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 insulatione with stone wool core
- Fire resistance of more than 2 hours possible with stonewool core

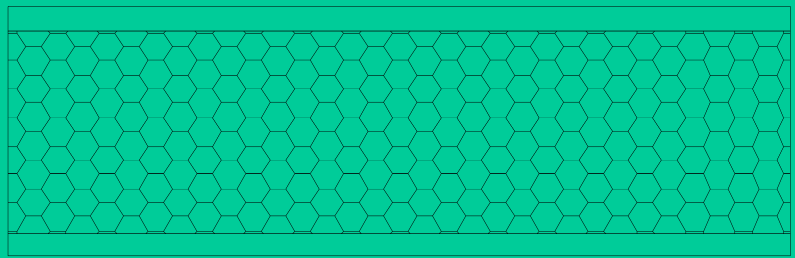
Hans Timm Fensterbau, Germany

- Paroc Original-E
- 2 700 m^2

Saku Arena, Tallinn, Estonia

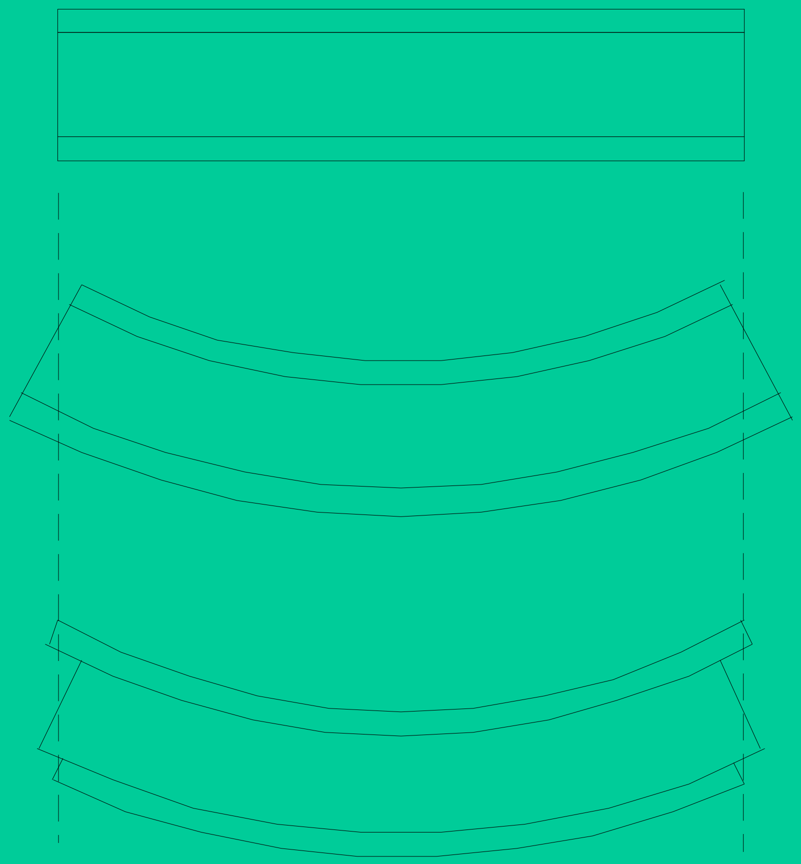
- Multi-purpose arena, Paroc stone wool cored panels

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

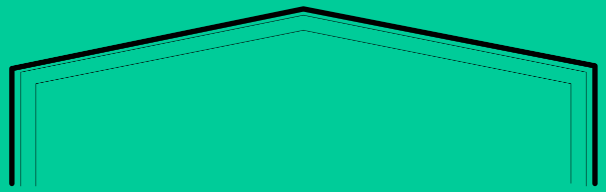
Safe applications

- external wall or roof cladding when <u>both</u> 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

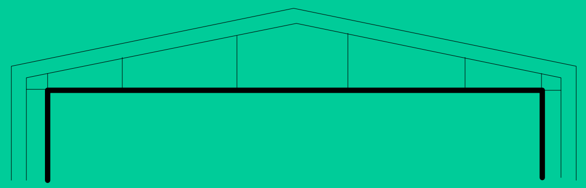
Potentially unsafe applications

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

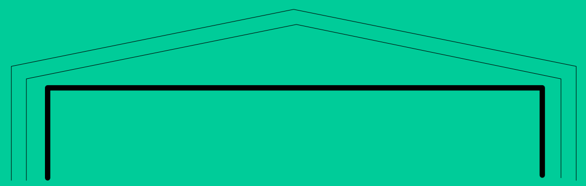
Sandwich panel uses in buildings



- External cladding. OK

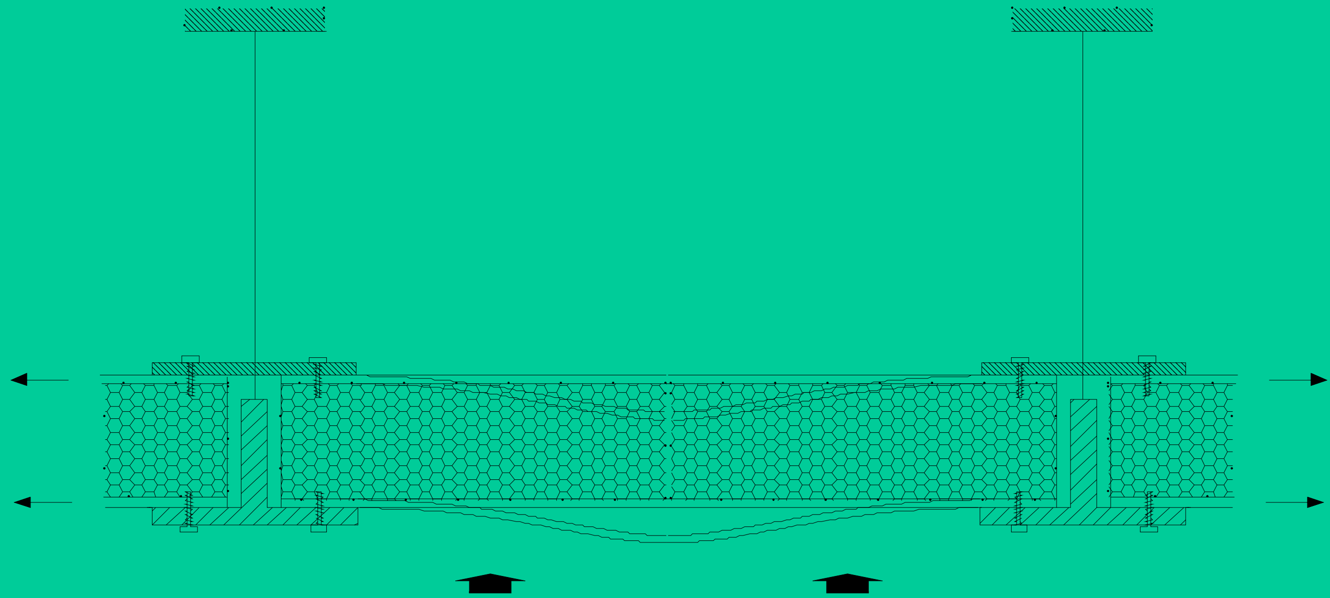


- Supported internal walls and ceilings. OK



- 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

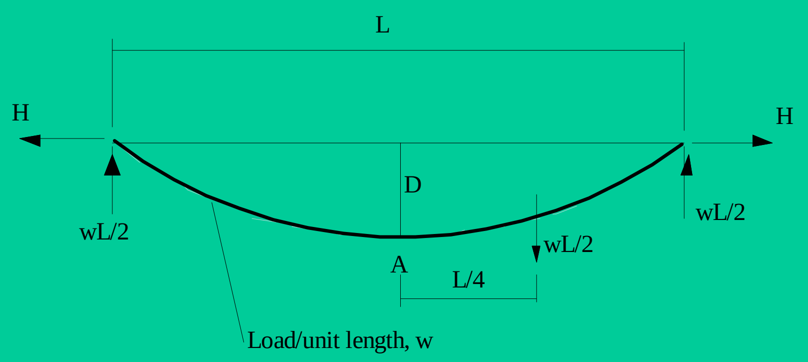
Catenary force equation

- Taking moments about point A

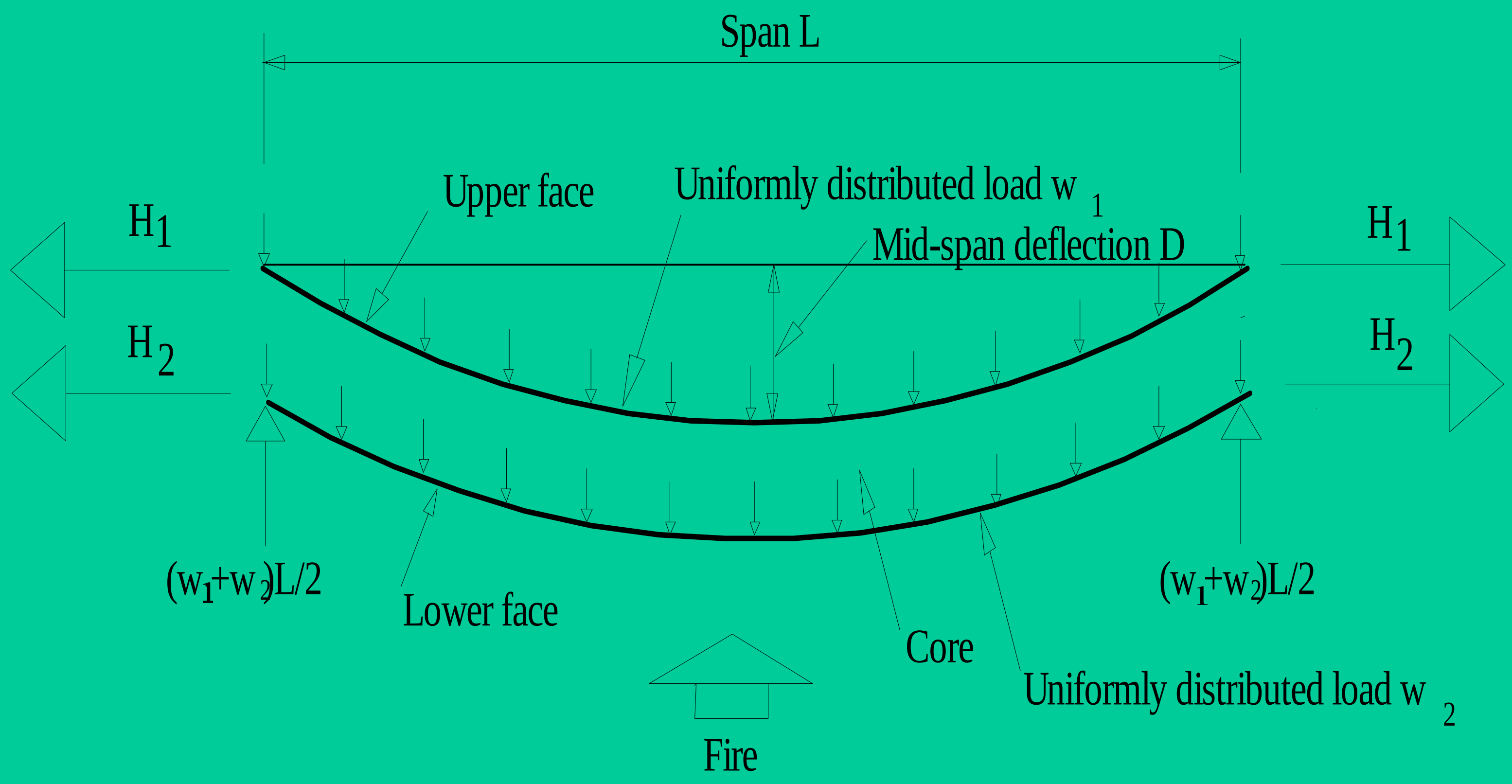
$$\frac{wL}{2} \times \frac{L}{2} = H.D + \frac{wL}{2} \times \frac{L}{4}$$

Hence

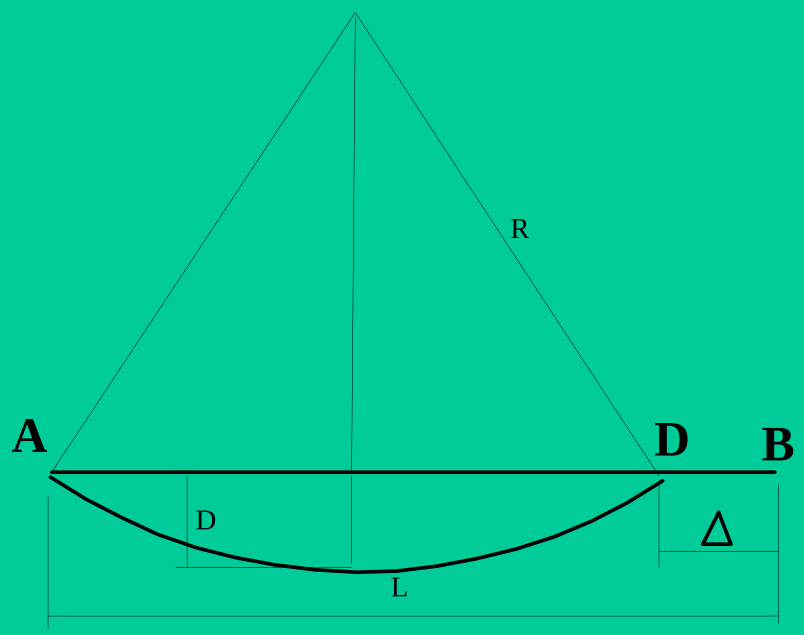
$$H = \frac{wL^2}{8D}$$



2-layer catenary



Bow due to end movement



From geometry

$$D = \sqrt{0.375 L \Delta}$$

Longitudinal expansion of length L is

$$\Delta = \alpha L T$$

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

$$D = L\sqrt{0.375\alpha T}$$

Equations used for fire condition

$H = wL^2/8D$ (1)

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

$D = L\sqrt{(0.375\alpha T)}$ (2)

Where α = 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 m^3
Density of steel = 7850 kg/m^3
Weight of one facing = 4x1x0.0006x7850 = 18.84 kg
Weight per unit length = 18.84/4 4.71kg
Load per unit length (w) = 4.71x9.81 = 46.2N/m

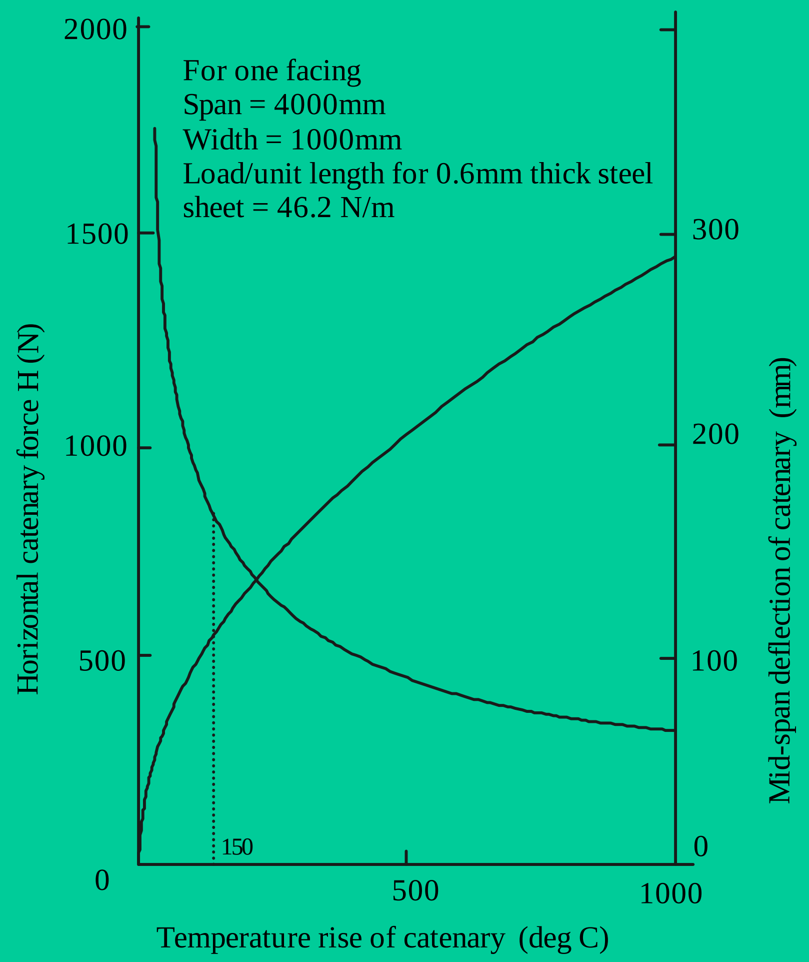
From equation (1) $H = 46.2x4^2/8D$ (3)

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

$D = 4000(0.375x0.000014xT)^{1/2}$ assuming steel face (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



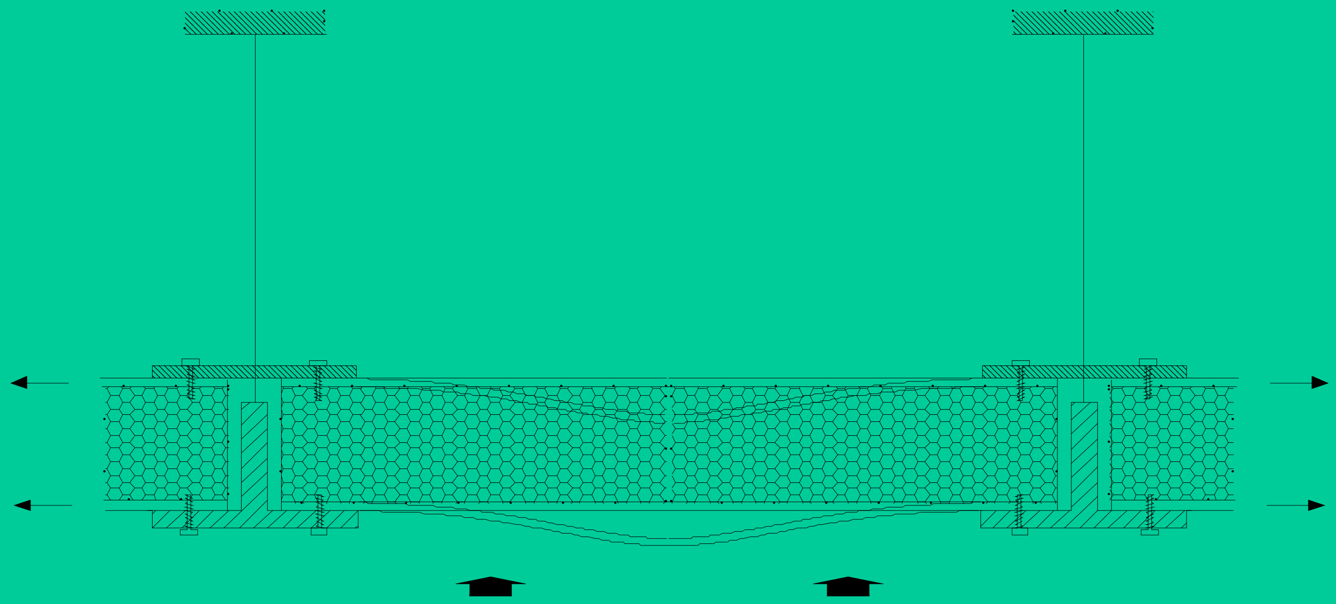
Spectrum of calculation conditions

- 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 <u>both</u> panel facings are mechanically attached and restrained by the supporting structure
- Ensure that <u>at least</u> 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

Lightweight sandwich construction, (chapter 5 ‘Fire’), edited J M Davies, published Blackwell Science, Oxford, UK, 2001

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