Experimental study on the performance of steel and composite plate shear walls under cyclic behaviour

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LWT–FLOOR
RESEARCH PROJECT

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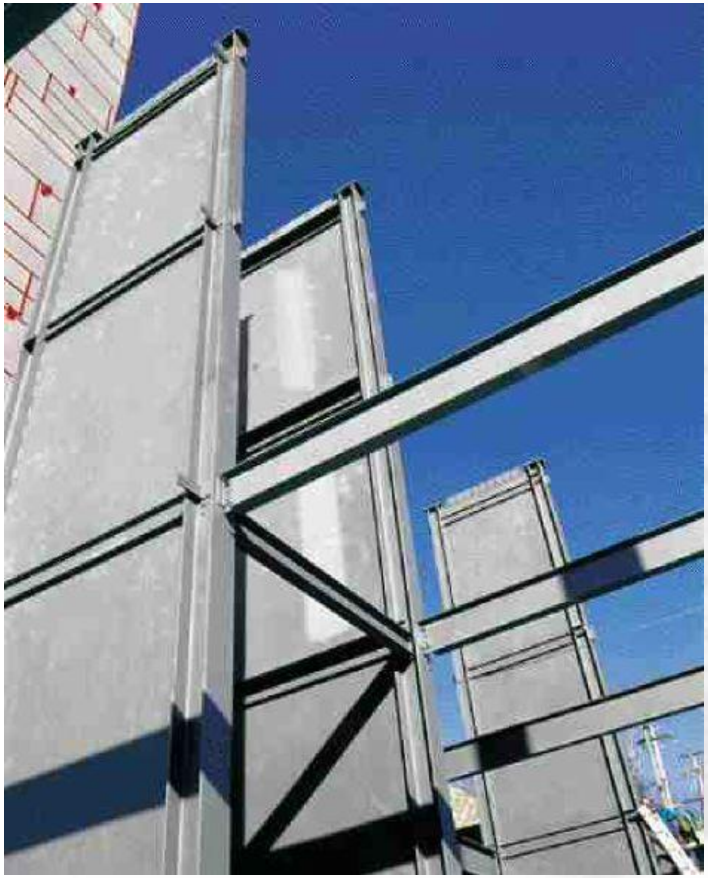
Croatian Science Foundation

CROATIAN CENTER FOR EARTHQUAKE ENGINEERING

Presentation Agenda

- Steel plate shear walls (SPSW)
- Composite plate shear walls (CPSW)
- Experimental research
- Results
- Conclusions

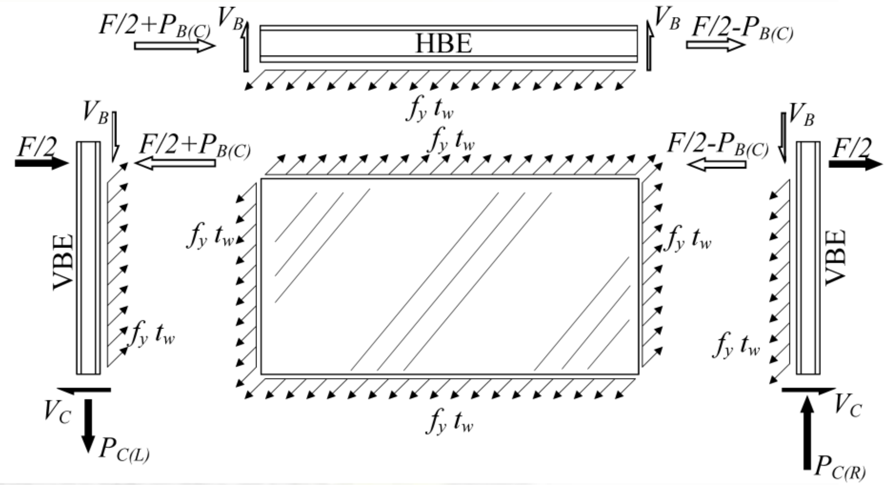
Steel plate shear walls (SPSW)



- **USE**: high lateral loads due to wind or earthquake
- **COMPONENTS:** frame (HBE and VBE) + steel infill plate
- **LOAD TRANSFER:** dominantly through tension diagonal/field in the steel infill panel (in post-buckling phase)
- **STRENGHT:** only steel infill panel (frame resistance is not accounted for)

Steel plate shear walls (SPSW)

- **INCREASE OF STEEL INFILL PANEL STRENGHT**
  - **pre-buckling**: thicker plate, various panel types, plate stiffening …
  - **post-buckling**: thicker plate, higher material strength, widening tension diagonal…



✓ Cost-effective
✓ Ductile behaviour

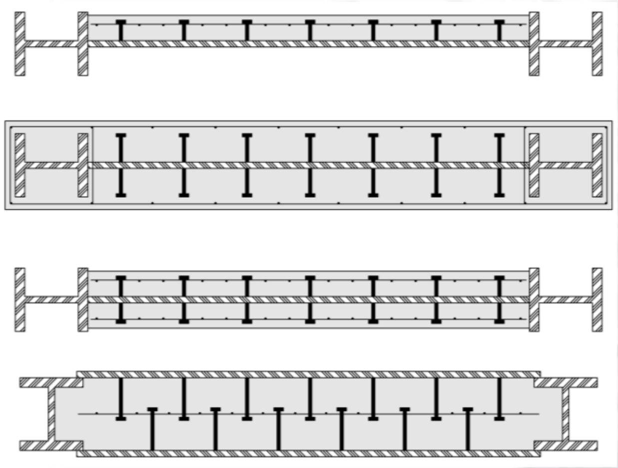
Tension field in infill panel

- **SPSW STRENGTH:** $V_n = 0.42 \cdot t_w \cdot L_{cf} \cdot f_y \cdot \sin 2\alpha$

☹ Increased requirements on boundary members

Composite plate shear walls (CPSW)

Decrease requirements on boundary members by yielding of the plate in shear before buckling

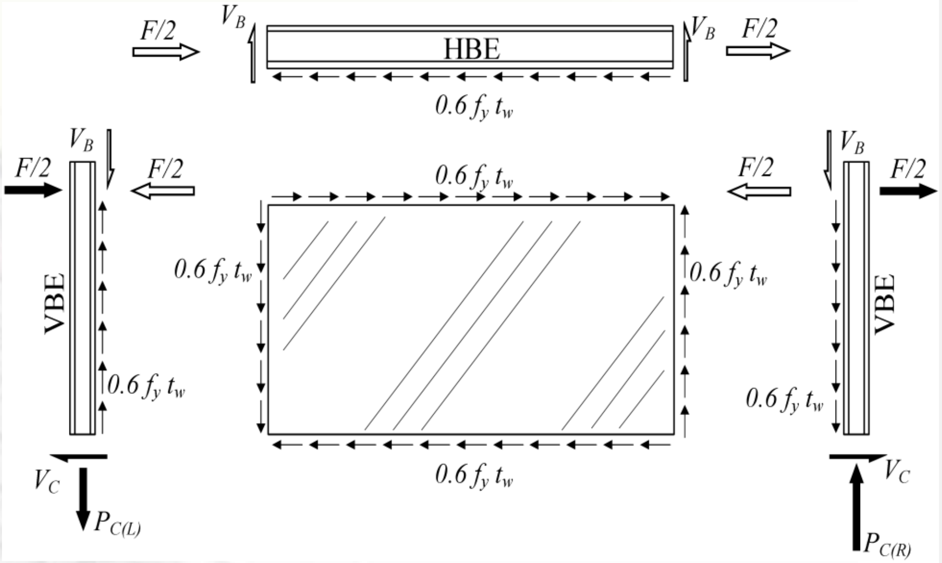


- **USE**: high lateral loads due to wind or earthquake
- **COMPONENTS:** frame (HBE and VBE) + composite infill panel (RC and steel plate with discrete connection)
- **LOAD TRANSFER:** dominantly through shear yielding of steel plate (in pre-buckling phase)
- **STRENGHT:** only composite infill panel (frame resistance is not accounted for)

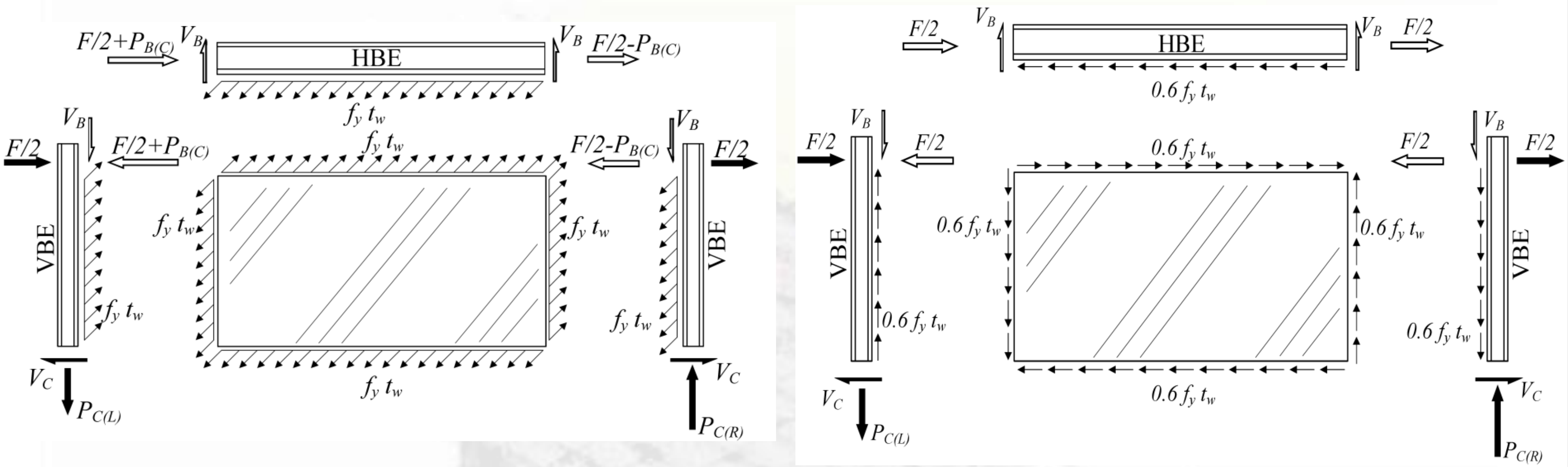
Composite plate shear walls (CPSW)

- **CPSW STRENGTH:**

$$V_n = \frac{f_y}{\sqrt{3}} \cdot t_w \cdot L_{cf} \approx 0.6 \cdot f_y \cdot t_w \cdot L_{cf}$$

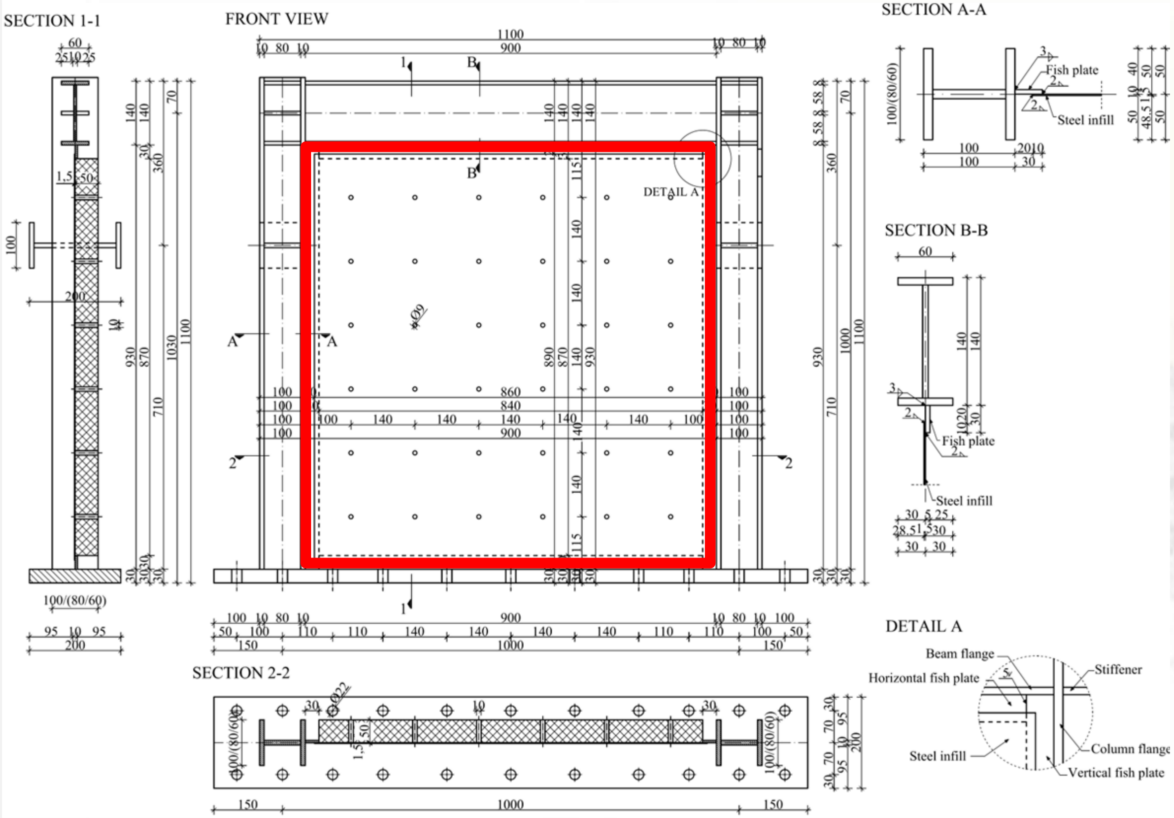


SPSW vs. CPSW



- Prevent column „pull-in”: $I_c = \dfrac{0.0031 \cdot t_w \cdot H^4}{L}$

Experimental research



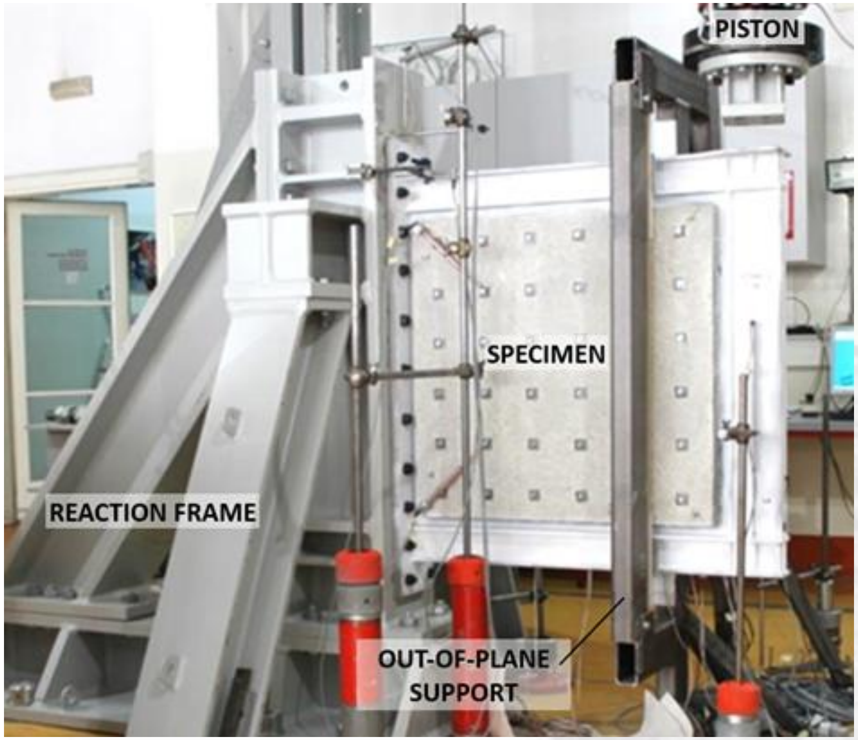
Specimens

- 3x F, 3x SPSW, 6x CPSW

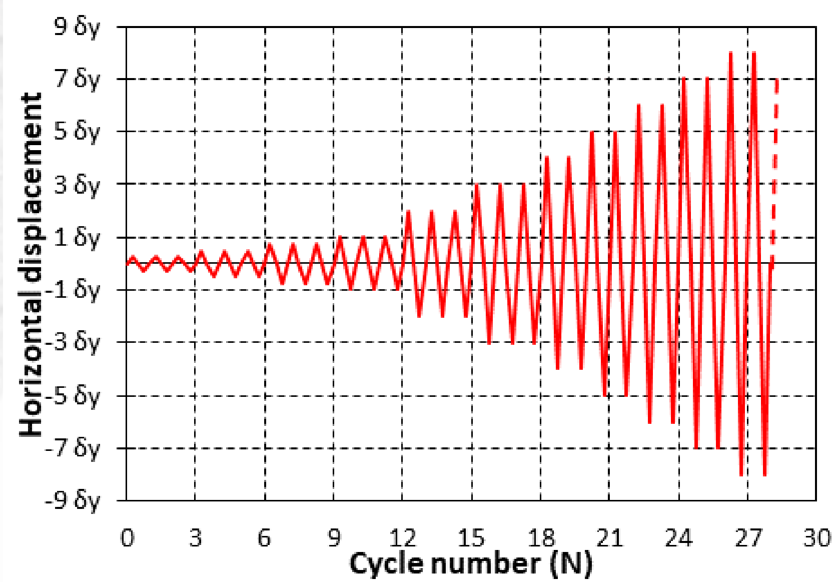
Column flange width variation

- 100 mm = EI
- 80 mm = 0.82% EI
- 60 mm = 0.64% EI

Experimental research



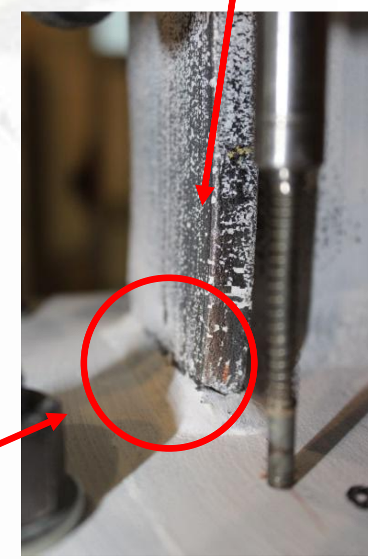
Loading protocol
- Quasi-static
- ECCS and ATC-24 protocol
- Yield displacement: 3 mm (SW) and 12 mm (MRF)
- Displacement controlled



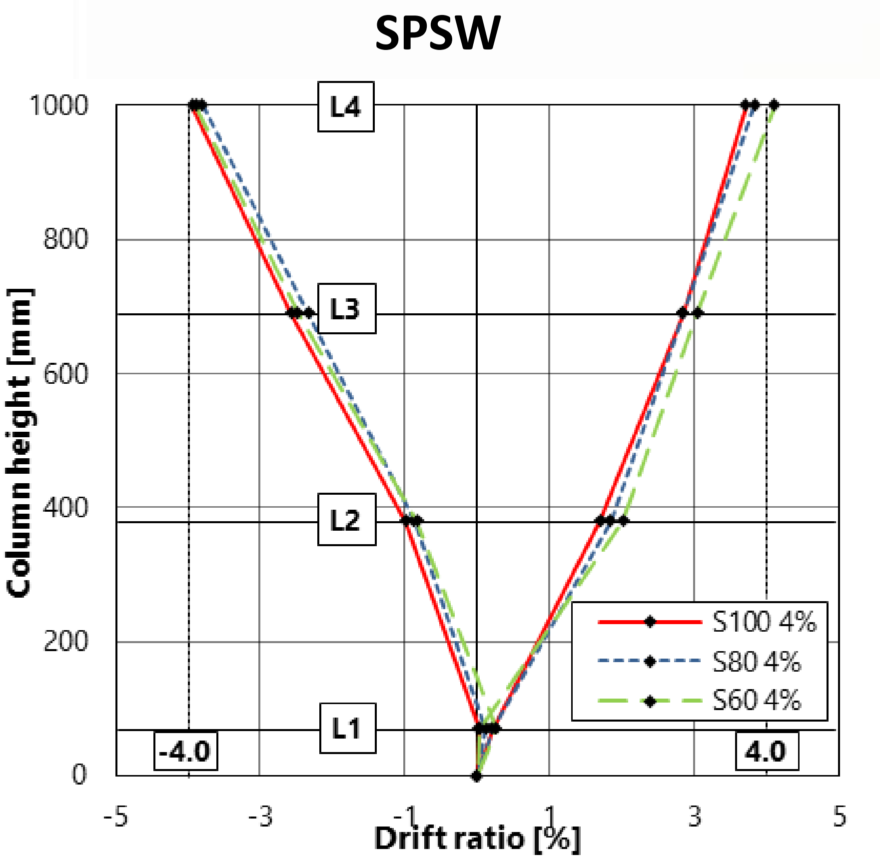
Test setup
- Rotated position 90°
- Fixed column base
- OOP support

Results

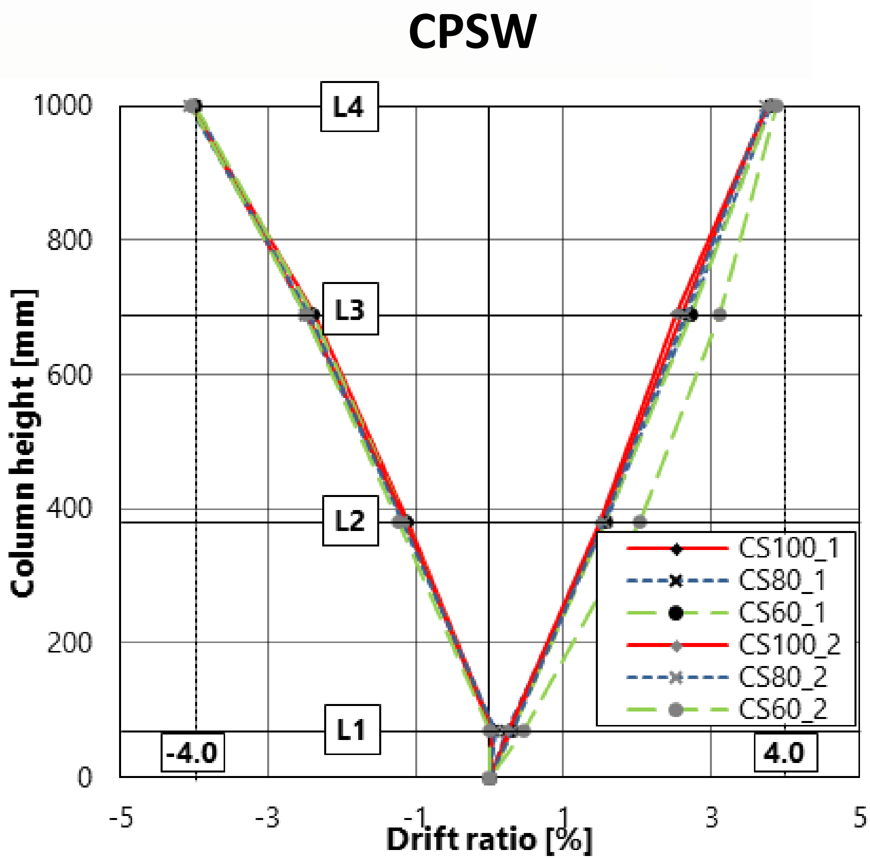
Spec. group	Initial stiffness	Ultimate strength		Maximum displ.	
	[kN/mm]	[kN]	[mm]	[kN]	[mm]
F100	13.7	208	68.7	159	80.3
F80	12.3	178	75.1	157	84.5
F60	10.7	137	51.8	120	64.7
S100	100	371	33.8	323	42.8
S80	75	342	36.0	272	49.4
S60	89	321	33.3	243	51.4
CS100	120	396	30.2	319	42.3
CS80	104	379	30.2	279	47.1
CS60	107	359	27.6	267	42.9



Results

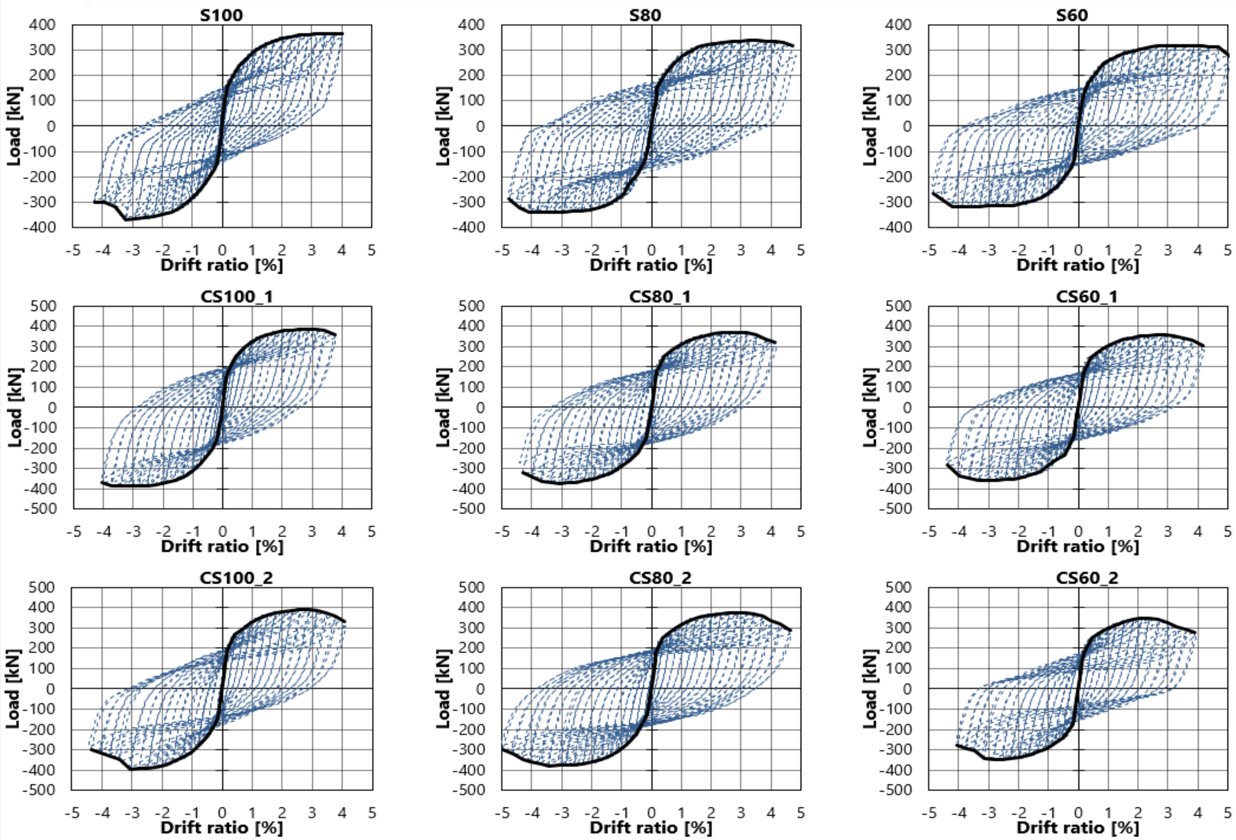


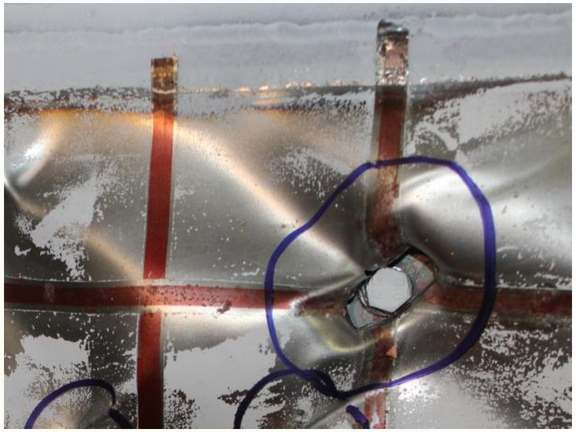
SPSW
1000
800
600
400
200
0
L4
L3
L2
L1
-4.0
4.0
Column height [mm]
-5
-3
-1
1
3
5
Drift ratio [%]
S100 4%
S80 4%
S60 4%



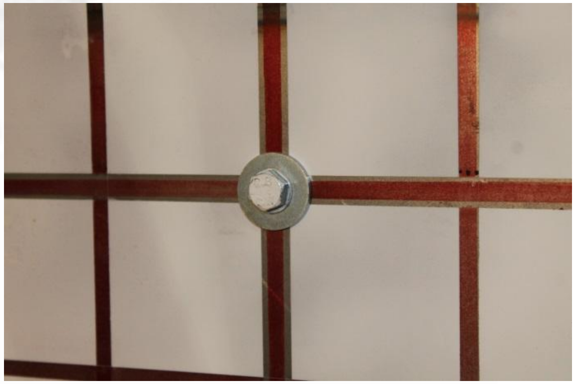
CPSW
1000
800
600
400
200
0
L4
L3
L2
L1
-4.0
4.0
Column height [mm]
-5
-3
-1
1
3
5
Drift ratio [%]
CS100_1
CS80_1
CS60_1
CS100_2
CS80_2
CS60_2

Results

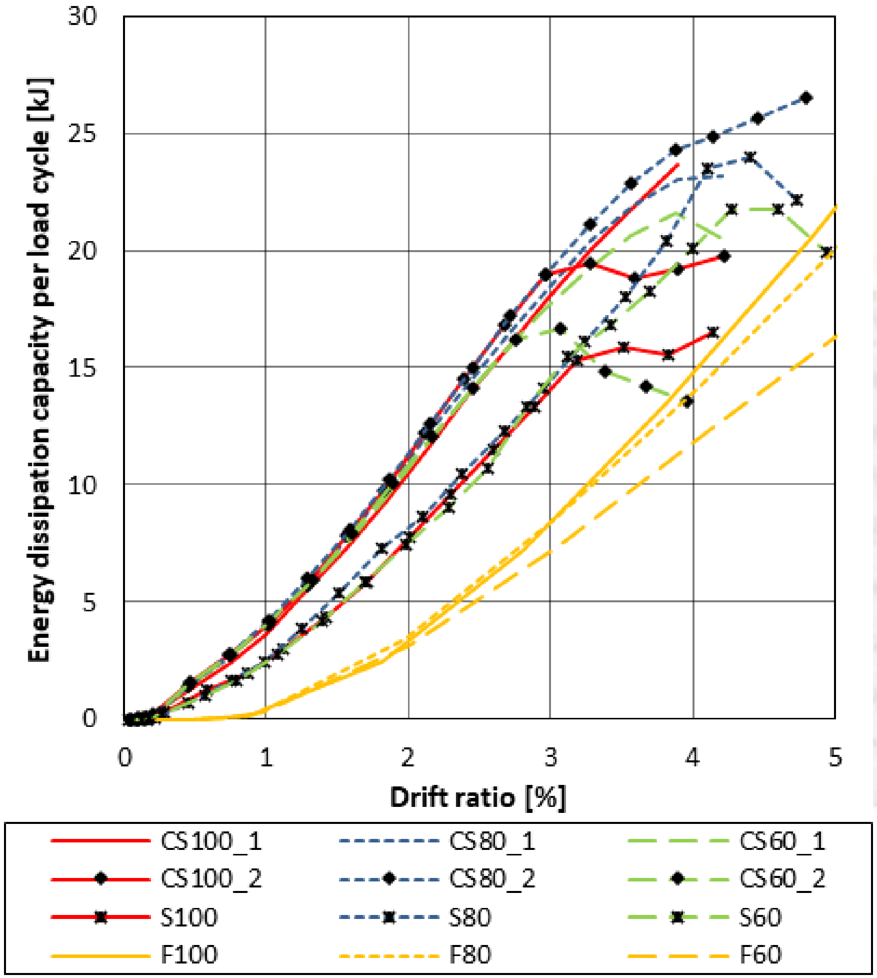




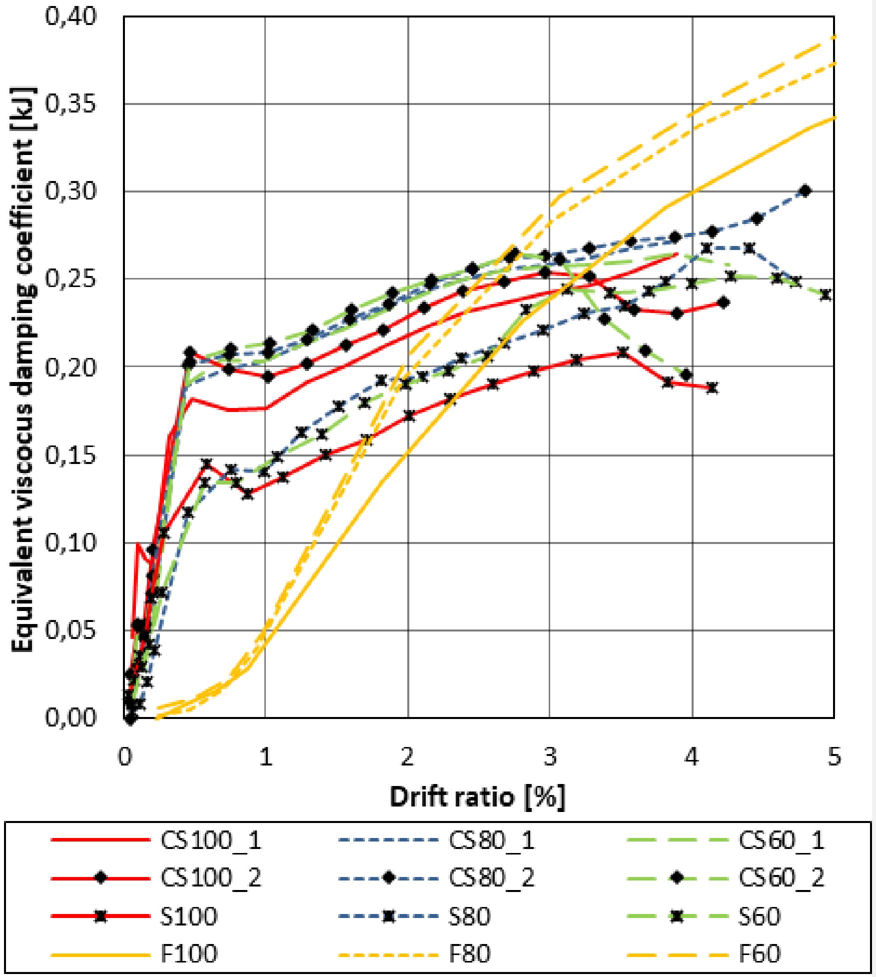
Infill steel plate hole bearing failure (CPSW)



Results



Energy dissipation capacity per load cycle [kJ]
30
25
20
15
10
5
0
0
1
2
3
4
5
Drift ratio [%]
CS100_1
CS80_1
CS60_1
CS100_2
CS80_2
CS60_2
S100
S80
S60
F100
F80
F60



Equivalent viscous damping coefficient [kJ]
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
0
1
2
3
4
5
Drift ratio [%]
CS100_1
CS80_1
CS60_1
CS100_2
CS80_2
CS60_2
S100
S80
S60
F100
F80
F60

Conclusions

- Infill panel has significantly greater influence on the initial stiffness of the shear walls than the flexural stiffness of the column.
- Experimental results showed that reduction of column flexural stiffness by 36% did not have adverse impact on cyclic shear wall behaviour, which were able to tolerate 4% drift ratios before failure
- Column „pull-in" column deflections of CPSW were lower than the ones of SPSW.
- Overall experimental results indicate that column flexural stiffness requirement can be reduced for CPSW, and maybe even entirely omitted for SPSW and CPSW.
- Design procedure of the conection between steel infill plate and RC panel has to be revised to increase energy dissipation capacity of CPSWs, especially when prefabricated RC plates are used.

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