

Steel Frames with Precast Concrete Infill Panels

‘Experimental and Numerical Analyses’

Supervision

- ▶ prof. ir. C.S. Kleinman
- ▶ prof. ir. H.H. Snijder
- ▶ dr. ir. H. Hofmeyer

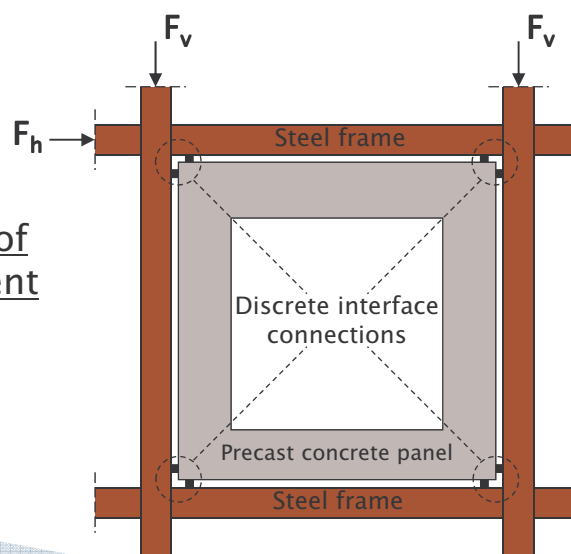
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Introduction

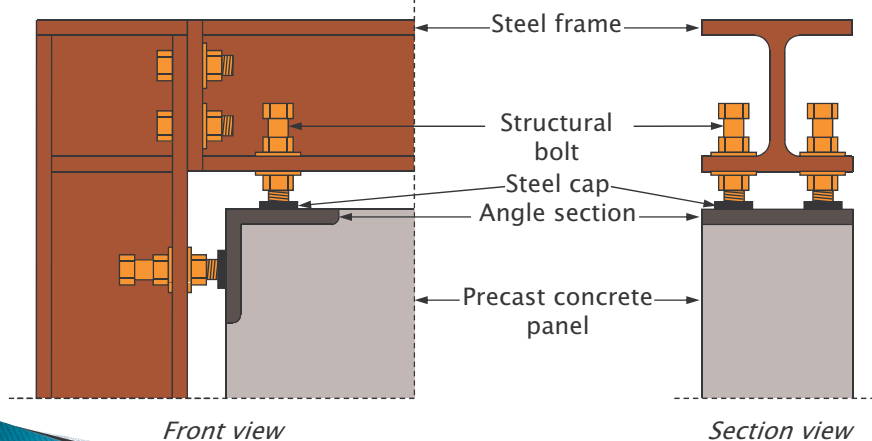
- Structure

≠ simple sum of
two component
structures



Introduction

► Discrete steel-to-concrete connection



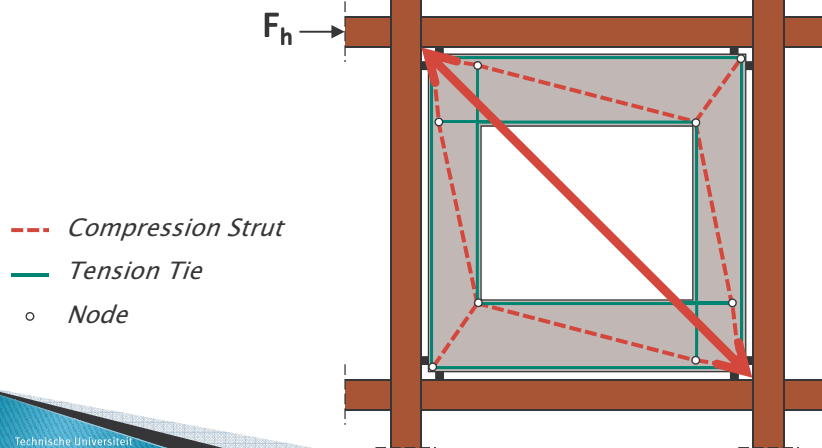
Introduction

► Properties discrete steel-to-concrete connection

- Structural:
 - Acting in compression only
 - Designed to govern strength of the structure
- Constructional:
 - Adopt tolerances and position panels
 - Dry connection: increasing speed of construction

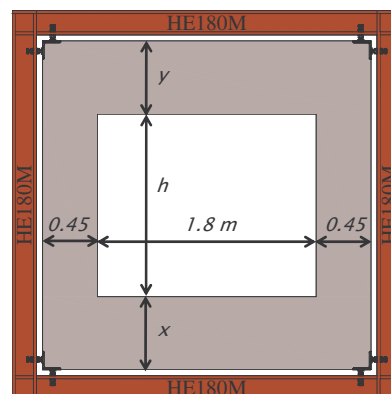
Introduction

- ▶ Structural behavior
 - Strut-and-Tie-model



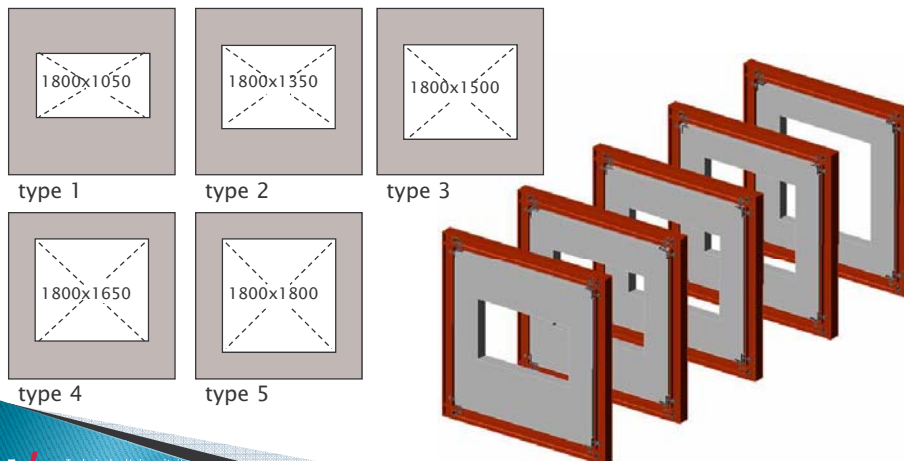
Full-scale experiments

- ▶ 1-storey, 1-bay (3 x 3 m) specimens (5 types)
 - Steel frame
 - HE180M sections; in S235
 - simply connected
 - Precast concrete panel
 - $t = 200$ mm; in C45/55
 - Window opening ($1.8 \times h$)
 - Steel-concrete connection
 - 8.8M24 bolts



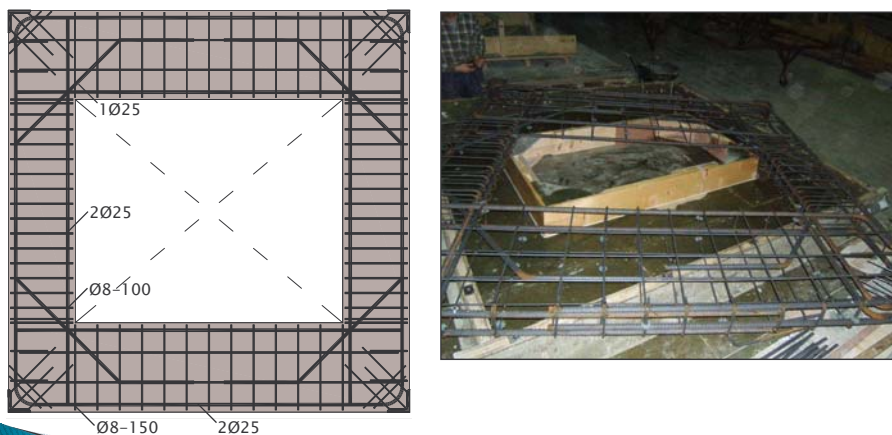
Full-scale experiments

► Specimen types



Full-scale experiments

► Reinforcement



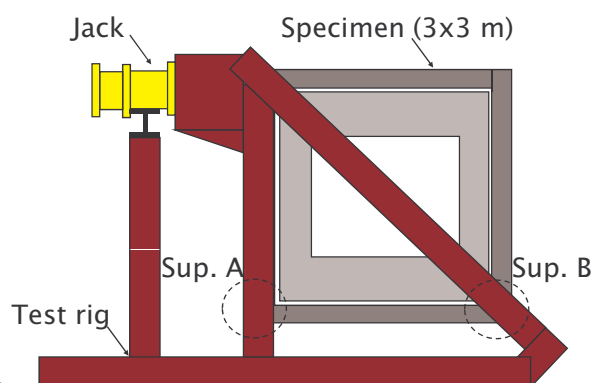
Full-scale experiments

► Test program

Test no.	height opening h [m]	Opening %	Vertical position x/y
0	<i>Bare frame</i>	100%	–
1	1.05	25.9 %	1.20
2	1.35	33.3 %	1.25
3	1.50	37.0 %	1.00
4	1.65	40.7 %	1.33
5	1.80	44.4 %	1.00

Full-scale experiments

► Test-setup

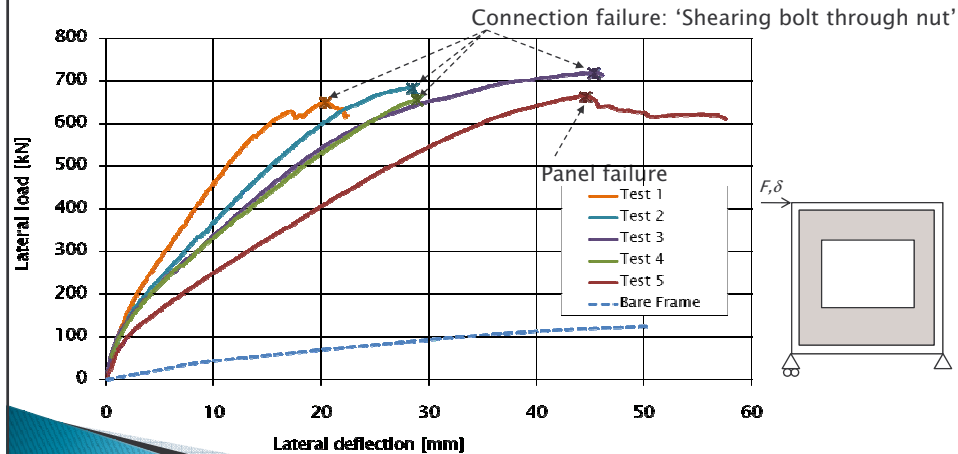


Support A Support B



Full-scale experiments

► Results: Load – deflection response



Full-scale experiments

► Failure test 1 to 4: Connection failure

- Bolt shear through nut



Full-scale experiments

- ▶ Failure test 5: Panel failure
 - Crushing of concrete strut with spalling and yielding wedge reinforcement



Full-scale experiments

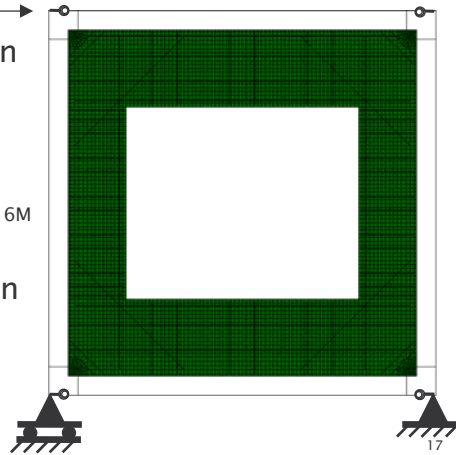
▶ Results

Test no.	F_u [kN]	Failure mode	Stiffness [kN/mm]	Stiffness factor α
1	650	Connection	46.1	10.0
2	684	Connection	36.9	7.9
3	719	Connection	33.9	6.9
4	656	Connection	33.2	7.7
5	664	Panel	25.1	5.5

Finite element analysis

► 2D-Finite element model (DIANA)

- Frame
 - Beam elements CL9BE
- Column-beam connection
 - Rigid offset +
 - Rotation spring SP2RO
- Panel
 - Plane-stress elements CQ16M
 - Embedded rebars
- Steel-concrete connection
 - Translation springs SP2TR
 - (no tension capacity)



Finite element analysis

► Material properties

- Panel:
 - Smeared crack model + Drucker-Prager yield criterion
 - Multi-directional fixed crack model
 - Linear tension cut-off + linear tension softening based on G_f
- Reinforcement:
 - Elastic-perfectly plastic (Von Mises plasticity)
- Frame:
 - Elastic-perfectly plastic (Von Mises plasticity)
 - Rotation springs calibrated on test results bare frame
- Discrete steel-concrete connection:
 - Calibrated on test results individual connections

Finite element analysis

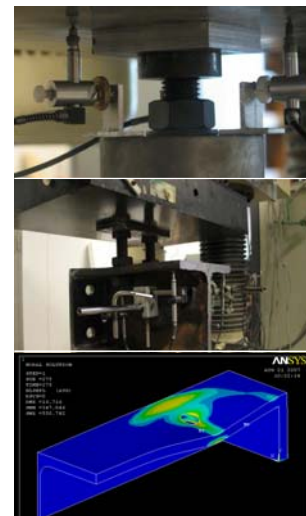
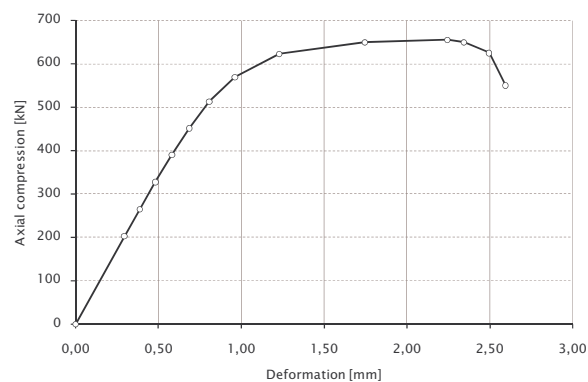
► Concrete material properties

Test	E_c [N/mm ²]	f_c [N/mm ²]	f_{ct} [N/mm ²]
1	3.54E+04	62.2	3.9
2	3.67E+04	64.4	3.9
3	3.66E+04	70.6	4.2
4	3.70E+04	75.6	4.4
5	3.72E+04	66.0	3.9



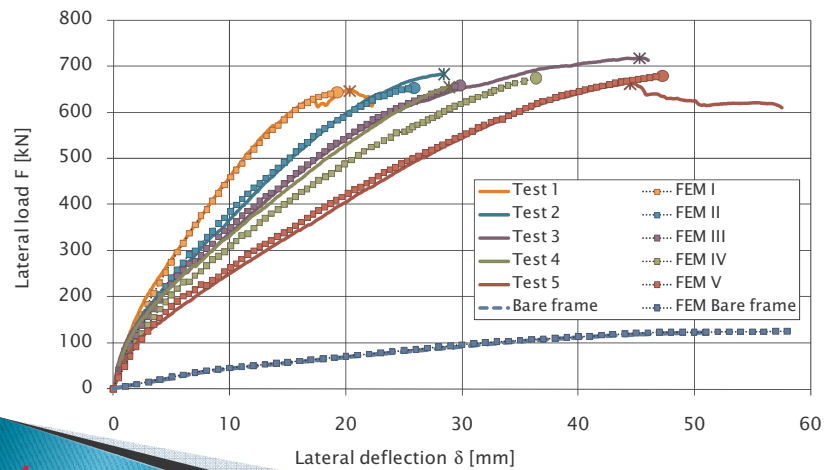
Finite element analysis

► Discrete steel-concrete connection



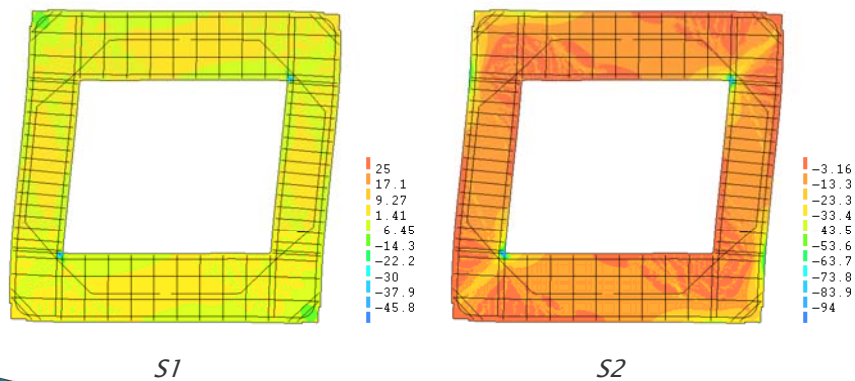
Validation finite element model

► Load – deflection behavior



Validation finite element model

► Principal stresses

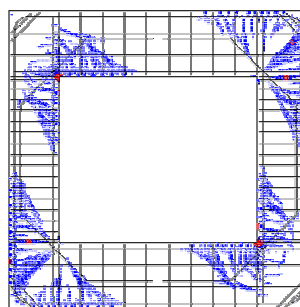


Validation finite element model

► Crack patterns (test 3)



Experimental crack pattern



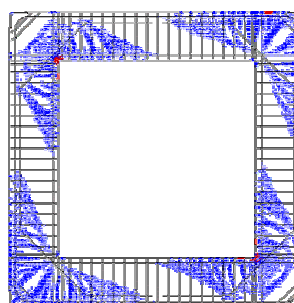
Smeared crack pattern

Validation finite element model

► Crack patterns (test 5)



Experimental crack pattern



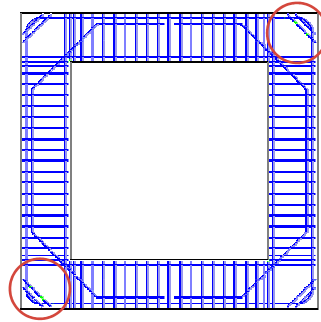
Smeared crack pattern

Validation finite element model

► Crack patterns (test 5)



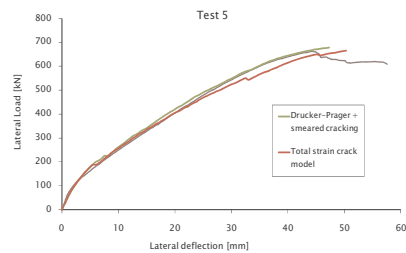
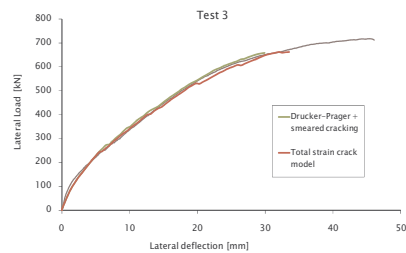
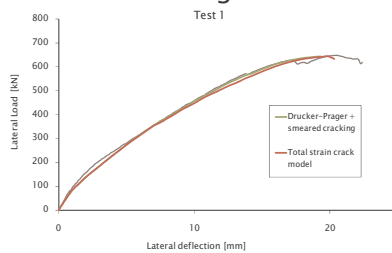
Experimental crack pattern



Yielding reinforcement

Validation finite element model

► Drucker-Prager+smeared crack vs total strain crack model



Conclusions

- ▶ Concrete infill panels with window openings can significantly improve performance steel frames
- ▶ FE-model developed and validated
 - Lateral load versus deflection relationship
 - Failure mechanism
- ▶ Future:
 - Parametric study
 - Development design rules

Thank you for your attention!

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