Tampere University

Shear Strength Test Methods of Steel Faced Sandwich Panels

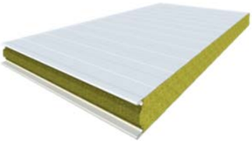
Shekhar Silwal, Kristo Mela (Tampere University)
Zhongcheng Ma (HAMK University of Applied Sciences

ruukki

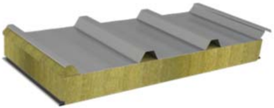
HAMK – Häme University of Applied Sciences

Introduction

- Sandwich panel is the structural element consisting of two thin metal facings joined together using a low-strength core material with the desired thickness.
- Sandwich panels are utilized for external walls or roofing and are exposed to transverse loads predominantly from wind and snow, resulting in bending and shear stresses.
- Sandwich panels used in construction typically consist of thin steel faces and a solid core made of materials such as mineral wool (MW), glass wool, polyurethane (PU), or polyisocyanurate (PIR).

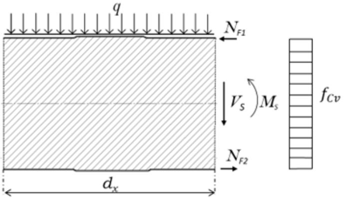


Flat-faced panel



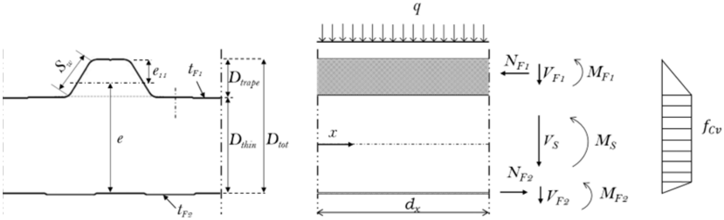
Strongly-profiled panel

Flat panel



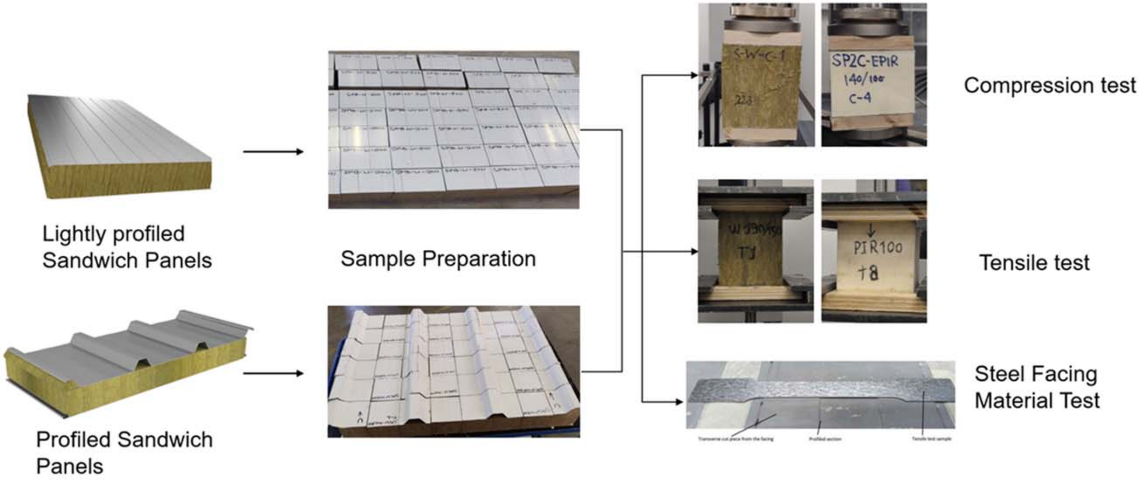
$$w''(x) = -\frac{M_s(x)}{B_s} + \frac{V_s'(x)}{A_c G_{eff}}$$

Profiled panel



$$w''''(x) - \left(\frac{\lambda}{L}\right)^2 w''(x) = \frac{1}{B_{tot}}\left(\frac{\lambda}{L}\right)^2 \left(M(x) + \beta L^2 q(x)\right)$$

Material Characterization

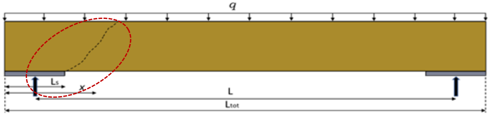


Tampere University

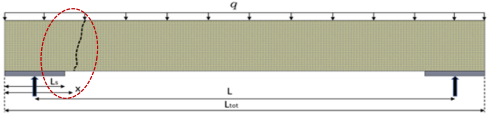
Shear strength test methods

- The shear strength of the panel is defined as the shear strength of the core
- Sandwich panel production and design are governed by the standard EN 14509:2013
- A new section of EN 1993 is being developed specifically for the design of steel-faced sandwich panels.
- EN14509:2013 Specifies two main test methods for shear test:

1. Two-point test (Shear beam test method)
2. Full-scale test



(a) Typical failure modes in PIR (foamed core) specimen

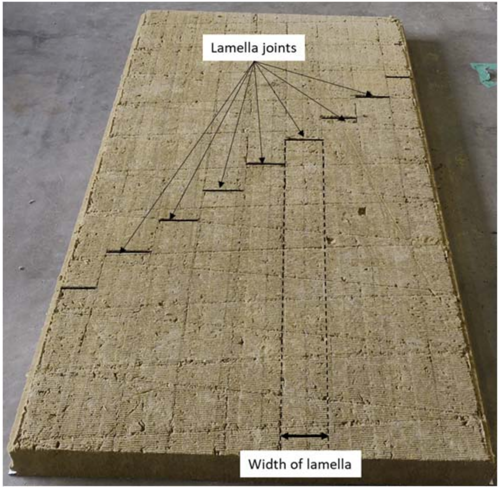


(b) Typical failure mode in MW specimen

Shear Beam Test Method

- In the early 2000s, it became clear that the 2-point loading method was suitable for thicker panel mainly with MW cores.
- In the EN 14509:2013 revision, a 4-point load test was incorporated and acknowledged.
- However, no specific formulas were provided for the computation of the shear modulus.
- EN 14509:2013 also lacks the guidelines on the test setup
- In present revision prEN 14509-3 more information is given on 4-point test methods.

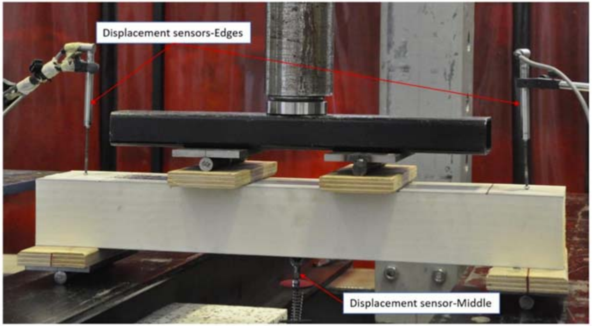
Beam Specimen (MW Panels)

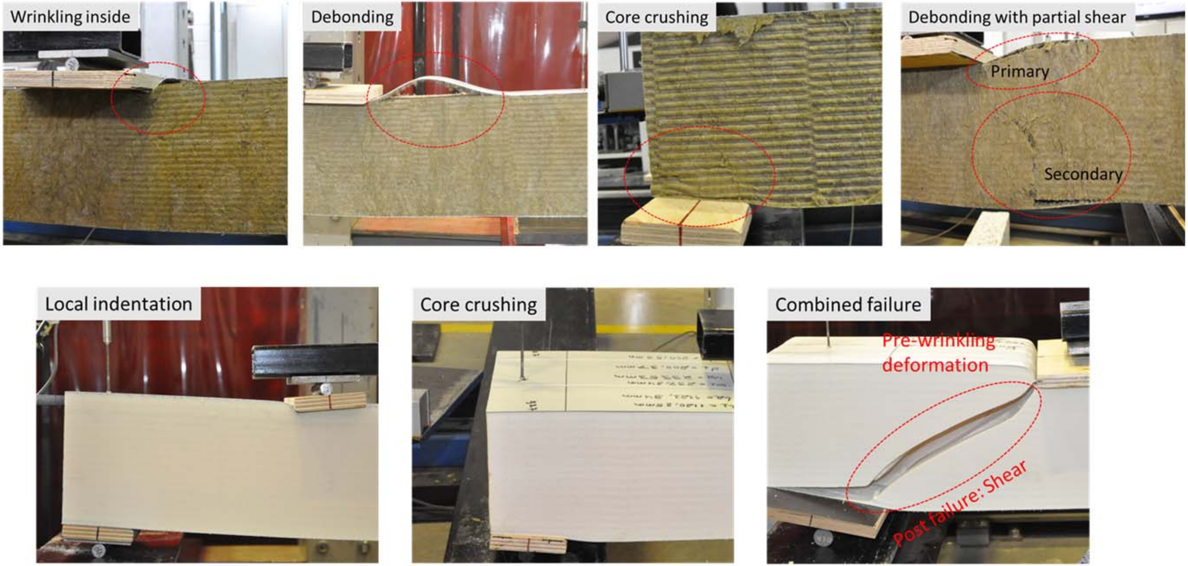


- Beam specimens must be cut using the full width of lamella
- Any Lamella joint within the span of the beam must be excluded

2-point Shear Beam Test Method (EN 14509)

- 2-point load beam test is dominant method for determining shear properties of sandwich panels.
- The progression of this approach has not kept pace with the developmental trajectory of the assessed products.
- This presents issues and emerges as a susceptibility within the framework of the EN 14509 standard.
- The widely adopted 2-point load beam test for assessing shear strength may not always lead to shear failure.
- This implies that the method does not provide the correct shear strength, as the full shear capacity is not reached in the test.




Wrinkling inside
Debonding
Core crushing
Debonding with partial shear
Primary
Secondary
Local indentation
Core crushing
Combined failure
Pre-wrinkling
deformation
Post failure: Shear

4-point Shear Beam Test Method

- The four-point loading test setup was developed based on a process of trial and error by:

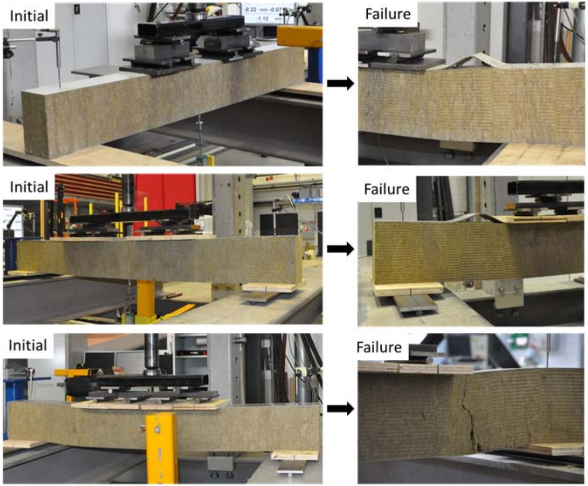
➢ Varying span length

➢ Loading and support plate widths

➢ Distance between loading plates

Until consistent core shear failure was attained.

- The trial tests were conducted using the thickest panel (200 mm)



Case 1:

U_{p1} = 200 mm
U_{p2} = 100 mm

Distance between U_{p1} and U_{p2} = 200 mm
Failure mode was delamination

Case 2:

U_{p1} = 200 mm
U_{p2} = 150 mm

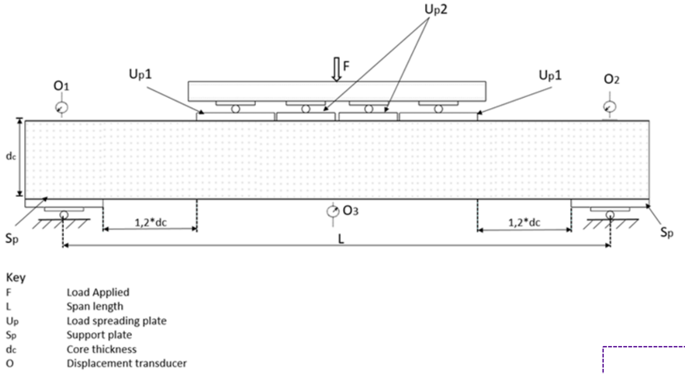
Distance between U_{p1} and U_{p2} = 100 mm
Failure mode was delamination

Case 3:

U_{p1}= 200 mm
U_{p2}= 150 mm

Distance between U_{p1} and U_{p2} = 15 mm
Failure mode was Shear

4-point Shear Beam test Method



$$\textbf{Shear Strength}, f_{Cv} = \frac{F_u}{2Be}$$

$$\textbf{Shear modulus}, G_C = \frac{\Delta F\, L}{6\, A_c \Delta w_s}$$

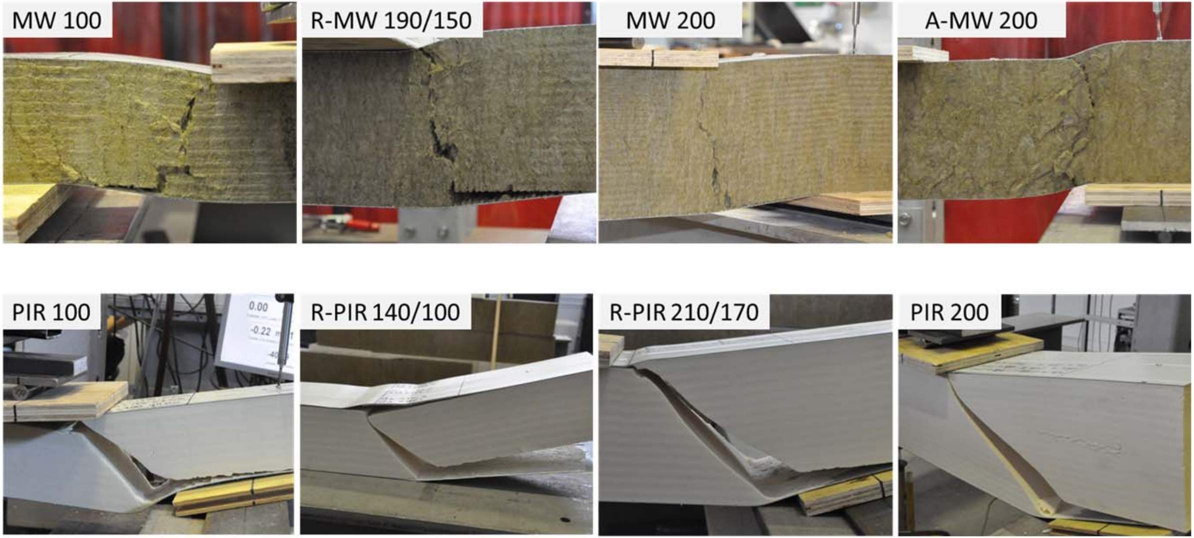
Total measured deflection

$$\Delta w_s = \Delta w - \Delta w_b$$

$$\Delta w_{b(0,5)} = \frac{\Delta F L^3 [(0{,}5 e_1 (0{,}75 - e_1{}^2) + 0{,}5 e_2 (0{,}75 - e_2{}^2)]}{12 B_s}$$

Tampere University

4-point test Method : Failure modes



2-point vs 4-point test

	Panel type	Shear Strength form 2-Load point test [MPa]	Shear strength from 4-point load test [MPa]	Change in shear strength [in %]
Flat	*MW 100*	0,0693	0,0688	-1 %
	MW 200	0,05314	0,0565	6 %
	A-MW 100	0,0684	0,0675	-1 %
	A-MW 200	0,05788	0,06936	17 %
	PIR 100	0,13	0,15332	15 %
	PIR 200	0,0874	0,1088	20 %
Profiled	*R-MW 140/100*	0,06472	0,06714	4 %
	R-MW 190/150	0,0514	0,0553	7 %
	R-PIR 140/100	0,12698	0,14174	10 %
	R-PIR 210/170	0,0939	0,1087	14 %

Full-Scale test Method

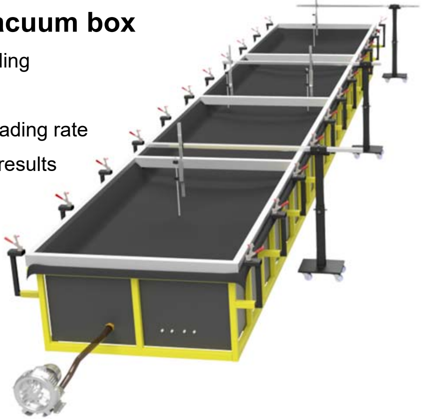
- Vacuum box is used to conduct a full-scale test which generates a uniformly distributed load over the sandwich panels.
- **Modernized Vacuum box**

✓ Accurate Load recording

✓ Fully-automatized

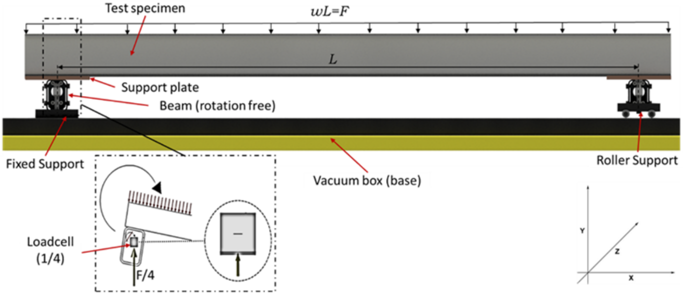
✓ Easy to control the loading rate

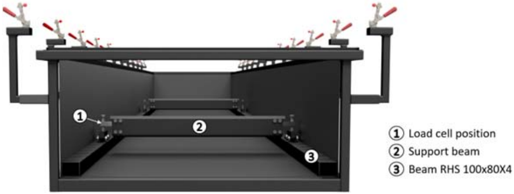
✓ Easy to optimize the results

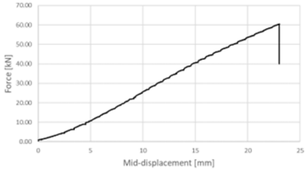


Tampere University

Vacuum box: Test setup

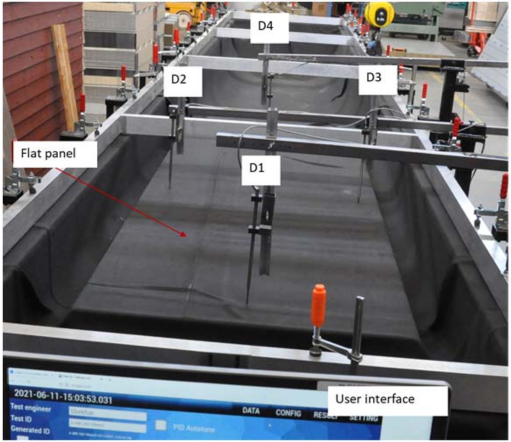




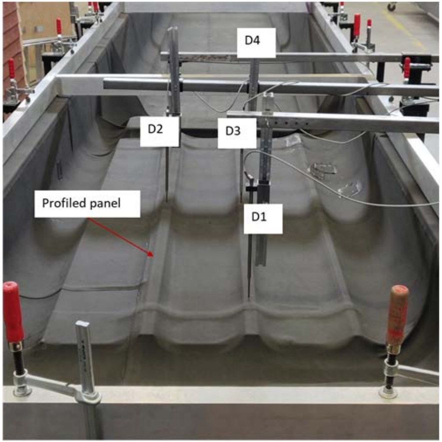


Force-displacement curve obtained after the test

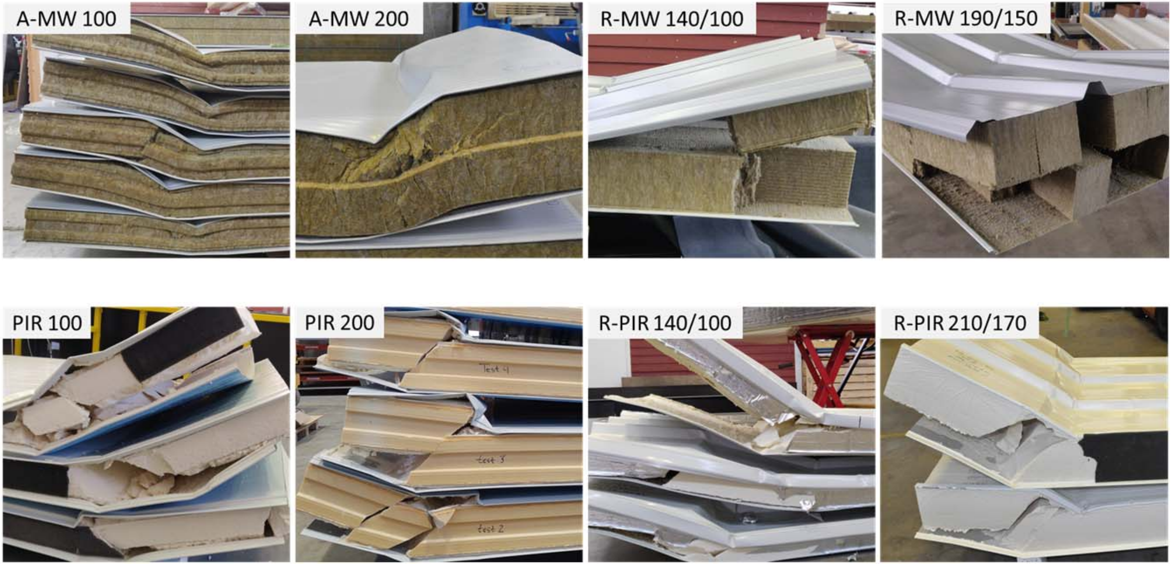
Full-Scale Test setup



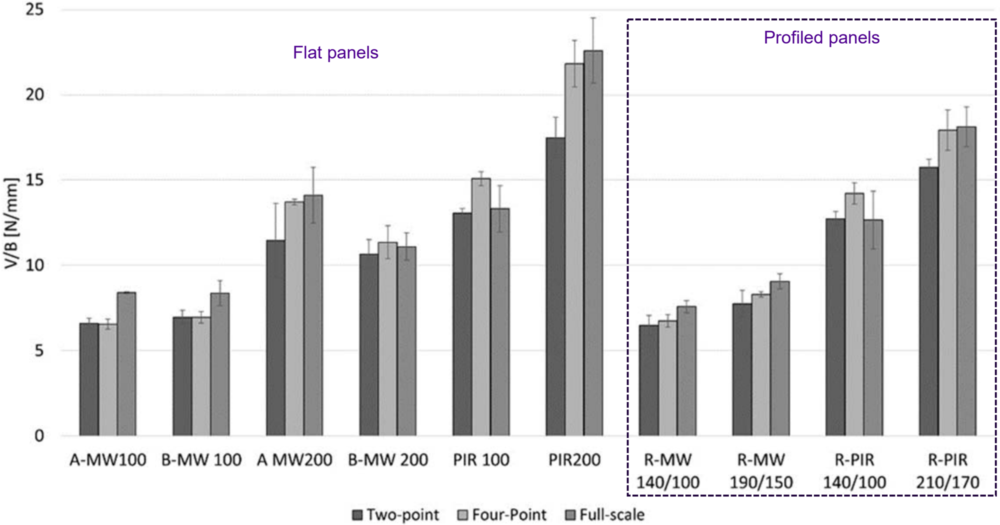
(a)



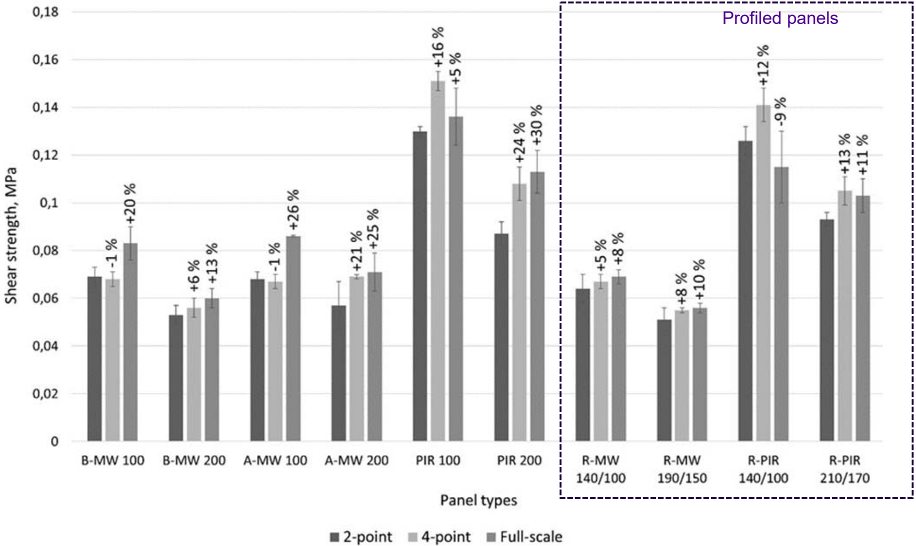
(b)


A-MW 100
A-MW 200
R-MW 140/100
R-MW 190/150
PIR 100
PIR 200
R-PIR 140/100
R-PIR 210/170

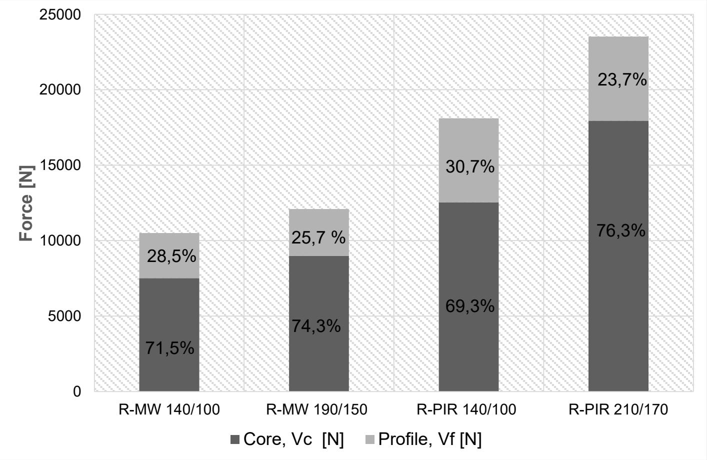
Shear force/Width



Shear Strength



Shear force distribution between core and Profiled face



For uniformly loaded Profiled panels:

$$V_f(\xi) = \frac{F_u \alpha}{(1+\alpha)} \left[\frac{1-2\xi}{2} + \frac{\sinh\left(\frac{\lambda(1-2\xi)}{2}\right)}{\alpha\, \lambda \cosh\left(\frac{\lambda}{2}\right)} \right]$$

$$V_S(\xi) = \frac{F_u}{(1+\alpha)} \left[\frac{1-2\xi}{2} + \frac{\sinh\left(\frac{\lambda(1-2\xi)}{2}\right)}{\lambda \cosh\left(\frac{\lambda}{2}\right)} \right]$$

Conclusion

- The 4-point loading method resulted in improved shear strength as compared to 2-point test method
- The full-scale test resulted in all the specimens failing in shear and it is found to be the most effective shear test method for the sandwich panels with MW cores and thicker PIR panels
- The detailed guidelines on the four-point loading test is developed

Thank You!

Shekhar Silwal
shekhar.silwal@tuni.fi