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Structural behavior of cold-formed stainless steel bolted connections at post-fire condition

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Outline

- **Research** background
- Post-fire tests
- □ Test results and analysis
- Proposed design rules
- Conclusions



Research background

Stainless Steel (Sustainability):

- corrosion resistance
- ductility excellence
- low life cycle cost
- ease of maintenance
- aesthetic appearance



Helix Bridge, Singapore (Duplex stainless steel)

Research background

Fire and post-fire disaster in steel structures









Research background

Cold-formed stainless steel	Label
EN 1.4301 (AISI 304)	Α
EN 1.4571 (AISI 316Ti)	Τ
EN 1.4162 (AISI S32101)	L

Over 400 tests together with 450 numerical results were investigated for cold-formed stainless steel bolted connection at elevated temperatures.

How about at post-fire condition?

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Post-fire tests

Design of connection plates

The spacing in the plate could generally satisfy the minimum requirements from ASCE and AS/NZS specifications and Euro Code.



Post-fire tests

Dimension of the connections (82 specimens)

				Nominal (n			
Specimen	h	L_2	<i>e</i> ₁	e ₂	ши) р1	<i>p</i> ₂	L_l
	10	72	36	25			381
T-S-1-12	10	72	36	25			381
L-S-1-12	10	72	36	25			381
A-S-2Pa-8	10	81	27	25	27		386
T-S-2Pa-8	10	81	27	25	27		386
L-S-2Pa-8	10	81	27	25	27		386
A-S-3-8	10	81	27	14	27	22	386
T-S-3-8	10	81	27	14	27	22	386
L-S-3-8	10	81	27	14	27	22	386
A-D-1-12			55	25			405
T-D-1-12			55	25			405
Table to be continued							
	Single shear Bolt hole of						diameter
			A-S-1	-12			

EN 1.4301 _____ One bolt hole ⁸



Heating: Heating rate of 40-60 °C/min Maintain: 5 ~ 10 minutes Cooling: Switch off the furnace

Post-fire tests



Typical temperature-time records of specimens cooled down from nominal high temperatures¹⁰

Post-fire tests



Bolted connection test set up

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Load-displacement curves of connection specimens with and without post-fire conditions

Specimen series	Temperature	$P_{u,N}$ or $P_{u,P}$	$P_{u,P}/P_{u,N}$	Failure Mode
	22	34.9*	1.01	B
	22	34.0	0.99	B
A-S-1-12	352	38.0	1.10	В
	653	38.9	1.13	В
	954	34.4	1.00	В
	22	38.9*	1.02	В
	22	37.5*	0.98	В
	357	40.1	1.05	В
	354	40.3	1.05	В
A-S-2Pa-8	653	40.0	1.05	В
	653	40.6	1.06	В
	652	39.9	1.04	В
	954	35.5	0.93	В
	950	33.5	0.88	В
A-S-3-8	22	45.4*	1.03	B+NS
	22	42.4*	0.97	B+NS
	356	46.9	1.07	B+NS
	652	47.5	1.08	B+NS
	653	47.2	1.08	B+NS
	954	40.1	0.91	B+NS
Note: * reported in Cai and	d Young [11]			

Post-fire test results; e.g.: single shear of EN 1.4301 (Type A)



22 °C





654 °C

952 °C

Bearing failure mode of specimens with and without post-fire conditions, e.g., Series T-S-1-12



Location of sampling



Polished samples for scanned electron microscope (SEM)



SEM images cold-formed stainless steel with and without post-fire conditions, e.g., Type T (EN 1.4571)¹⁷

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Proposed design rules



Proposed design rules



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Conclusions

- Structural behavior of cold-formed stainless steel bolted connections at post-fire condition
- Three grades of stainless steel EN 1.4301 (AISI 304), EN 1.4571 (AISI 316Ti) and EN 1.4162 (AISI \$32101).
- A total of 82 bolted connection tests;
- Single shear & double shear

Conclusions

• Specimens cooled down from 350, 650 and 950 °C;



Conclusions

• Similar failure modes; with and without post-fire condition



 Proposed equations; CFSS bolted connections exposed to high temperatures up to 950 °C; 24

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