FIRE DESIGN METHOD FOR COLD-FORMED STEEL SHEETING SYSTEM

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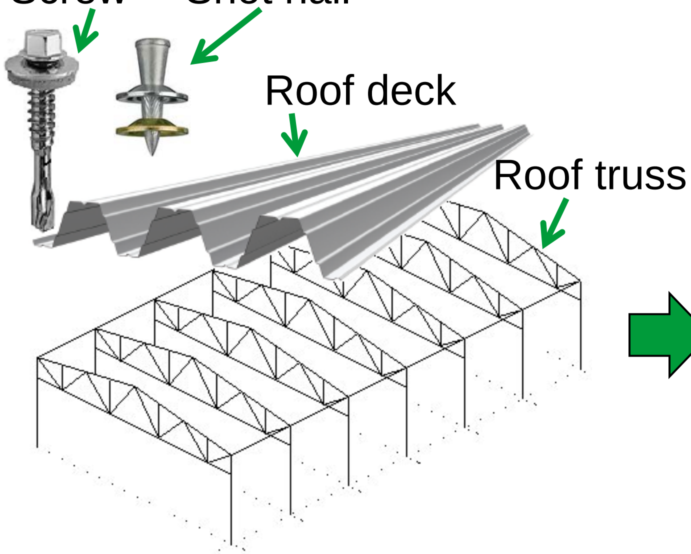
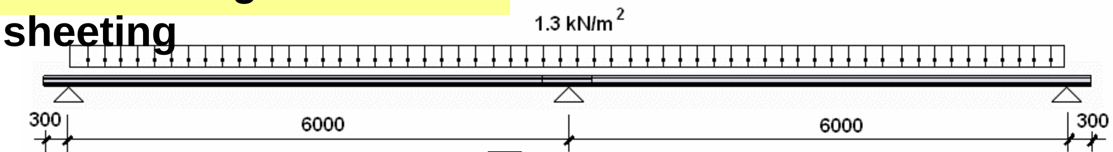
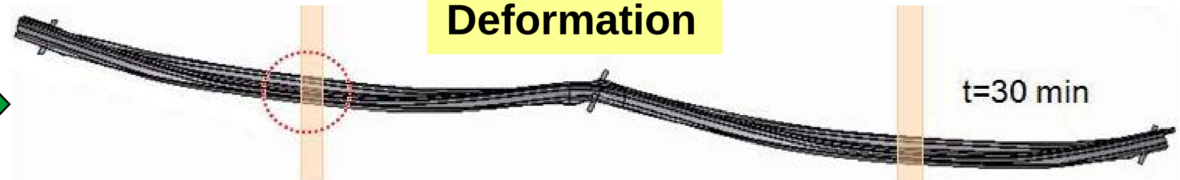
Applications and objectives



FE modeling of sheeting

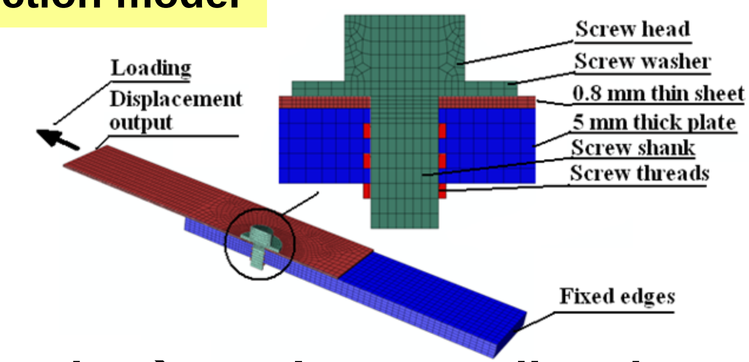


Deformation



Assumptions: No failure occurred in connection; Temperature is uniformly ... **sheeting**

Connection model

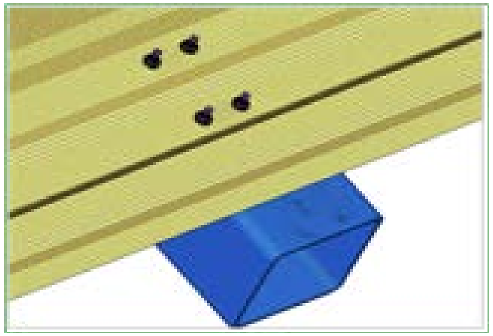


Objective of this research:

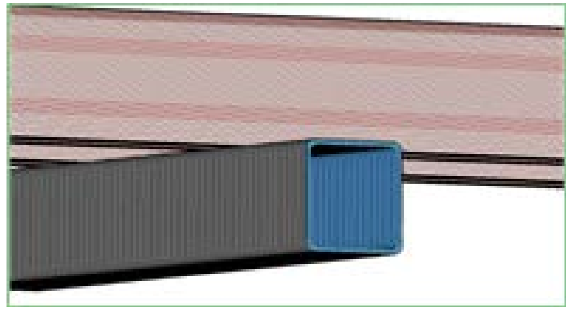
- **Temperature distribution near joint with or without fire protections**
- **Behaviour of sheeting system when connector is modelled**

Drawback → Only one direction shear is modelled.

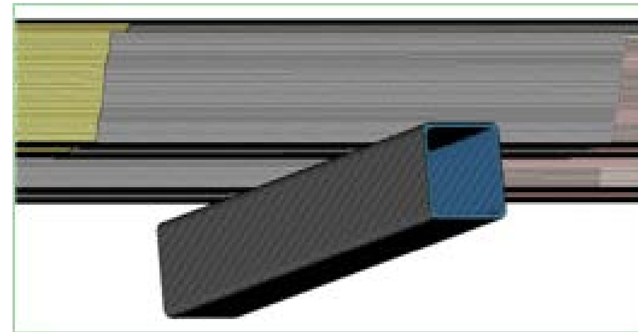
Geometrical model with fire protections



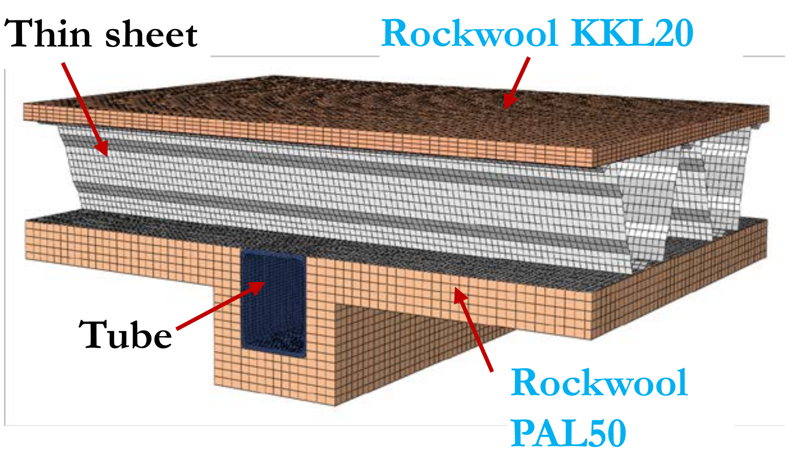
Connection details

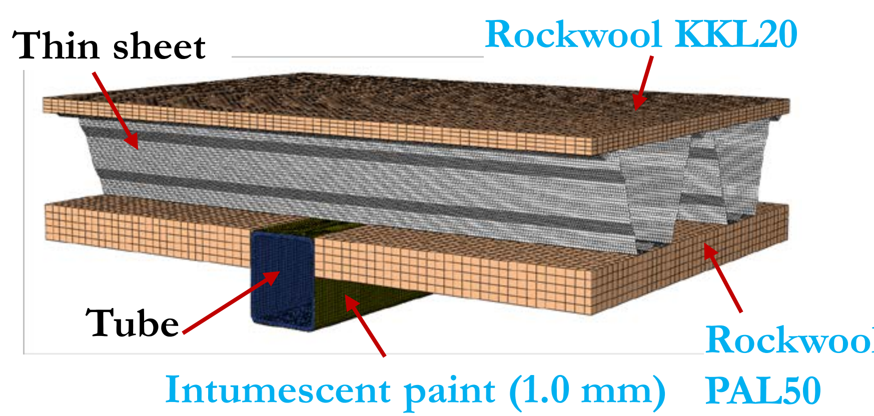


Only tube protected → intumescent paint (1 mm)



Both tube and sheeting (500 mm) protected → intumescent paint (1 mm)





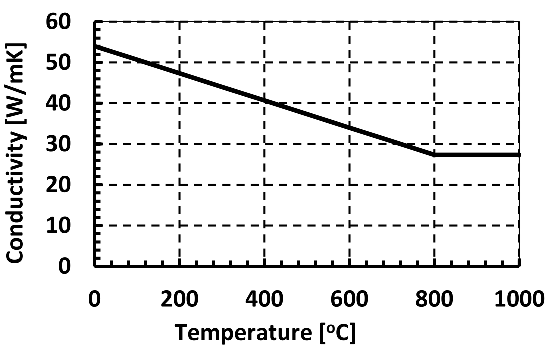
FE models

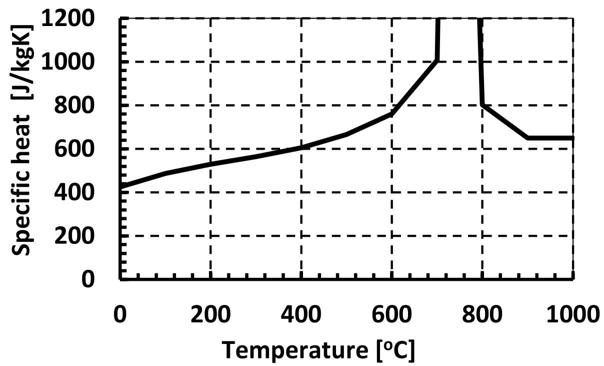
Cases	Fire Protections			Output	Fire model
	Tube	Sheeting	Nail		
Case A	no	no	no	Nail Steel sheeting	ISO fire
Case B	ITUPaint	no	no		
Case C	ITUPaint	ITUPaint	no		
Case D	RW	ITUPaint	no		
Case E	RW	RW	no		

- **ABAQUS / Standard**
- **Diffusive heat transfer elements, which allow for the heat storage (specific heat and latent effects)**
  - **Steel sheeting ⇒ shell elements DS4**
  - **Tubular chord ⇒ solid elements DC3D8**
  - **Nails ⇒ solid elements DC3D8.**
  - **Intumescent paint ⇒ solid elements DC3D8 (3 layers in 1 mm thickness)**
  - **Rockwool panels ⇒solid elements DC3D8**

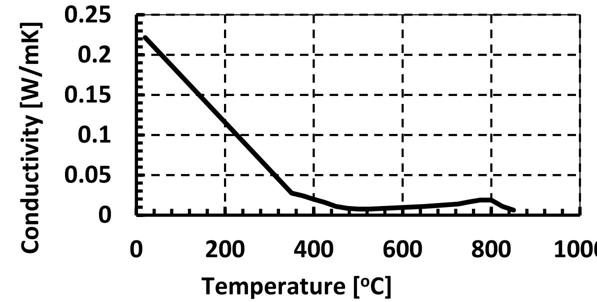
Thermal material properties

Steel → EN 1993-1-2



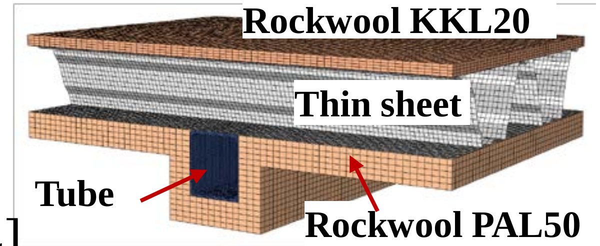


Intumecent paint



- Thermal properties of Rockwool
  - Thermal conducitivity for Rockwool 0.045 W/mK
  - Density for Rookwool: PAL50 → 155 kg/m^3 for KKL20 → 235 kg/m^3
- Intumecent paint
  - Thickness of intumescent paint is assumed to be constant
  - Equivalent thermal conductivity is varied with time

Thermal load



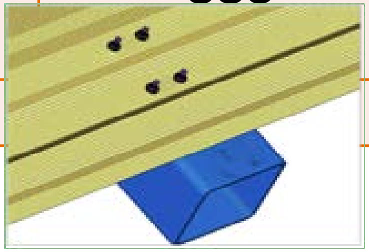
- Heat flux through exposed surface

$$q = \alpha_c \cdot (T_g - T_s) + \sigma \cdot \varepsilon \cdot \left[(T_g + 273)^4 - (T_s + 273)^4 \right]$$

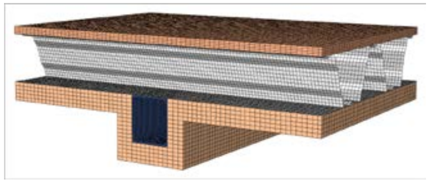
- Convection in ABAQUS using keyword *SFILM with Film properties
  - 25 W/mK → exposed surfaces to hot gas
  - 8 W/mK → upper surface exposed to ambient temperature
- Radiation →*SRADIATE with emissivity of 0.6 for both steel and protection
- Cavity radiation
  - Inner surfaces of tube
  - Surface between rockwool panel and folds of sheeting
- Approximate cavity radiation approach in ABAQUS, assuming
  - Equal view factors and constant emissivity in the cavity surfaces (0.3)
  - Full thin coat with high conductivity is modeled
- Contact conductance
  - Steel to steel → 2000 W/m^{2}K
  - Rockwool to steel → 200 W/m^{2}K

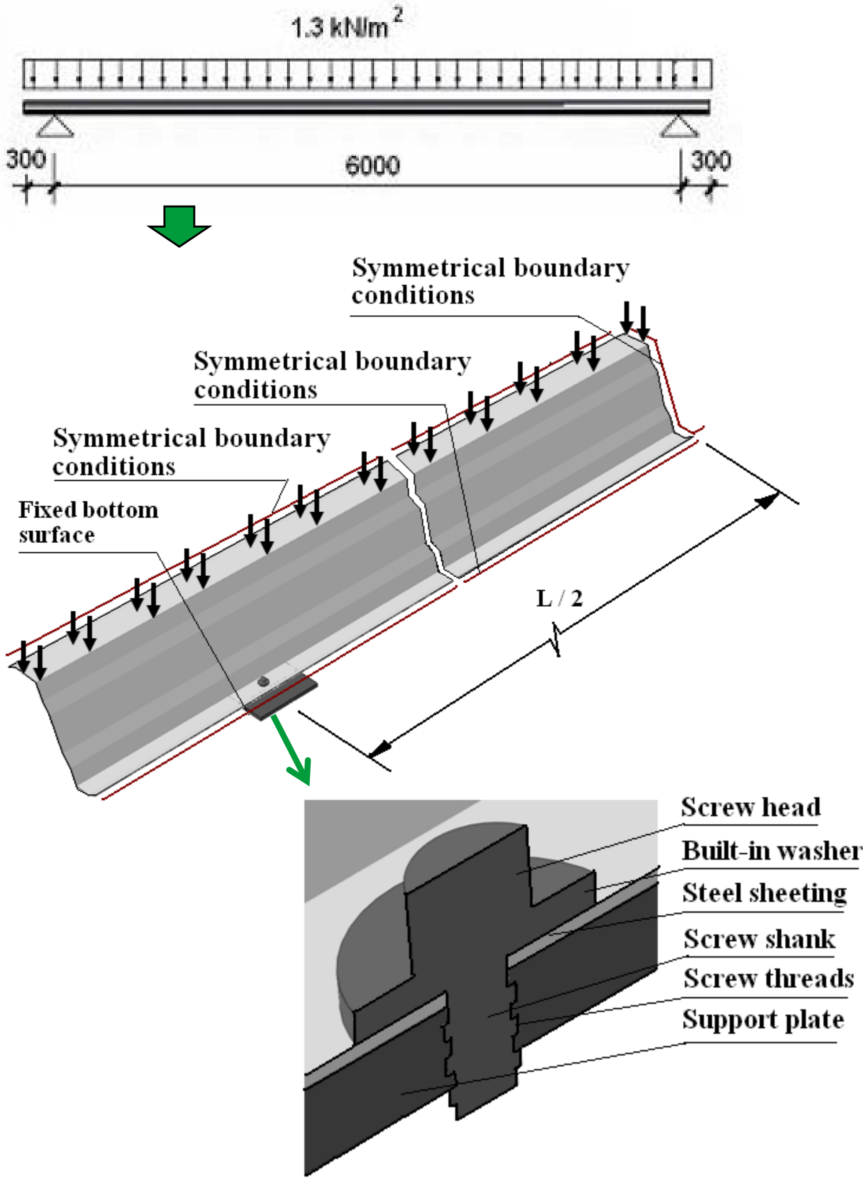
Comparisons of temperatures at 30 min

CASES	Sheet [°C] (top)	Sheet [°C] (bottom)	Tube [°C]	Nail-shank [°C]
No protection (A)	565	831	720	710
Tube ITU, sheet no (B)	470	831	475	565
Tube ITU, sheet ITU (C)	340	450	475	460
Tube ITU, sheet RW (D)	45	-	390	385
Both Rockwool (E)	30	-	51	[illegible]



- Steel sheeting temperature
  - Affected by protection applied to sheeting
  - Top or bottom sheeting
- Steel tube temperature → affected by protection on it
- More effective → Rockwool
- Location of nails
- Nail temperature → affected by the tube protection





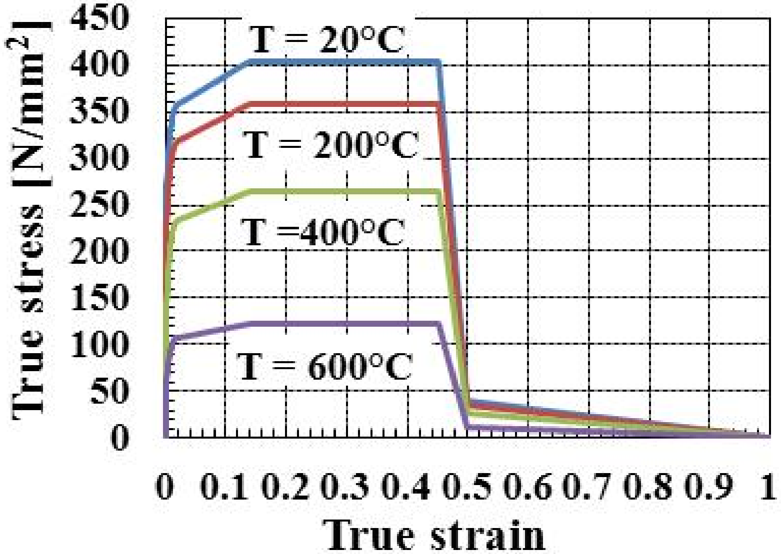
FE model

- Geometrical model
  - Single span (L = 6 m) with uniform load
  - Steel sheeting R120, t=0.8mm
  - Screw ϕ5.5
  - Connected to thick plate (5 mm)
  - Bottom surface of thick plate is fixed
- Two step loading process:
  - Mechanical loading →1.3kN/m^2
  - Temperature increase → ISO fire
- ABAQUS / Explicit
- Symmetrical properties
  - Profile
  - Half span
- Geometrical nonlinearity and material non-linearity
- Solid elements → C3D8R for all parts
- General contacts

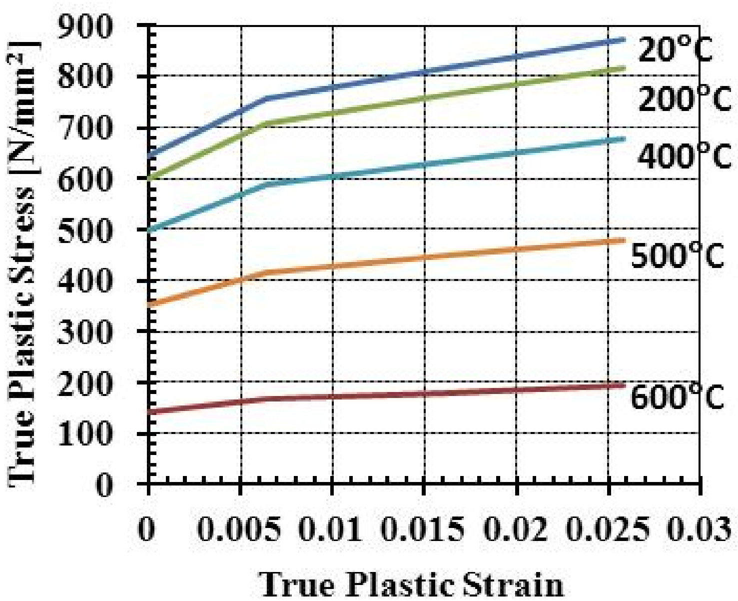
Material properties

	Sheeting	Support	Connector
Steel grades	S350	S355	8.8
Damage initiation	0.45 true strain	No	No

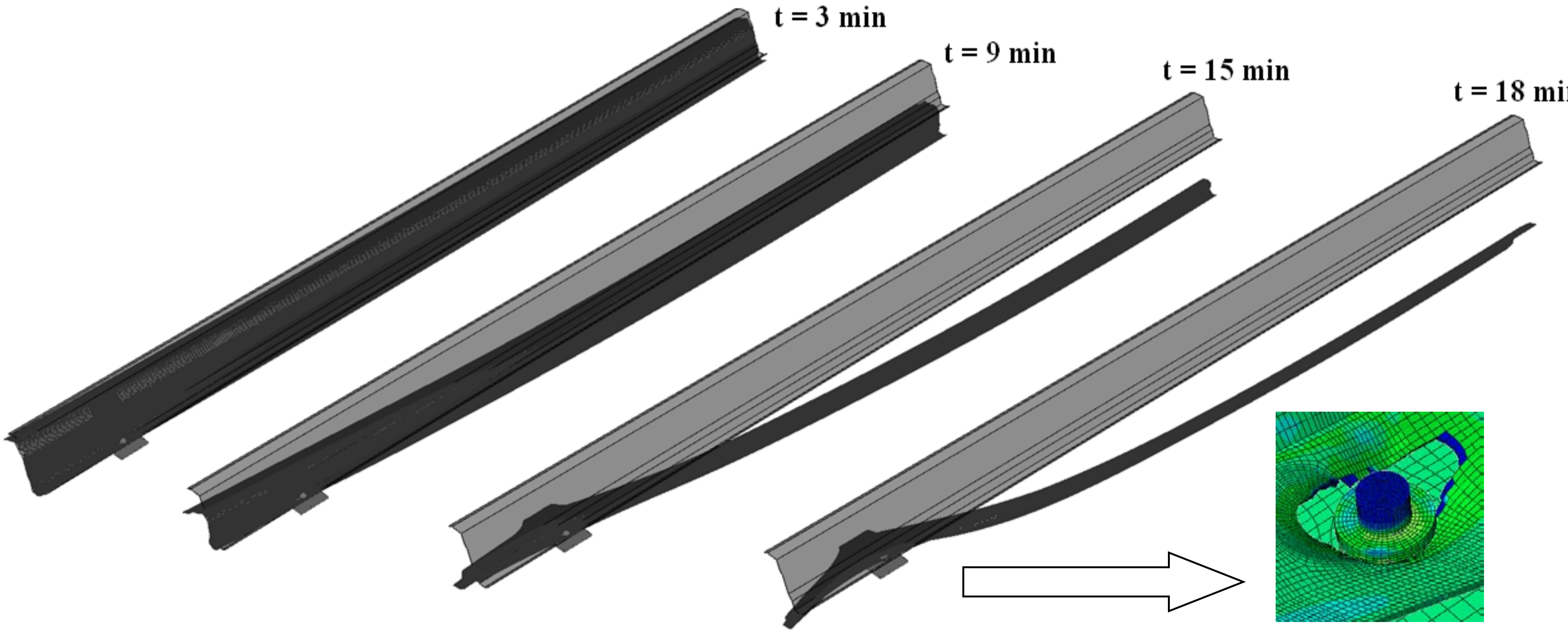
True stress – true strain curve for S350 with damage model



True stress – true strain curve for bolt 8.8

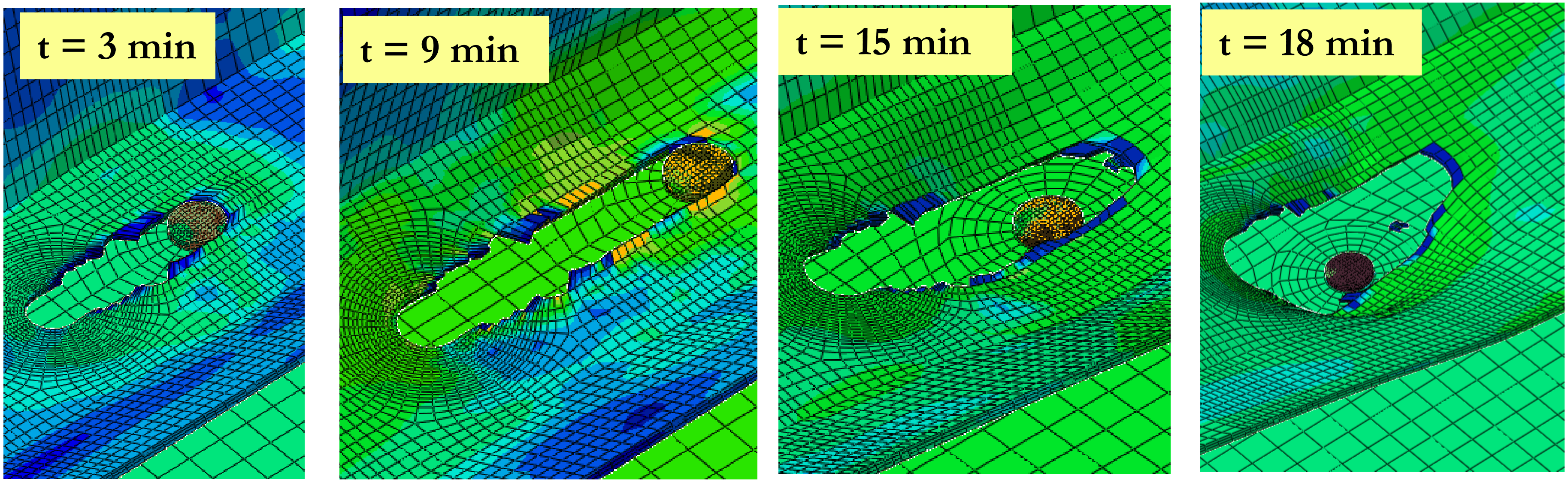


Deformation histories



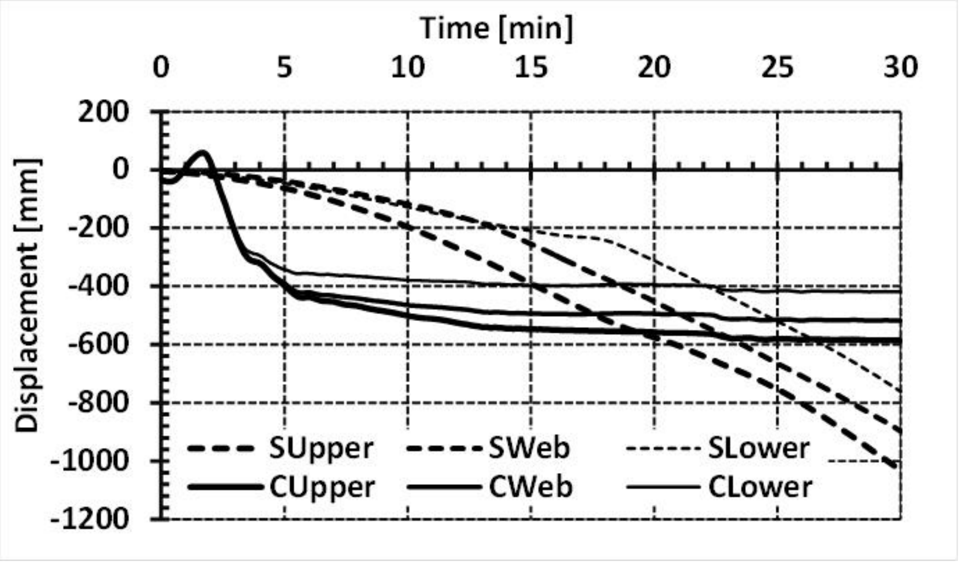
- t = 9 min → top flange deformed more than web and lower flange
- t = 15 min → profiled cross-section collapsed at support
- t = 18 min → profiled cross-section collaped in mid span
- Pull – through failure of sheeting has been observed

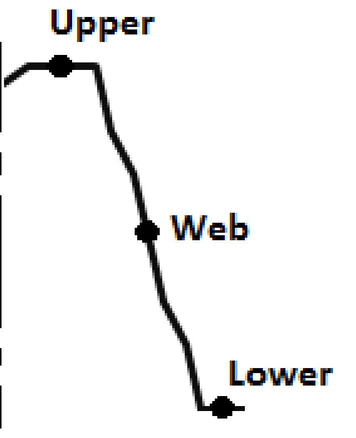
Local deformation at joint



- t = 3 min → bearing failure of sheeting
- t = 9 min → bearing force start to change direction
- t = 15 min → sheeting in the process of catenary action
- t = 18 min → profiled cross-section changed to simple sheet
- Uplift force → pull – through failure of sheeting observed

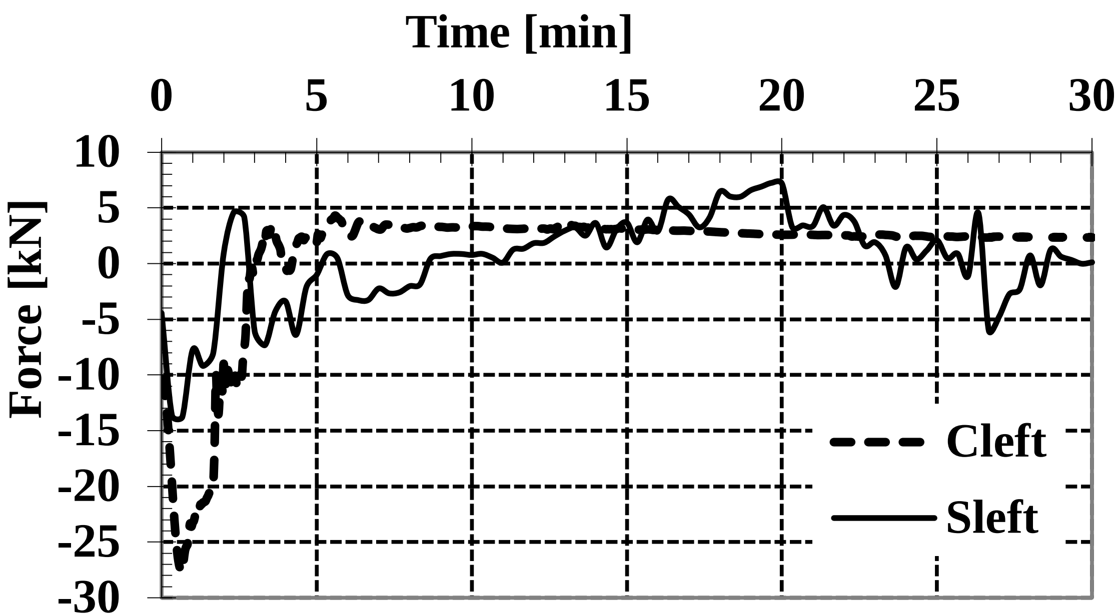
Displacement - time curves

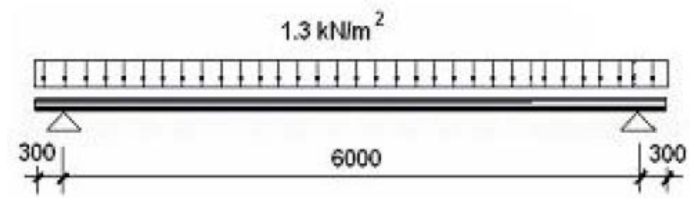




- Location of output points → upper, web and lower
- Solid lines → FE model with connector elements
- Dotted lines → FE model with screw being modelled
- Buckling of sheeting → earlier for model with connector element
- Rigidity → more rigid of joint → higher compressive load
- Pull – through failure → FE model with screw being modelled

Variation of reaction force at left support





- Solid lines → FE model with screw being modelled
- Dotted lines → FE model with connector elements
- Stiffness of joint → higher compressive force developed
- Compression to tension → gradually or suddenly

Conclusions

- **Rockwool protection is more efficient than ITUPaint (1mm thickness)**
  - **Thickness of ITUPaint need to be improved in order to get same efficiency**
- **3D FE sheeting system model including the actual screw dimensions**
  - **Current model captures main behaviour up to 20 minutes**
- **Comparing to FE model with connector elements**
  - **Current model showed a reduced maximum compressive force developed from restrained thermal elongation**
  - **A delayed buckling of steel sheeting**
  - **Benefit for both steel sheeting and joint**
- **Future researches**
  - **Improvements for FE model**
  - **Integrate temperatures distribution at joint into FE model of sheeting system**