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EMBEDDED COMPOSITE COLUMNS IN FIRE

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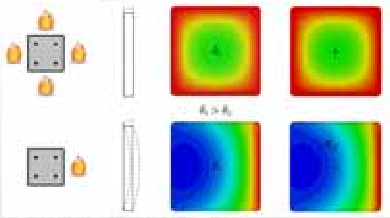
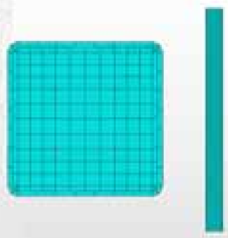
- Concrete filled steel tube (CFT) columns are common
- CFT columns have been studied well and there are several design manuals for them
- Behavior in fire is also pretty well known
- Most of the research only considers columns in the middle of the room, which are exposed to heat uniformly during fire.
- In reality, many of the columns are located next to walls, in corners or partly inside walls. Influence of fire is then non-uniform.



The second CFT column:
- Bends due to thermal expansion
- Has lower average temperature
- The loading gets more eccentric

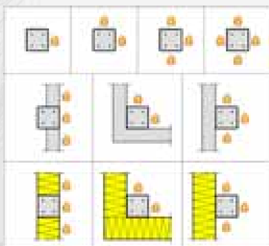
The ratio of these effects is unknown => Current methods could lead to unsafe or uneconomical columns

- The problem has been studied in my master's thesis
- Numerical study using FEM (ABAQUS)
- Model with solid elements
- Non-linear material models from Eurocode 4
- ISO fire. Temperature constant along the column.
- Thermal analysis and mechanical analysis are done separately

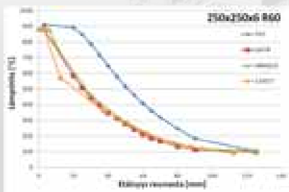


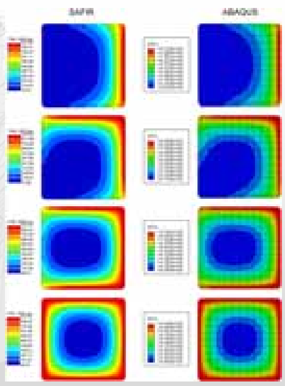
CFT column	Length [m]	Steel tube	Reinforcement	Concrete
I	2	CFRHS150x150x5, S355	4T12, A500HW	C40/50
II	3	CFRHS150x150x5, S355	4T12, A500HW	C40/50
III	3	CFRHS250x250x6, S355	4T20, A500HW	C40/50
IV	5	CFRHS250x250x6, S355	4T20, A500HW	C40/50
V	3	CFRHS400x400x10, S355	8T25, A500HW	C40/50
VI	6	CFRHS400x400x10, S355	8T25, A500HW	C40/50

- Six different reinforced CFT columns with square sections studied
- Cases where fire is acting at one, two (adjacent) or three sides of the column are considered, and they are compared to uniform fire case.
- Three different methods to partially insulate the column were used:
  - Adiabatic surfaces (ideal case)
  - Concrete wall
  - Sandwich-panel

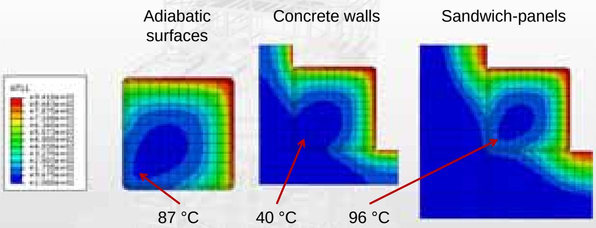


- Comparison temperatures from literature:
  - Finnish design manual (TRY), only for the uniform case
  - CIDECT study, only for the uniform case
  - Kivimaa BSc thesis (SAFIR), for all studied cases





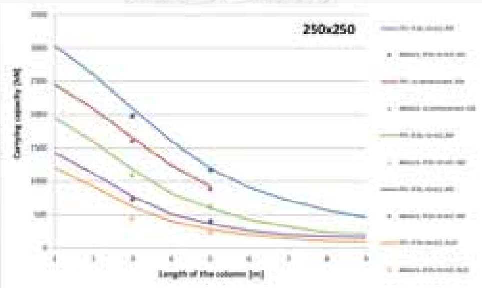
250x250, fire on two sides, after 60 min fire



- Concrete wall can act as a heat sink reducing the temperature in columns noticeably
- Highest temperatures with sandwich-panels, but still close to adiabatic surfaces

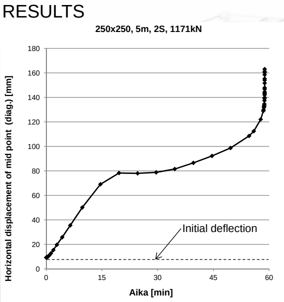
- The temperatures are read to the mechanical analysis and the columns are compressed with constant loads to failure => fire resistant times
- Each case has been studied with four different loads
- Loads were chosen (from design manual) so that the fire resistance times would be approximately 30, 60, 90 and 120 min in the case with uniform fire.
- Initial deflection L/666
- Hinged supports
- Static analysis

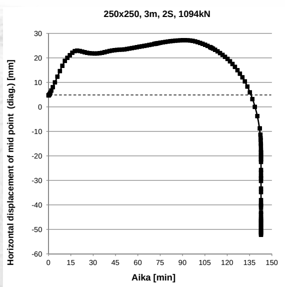
- The model with uniform fire is also compared to the carrying capacity values found in the design manual using fixed temperatures and calculating maximum loads.



- Convergence problems from concrete material model
- Very simplified model for concrete tensile behavior
- Abaqus has multiple different ways to model concrete:
- *Concrete smeared cracking*
  - Used in this study
  - Easy to set up
- *Concrete damaged plasticity*
  - More common in literature
  - Better (?)
  - Difficult to set up (many variables, temperature dependence, no example values)
- Convergence problems also from concrete-steel contact, but they disappeared when using *contact controls*

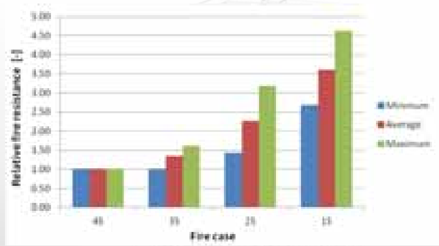
RESULTS





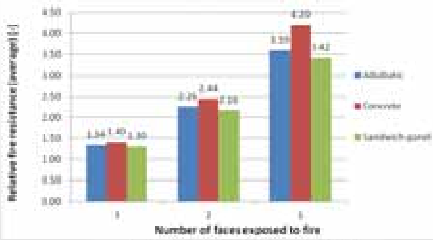
- Large displacements compared to the initial deflection
- Slender columns buckle towards fire (relative slenderness > 0.8)
- Stocky columns buckle away from fire (relative slenderness < 0.4)

RESULTS



- Resulting fire resistance periods in non-uniform fires (3S,2S,1S) are compared to corresponding periods in uniform case (4S)
- On average the fire resistance periods increase 1.3-fold in three sided fires, 2.2-fold in two sided fires and 3.5-fold in one sided fires.
- At the minimum these values are 1.0, 1.4 and 2.6

RESULTS

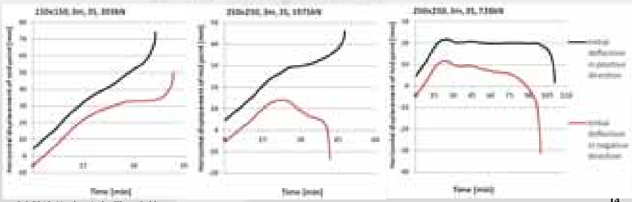


- The fire resistance periods are clearly longest with the partial concrete insulation. The sandwich panels produce the shortest fire resistance times.

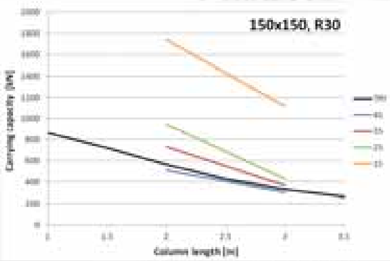
RESULTS

- Only an initial deflection towards positive direction (towards fire) has been considered
- A couple of cases has been studied also with negative initial deflection
- Positive initial deflection lowers the resistance in cases which buckle towards fire, increases the resistance in cases which buckle away from fire, and can even affect the buckling direction

=> All cases should be studied with both initial deflections

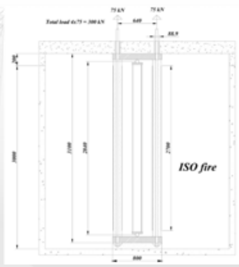


RESULTS



- Rough carrying capacity curves can be calculated using the fire resistance periods
- The capacities in uniform fire cases (4S) are close to the curves from design manual (TRY)

- Experimental tests are badly needed to validate the calculations
- TUT has a furnace, but the its floor cannot resist loading => the columns would have to be pulled against the furnace lid (or are there better options?)
- How to partially insulate the columns from fire (mineral wool or concrete)?
- How extensive tests are needed?



Thank you

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