Stability of lightweight structural sandwich panels exposed to fire

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Sandwich panel data

- A composite product comprising flat outer thin rigid metal sheet (usually coated steel or aluminium alloy) either side of a bonded core of insulating material
- Panel width normally 1.2m
- Panel span - up to 12m
- Cores can be EPS, PUR, PIR and stonewool
- Unequalled high thermal insulation with stone wool core
- Fire resistance of more than 2 hours possible with stonewool core
Hans Timm Fensterbau, Germany

- Paroc Original-E
- 2 700 m²
Saku Arena, Tallinn, Estonia

- Multi-purpose arena, Paroc stone wool cored panels
The delamination problem

- Panel faces are not mechanically attached to each other
- Delamination temperature can be in range 140 to 290°C according to tests by FRS, BRE, UK
- Delamination can therefore occur very early in a fire
- Falling face can act as missile before fully developed fire occurs
- Can be a hazard to fire-fighters
- Caused the death of two firemen in food processing factory in the UK
Change in flexural behaviour of panel

- No flexure, no delamination.
- Flexure, no delamination. Plane sections remain plane. Note flexure caused by self weight.
- Flexural strength lost at delamination.
Safe applications

• external wall or roof cladding when both facings mechanically attached to supporting structure. Facing cannot detach and act as missile if fire inside or outside the building
• Internal wall if both facings suspended from top
• Ceiling if at least lower face is restrained. Calculation or fire test needed
Potentially unsafe applications

- Free-standing internal walls ie walls not suspended from the top
- Ceiling panels with unrestrained lower face. Face can drop down
Sandwich panel uses in buildings

- External cladding. OK

- Supported internal walls and ceilings. OK

- Unsupported internal walls and ceilings. Generally not OK
A preferred suspension method
Calculation procedure for ceilings

1. **Calculate catenary sag, D.** Take account of delamination temperature and flexibility of panel assembly. The larger the D at delamination, the smaller the H.

2. **Calculate catenary force, H.** This requires assessment of dead load for lower face.

3. **Check panel-end fastenings.** Are they capable of resisting pull-out force H at appropriate temperature?

Note. Calculation only needed if span greater than fire tested span.
Catenary force equation

• Taking moments about point A

\[
\frac{wL}{2} \times \frac{L}{2} = H \cdot D + \frac{wL}{2} \times \frac{L}{4}
\]

Hence

\[
H = \frac{wL^2}{8D}
\]
2-layer catenary

Span $L$

- Upper face
- Uniformly distributed load $w_1$
- Mid-span deflection $D$
- Core
- Lower face
- Uniformly distributed load $w_2$
- Fire

$(w_1+\omega_2)L/2$

$(w_1+\omega_2)L/2$

$H_1$

$H_2$

$H_1$

$H_2$

Uniformly distributed load $w_1$

Span $L$

Mid-span deflection $D$

Fire

$(w_1+\omega_2)L/2$

Uniformly distributed load $w_2$
Bow due to end movement

From geometry

\[ D = \sqrt{0.375 L \Delta} \]

Longitudinal expansion of length L is

\[ \Delta = \alpha LT \]

Considering end movement as longitudinal expansion and substituting for delta we have

\[ D = L \sqrt{0.375 \alpha T} \]
Equations used for fire condition

\[ H = \frac{wL^2}{8D} \quad (1) \]

where \( w \) = uniformly distributed load per unit length
L = span of panel
D = central deflection

\[ D = L \sqrt{0.375\alpha T} \quad (2) \]

Where \( \alpha \) = coefficient of linear thermal expansion
T = temperature rise
Sample calculation for fire condition

Assume panel is 1000mm wide, 4000mm long with a facing 0.6mm
Volume of one facing = 4x1x0.0006 m³
Density of steel = 7850 kg/m³
Weight of one facing = 4x1x0.0006x7850 = 18.84 kg
Weight per unit length = 18.84/4 4.71 kg
Load per unit length (w) = 4.71x9.81 = 46.2N/m

From equation (1) \( H = \frac{46.2x4^2}{8D} \) \hspace{1cm} (3)

Substituting values of \( D \) calculated from equation (2) gives force data i.e.

\( D = 4000(0.375x0.000014xT)^{1/2} \) assuming steel face \hspace{1cm} (4)

Substituting values for \( T \) in equation (4) and then substituting in equation (3) gives values of \( H \)
Variation of H and D with temperature

For one facing
Span = 4000mm
Width = 1000mm
Load/unit length for 0.6mm thick steel sheet = 46.2 N/m
Spectrum of calculation conditions

- H at room temperature - small sag, large H, large tensile strength, high fastening pull-out strength needed

- H at elevated temperature - large sag, small H, low tensile strength, low fastening pull-out strength needed

- Checks needed at number of temperatures

- Remember H increases as the square of L
Strength of facings at elevated temperature

• The reduction in strength properties of steel at elevated temperature may be assumed to vary according to the relevant ENV or Euronorm. Information in ENV 1993-1-2 (‘Fire design of steel structures’) and ENV 1991-2-2 (‘Actions on structures exposed to fire’) may be used.
• Strength reduction factors for other metals can be obtained from national standards or laboratory tests
• When a European standard is not available a national standard may be used, e.g. in the United Kingdom by reference to BS 5950: Part 8: 1980 which gives strength reduction factors for hot rolled steel and cold formed steel.
A preferred suspension method
Conclusions

• Ensure that in all roof, external wall and internal wall applications both panel facings are mechanically attached and restrained by the supporting structure.

• Ensure that at least the lower face of a ceiling panel is mechanically attached and restrained by the supporting structure. Calculation needed if beyond fire-tested span.
Further reading


Cooke G M E, Stability of lightweight structural sandwich panels exposed to fire, Proc ‘Structures in Fire’ SiF 02 International Workshop, Univ of Canterbury, New Zealand, March 2002

Cooke G M E, Sandwich panels for external cladding - fire safety issues and implications for the risk assessment process, Published by Eurisol UK Ltd, UK, Nov 2000, pp 60