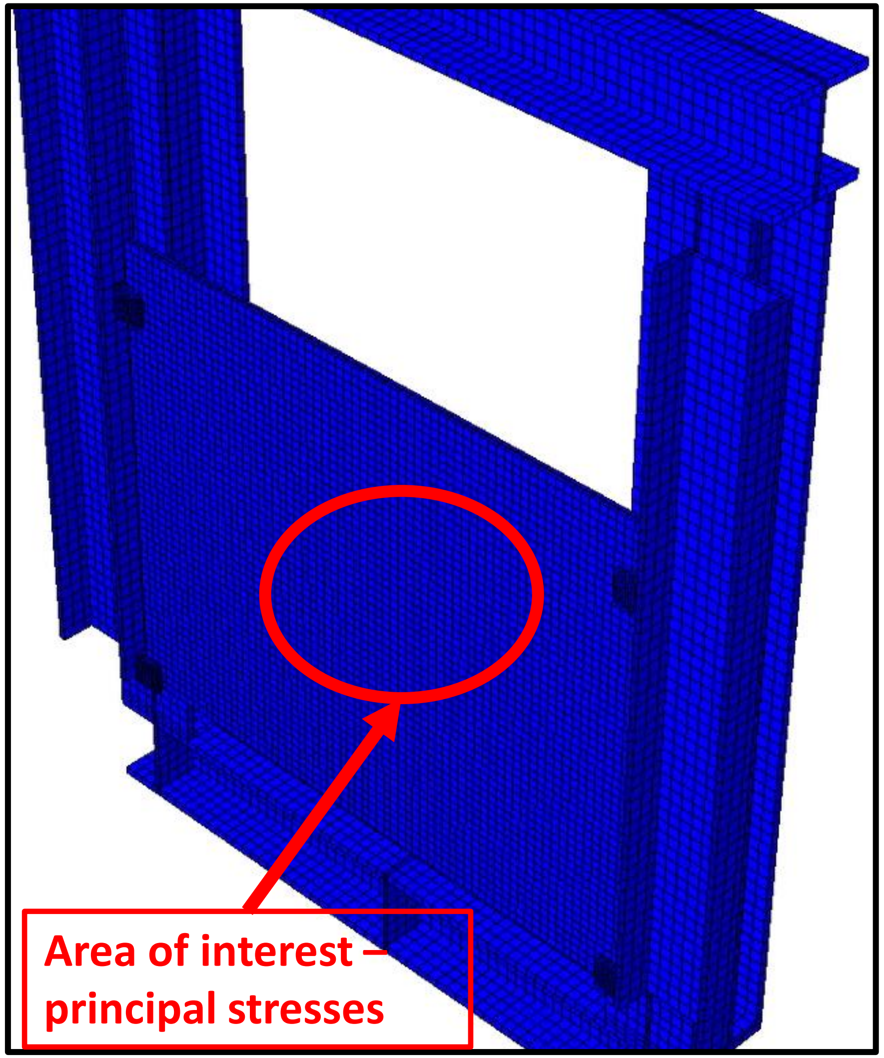




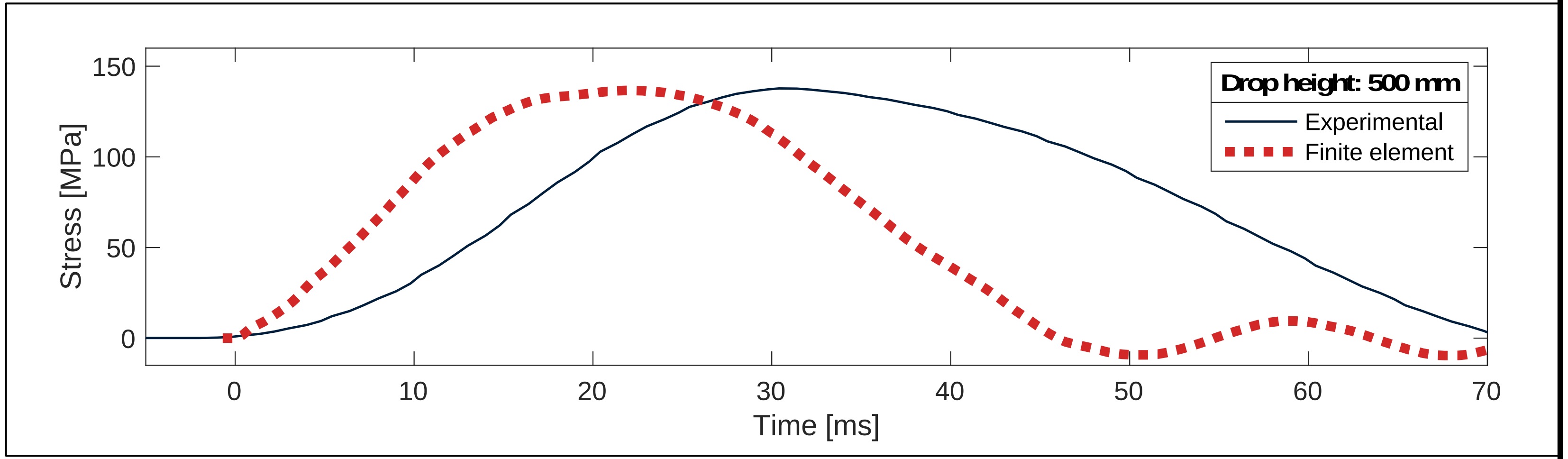
Simply-supported | Bolted | Clamp-fixed

Example of High-fidelity Model Simulation

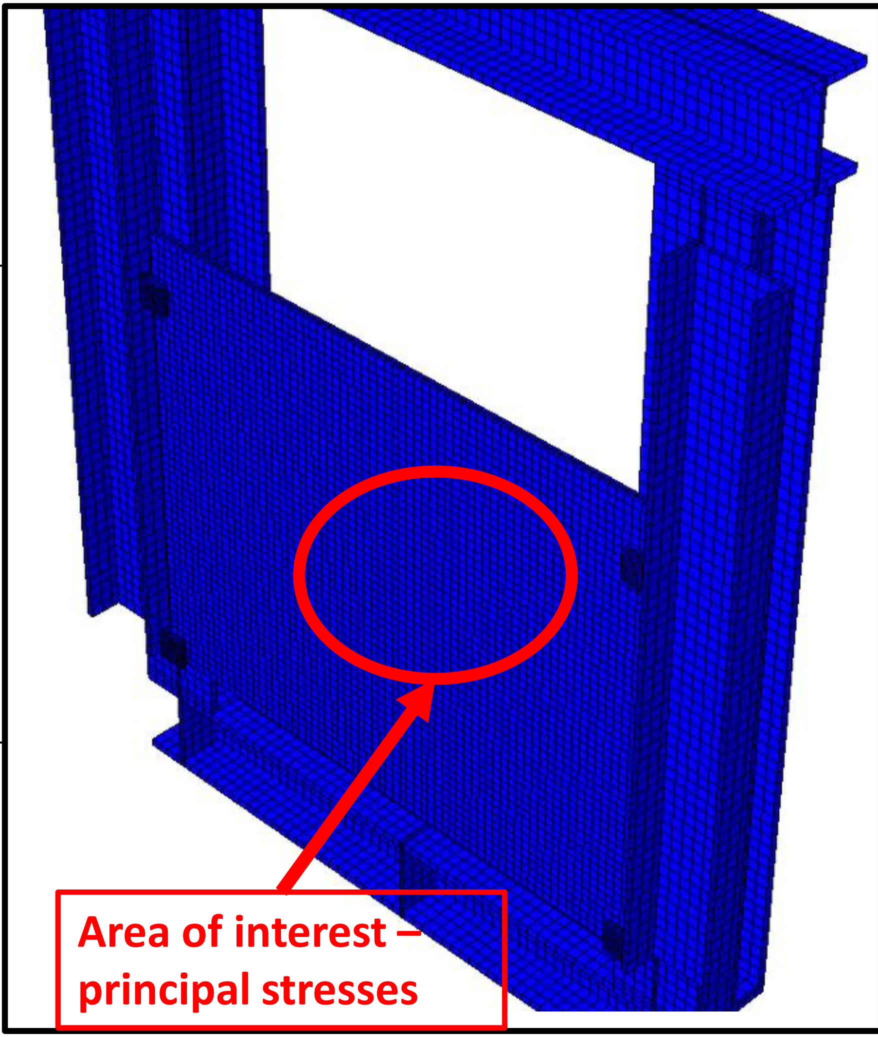




High-fidelity computational models – good results, albeit expensive



Simply supported setup, 10 mm monolithic glass, impactor drop height 500 mm.

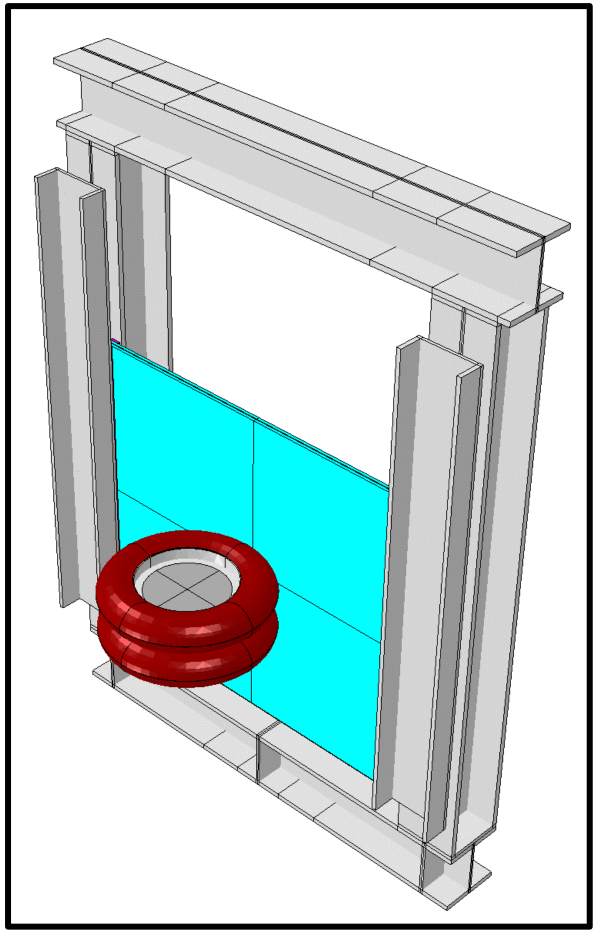


Average deviation in principal stress for the high-fidelity FE-models: 9%

Reduction of Finite Element Model

- The industry require *efficient* tools

- Reduce computational cost by reducing complexity:



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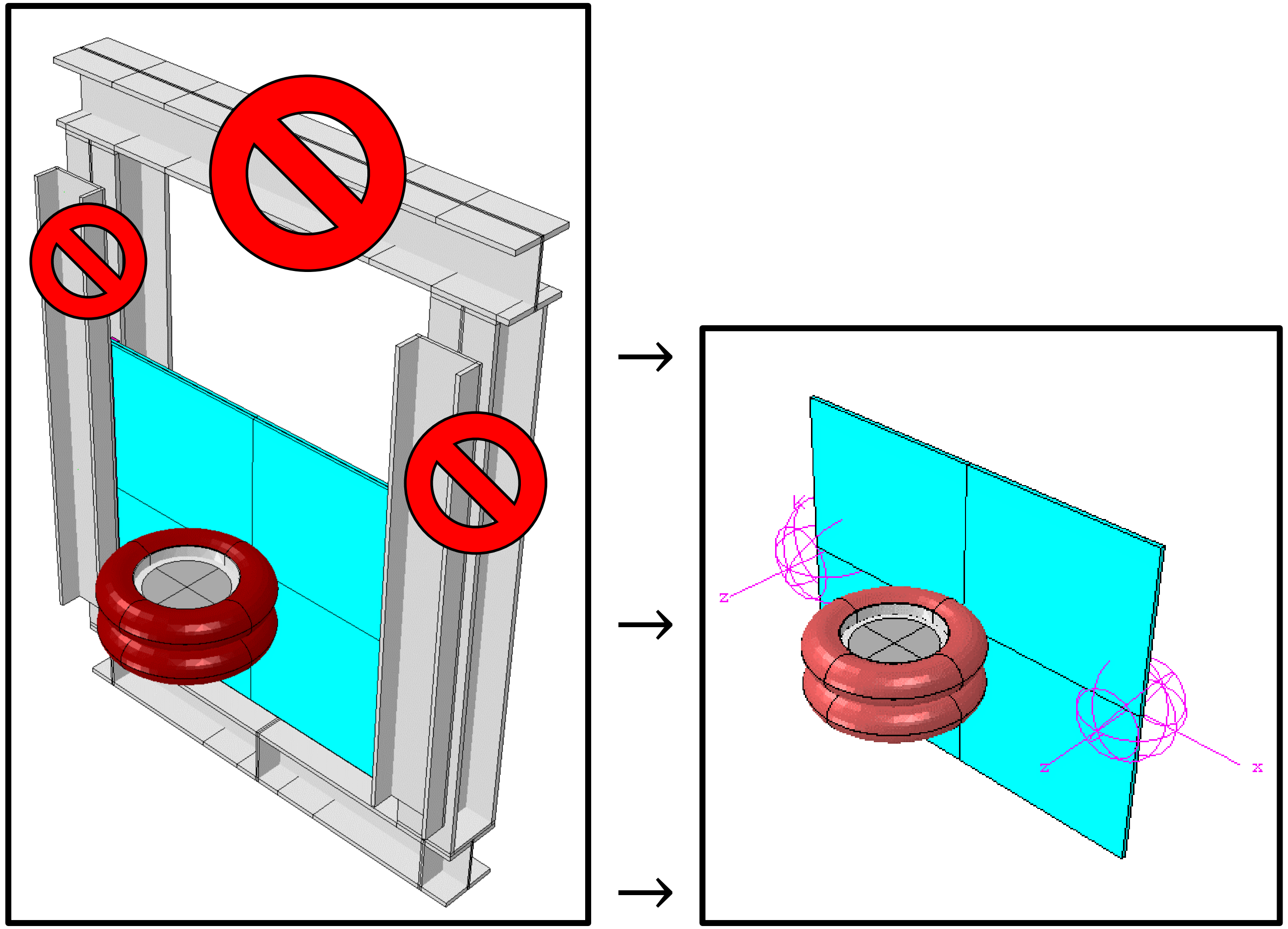
    - Geometry
    - Replaced with springs
    - Etc.



Reduction of Finite Element Model

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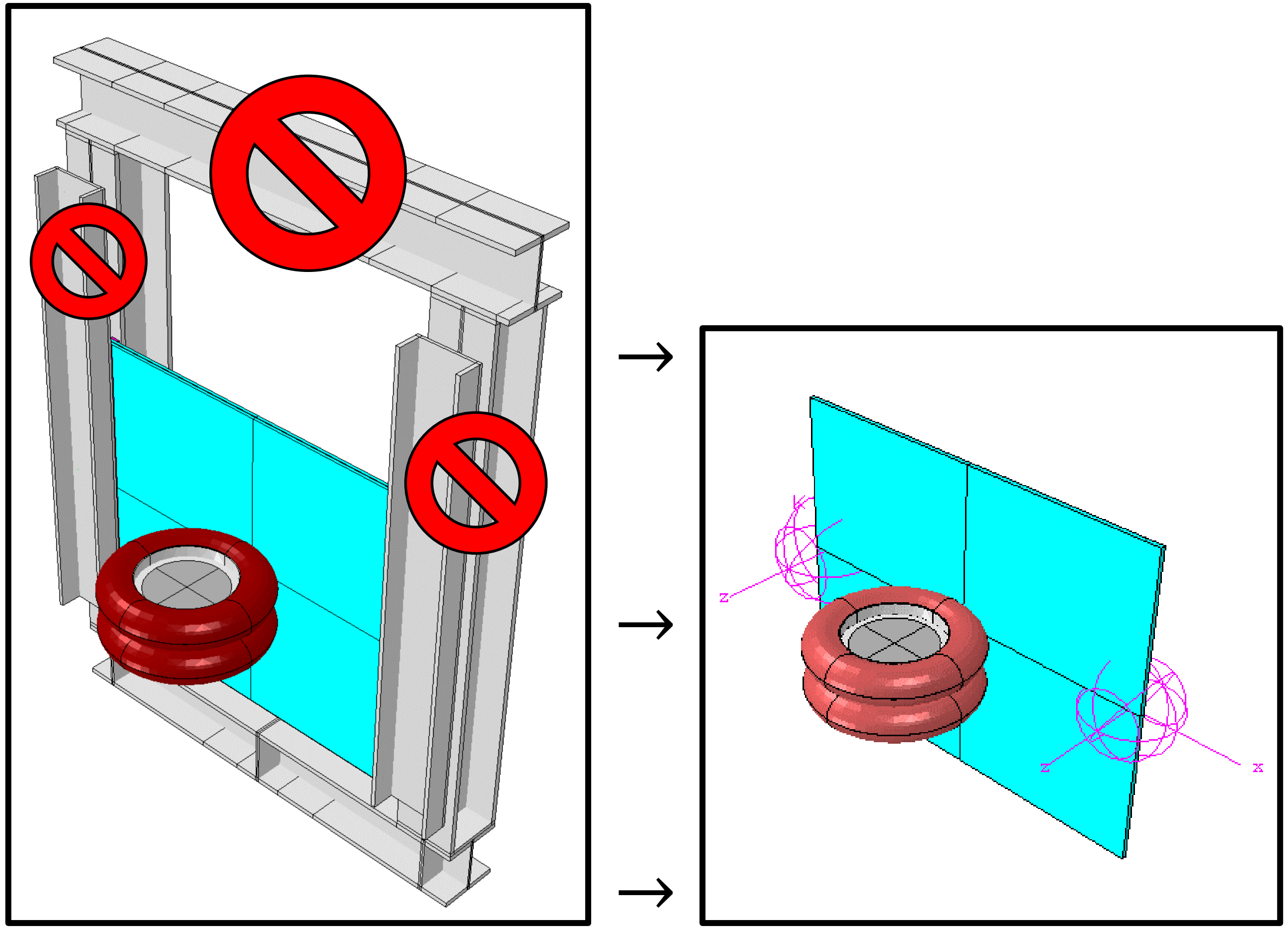
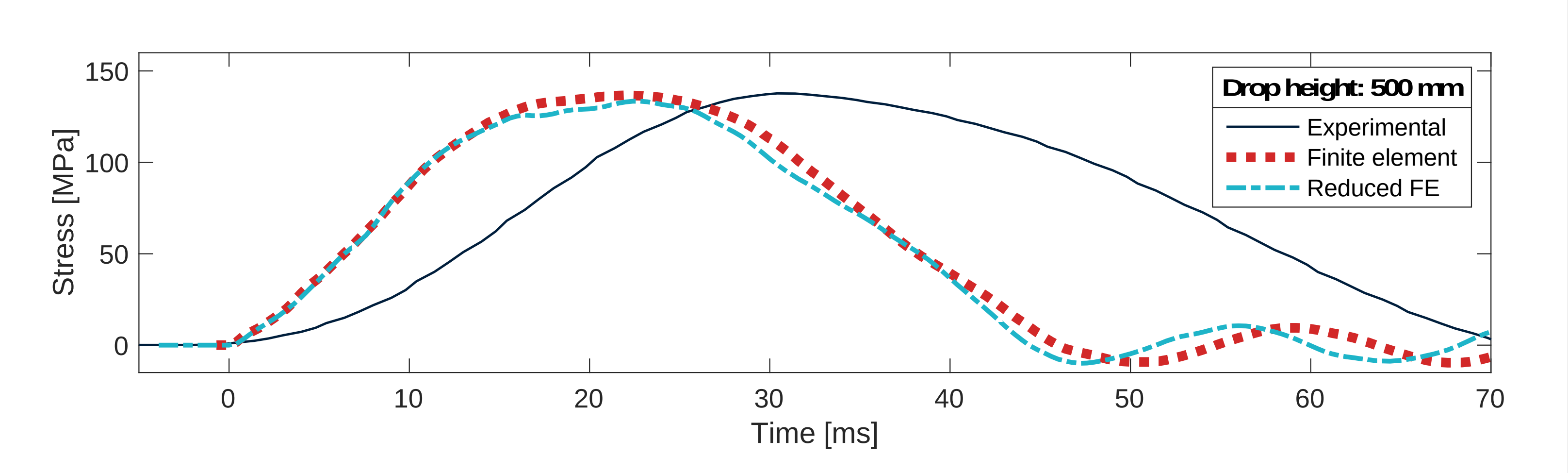
→ 70% faster



Reduced FE-Models – Accurate low-cost results



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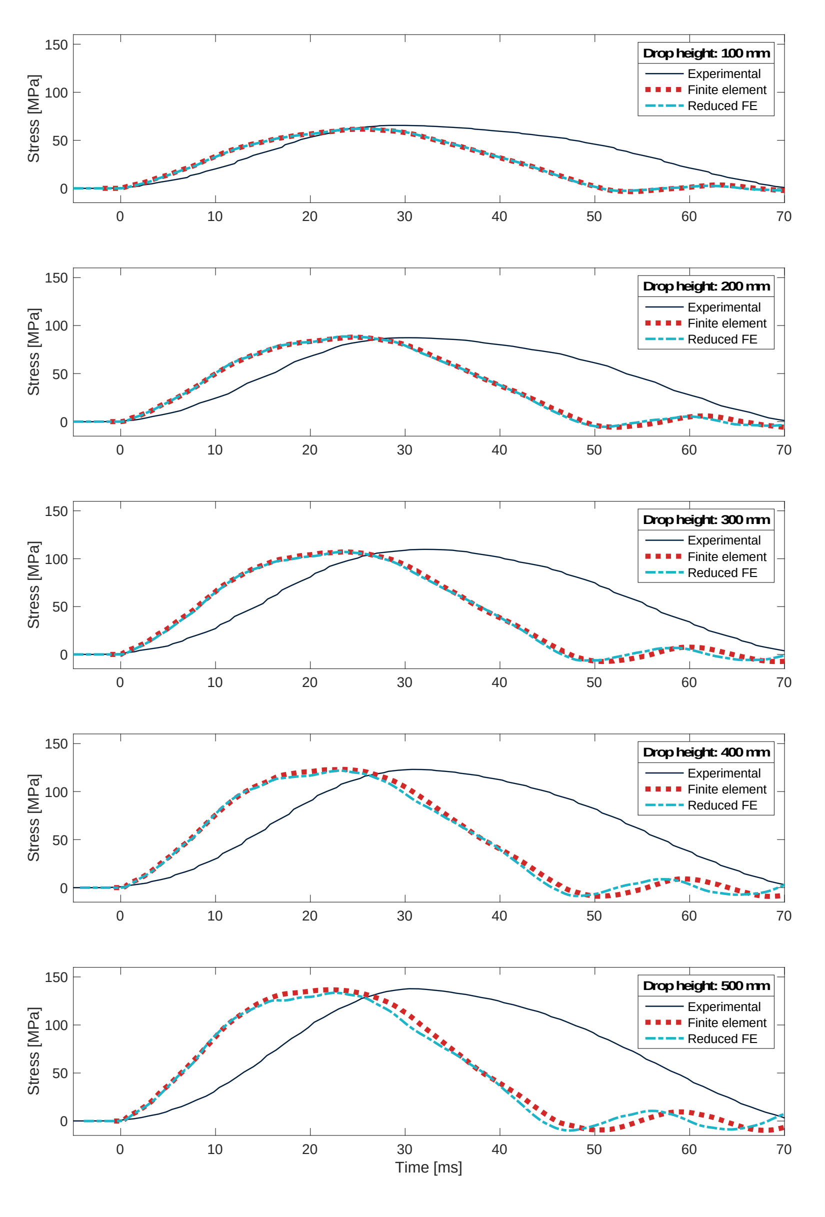


Avarage deviation in principal stress for the reduced FE-Model:
6 %

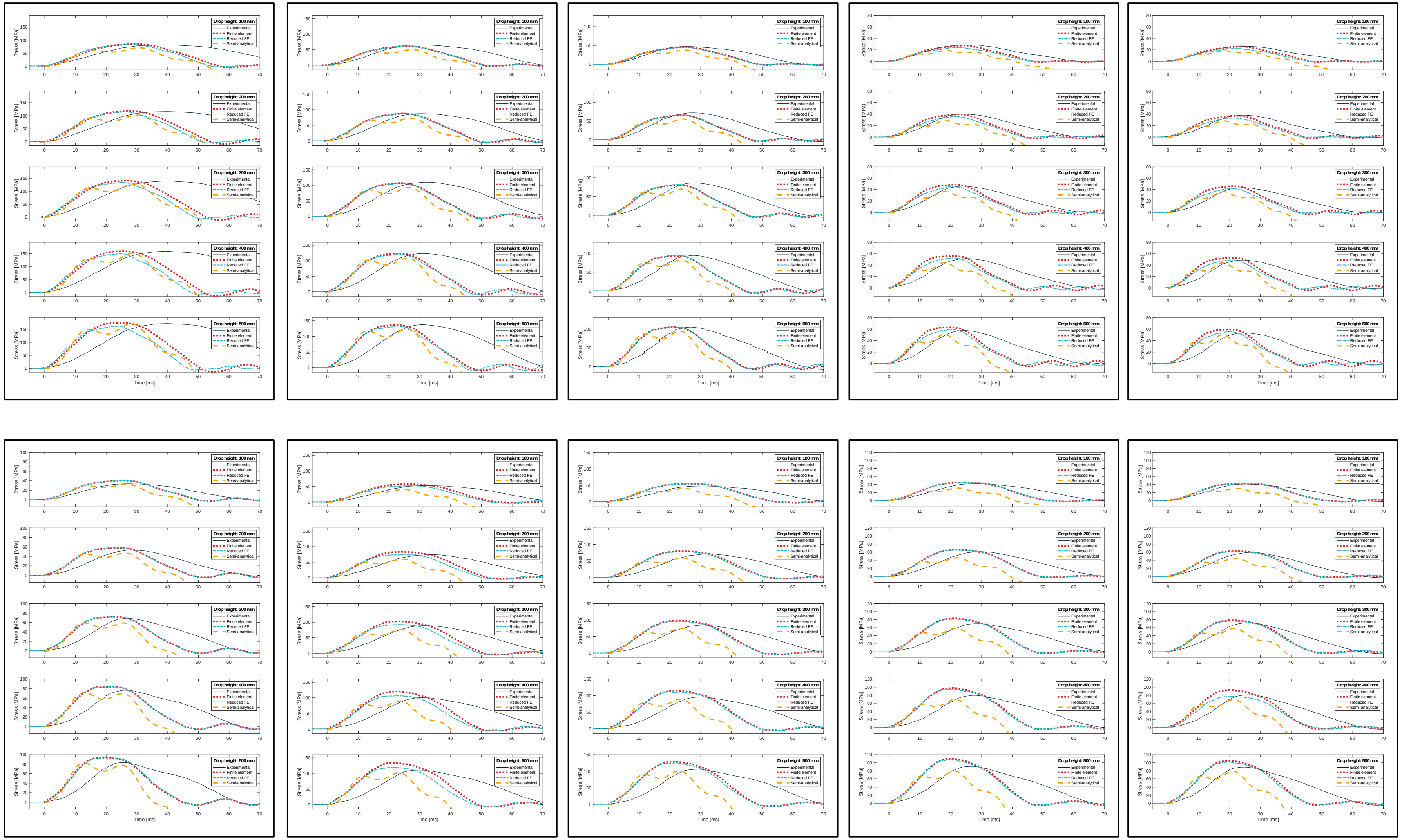
High robustness in the method

Approx. 200 experimental data series analyzed

50 simulations of high-fidelity models

50 simulations of reduced models

50 simulations of analytical models



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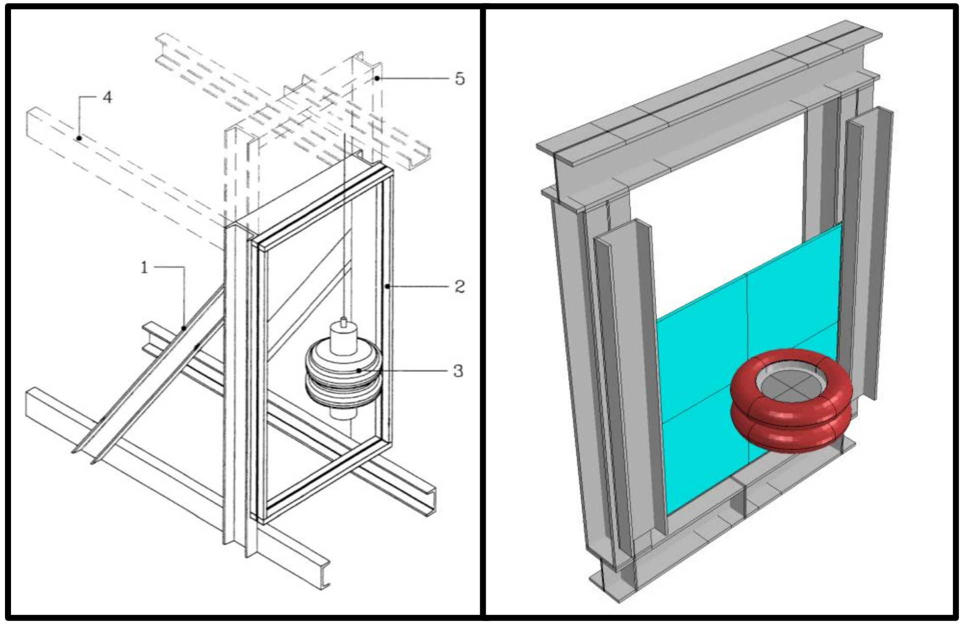
- Regulation (Eurokod, BBR, etc.) stipulates requirements for certain elements (e.g. balustrades) with respect to soft-body impact



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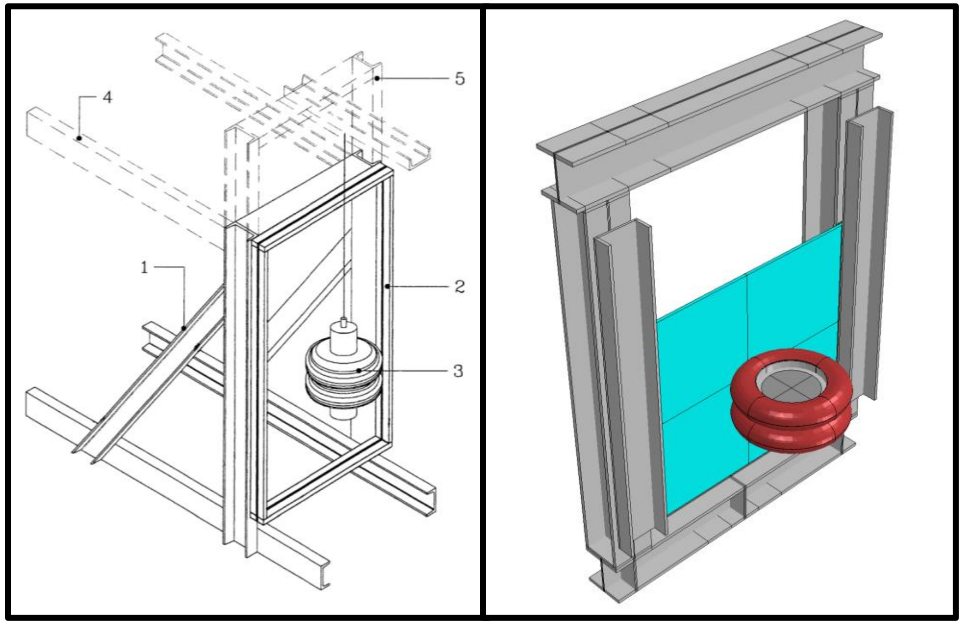

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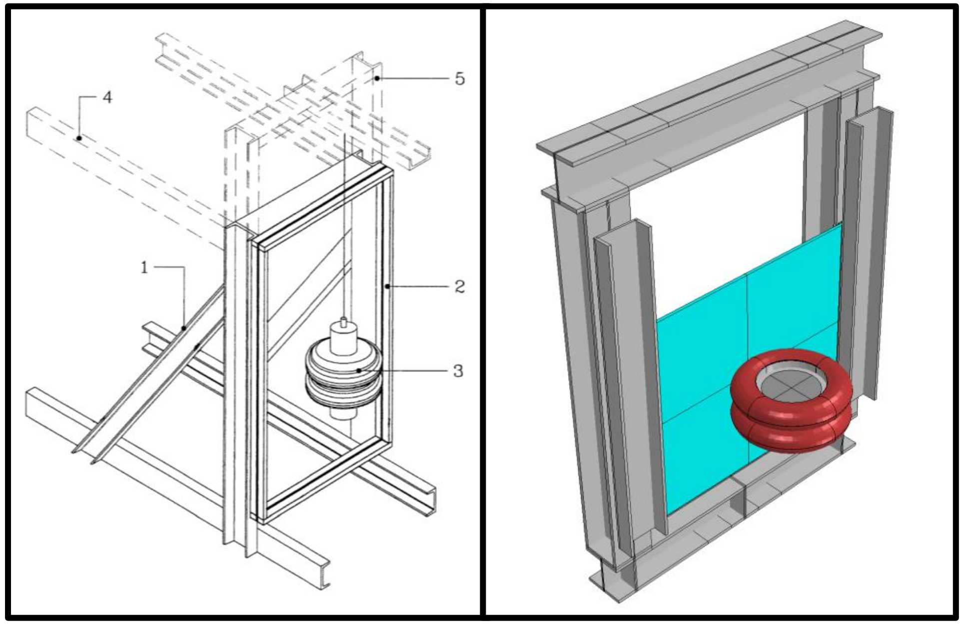

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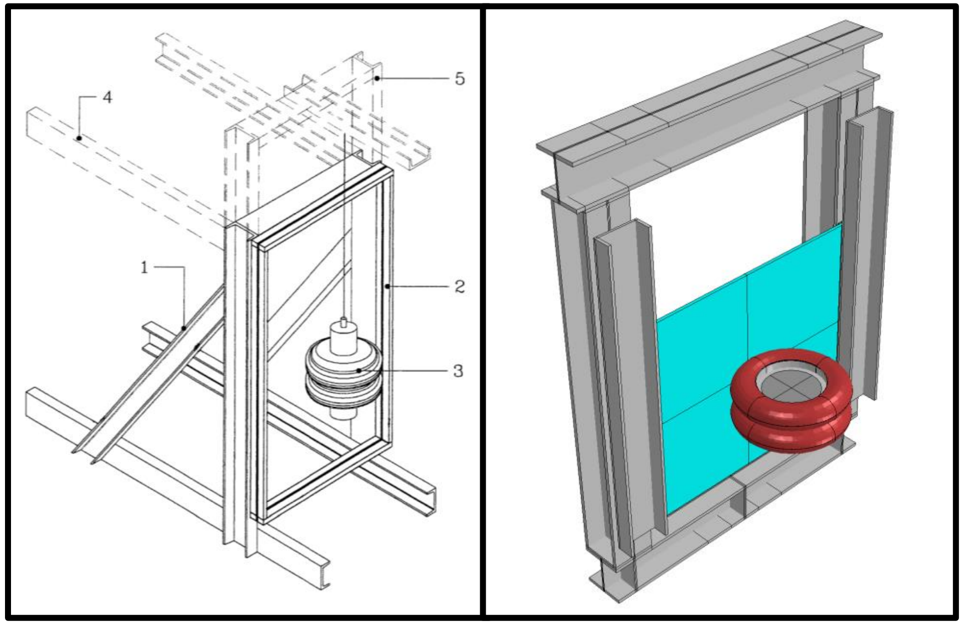
- The numerical method is universal
  → It has been successfully tested on various element profiles and connection types
  → Additional glass structures can be tested analagous to the methods shown here



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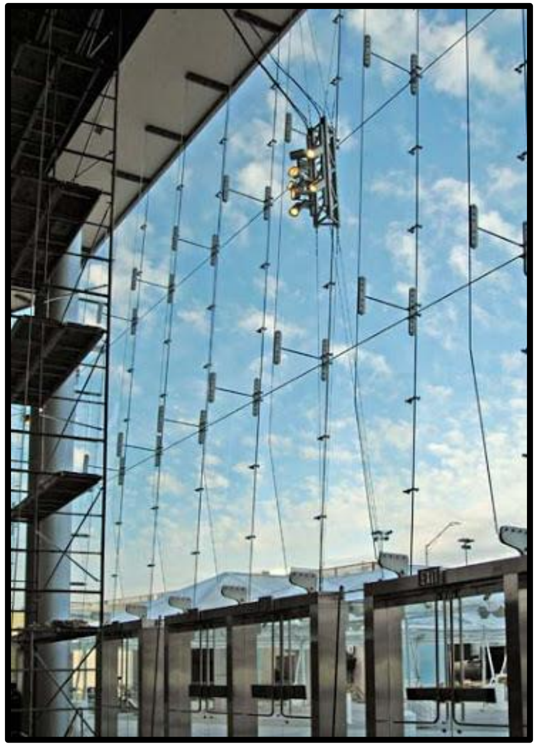
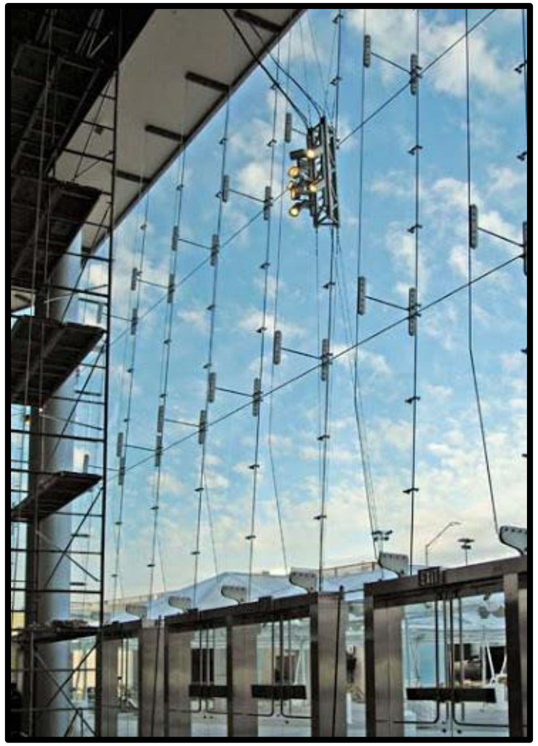
Streamlines design process of increasingly common glass elements such as glass facades, balustrades, etc.



Improves Viability of Glass for Structural Use

Streamlines design process of increasingly common glass elements such as glass facades, balustrades, etc.

Enables more intricate and innovative structural glass design because impact resistance uncertainty is reduced



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The numerical methods can be used as tools in the industry: the models accurately capture the principal stresses, including the reduced models.

Detta var sista slide

Tack

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