Benchmark modelling of concrete filled structural hollow (CFS) sections

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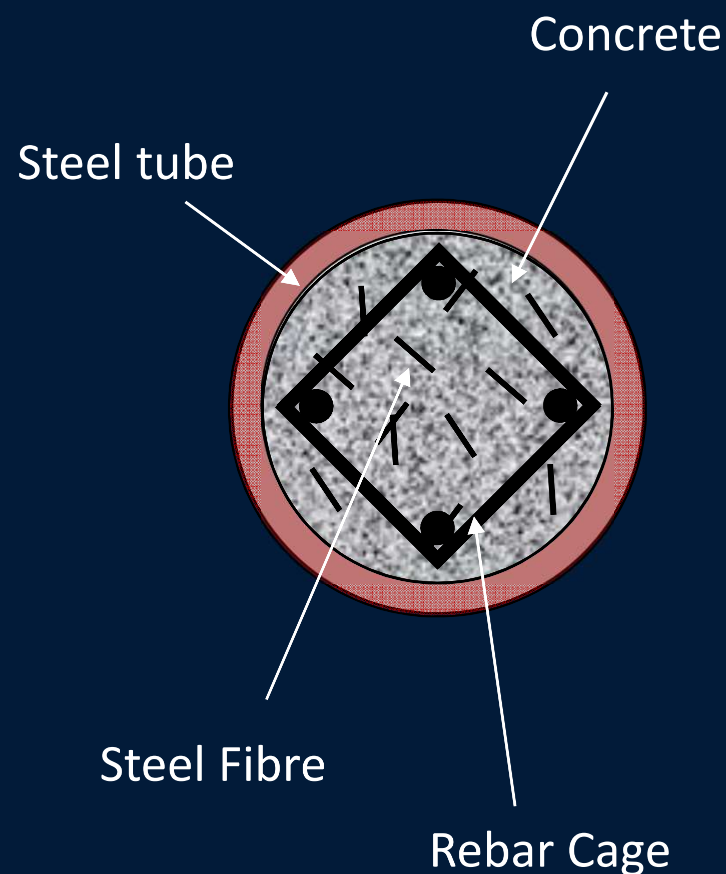

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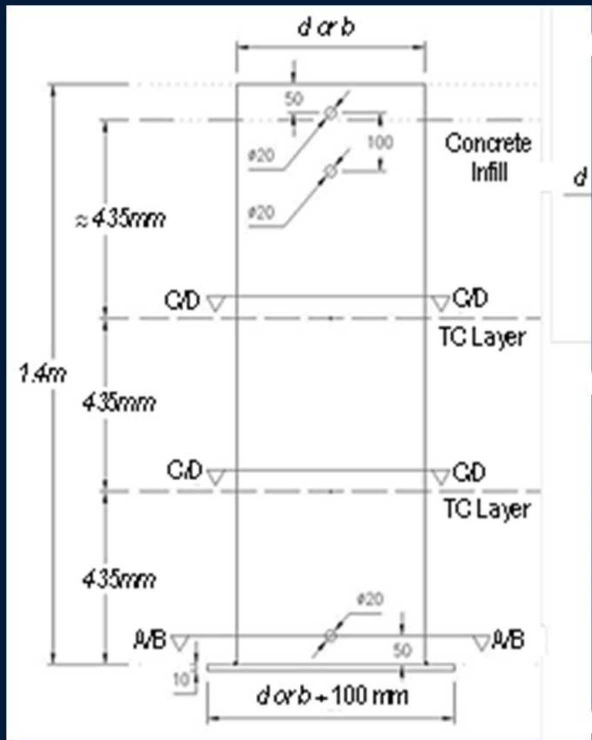
Benchmark study

- This study assesses the **inputs parameters** required to **predict the fire resistance** of furnace tests on **unprotected CFS columns**.
- Three stages:
  1. **Thermal tests** on 14 unprotected CFS sections (CFS);
  2. Development of a **thermal modelling approach** to predict the observed temperatures; and
  3. **Meta-analysis** of predicted versus actual fire resistance of 4 exemplar structural furnace tests

- THERMAL TESTS
- 14 specimens heated for 2 hours
  - “cooled” for 2 hours
- Temperatures recorded at 4 depths
  - Steel
  - Concrete face (within 2.5mm)
  - 35mm from interface
  - Centre of concrete



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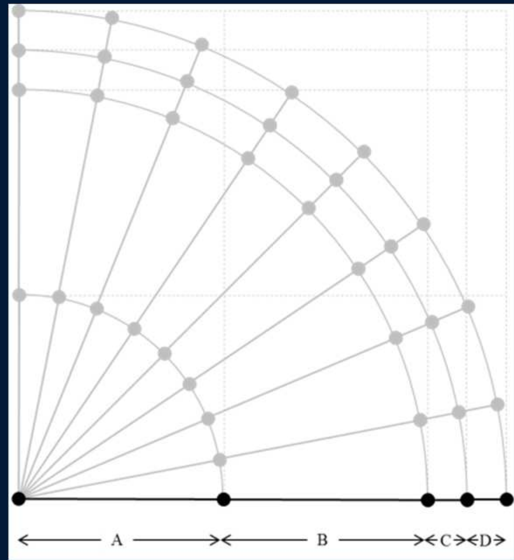
Test results and predictions

- **Sensitivity analysis** for mesh density performed
  - 2D quarter section
  - D2DC4 main elements
  - Triangular elements at centre
  - Looking for **less than 5°C change** from previous mesh density
  - Mesh density 9/8/4/4 for A/B/C/D
  - A/B/C are concrete, D is steel



- Test **temperatures predicted** using Eurocode design guidance:
  - $\varepsilon_f = 1.0$; $\alpha_f = 25 W/m^2{}^oC$, $\varepsilon_s = 0.7$
  - thermal conductivity (lower limit), λ,
  - heat capacity, *c*, (including **10% moisture content**)
  - **perfect contact** at the steel tube-concrete core interface
- Steel **temps. over-predicted**, concrete both **under-and over-** predicted (sometimes **by over 400°C**) depending on location

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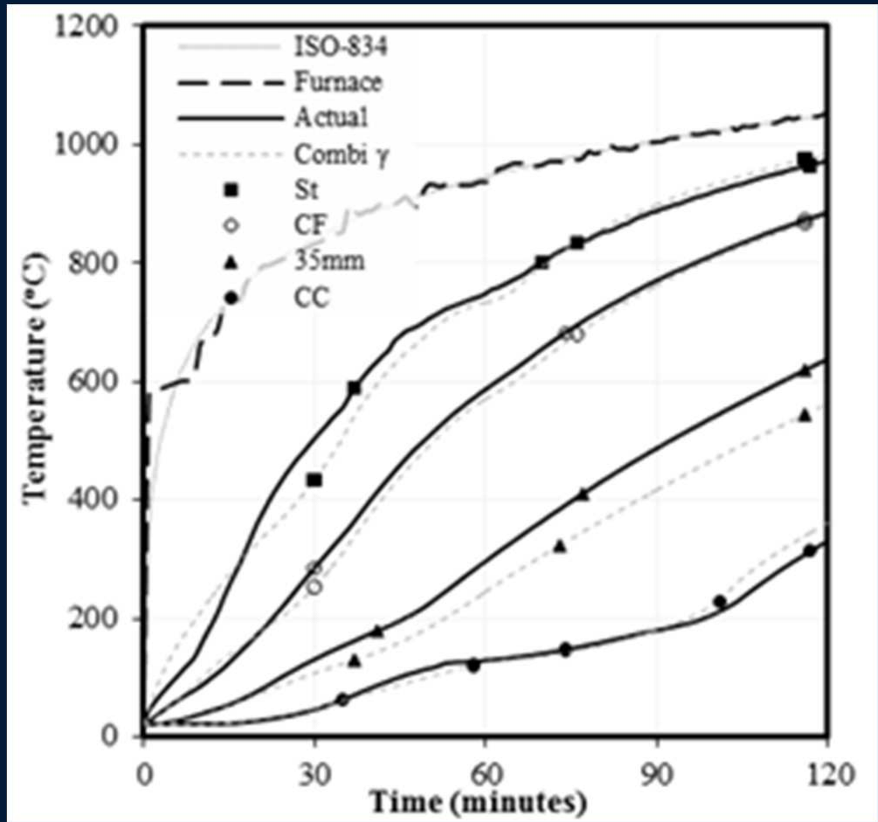
New modelling approach

- Same mesh used for section
  - **Additional elements outside** to simulate furnace temps
  - GAPCON.f **subroutine used to transfer heat**
    - Through **heating and cooling**

<u>*New model produced:*</u>

- ε_f = 0.38 (calibrated from one test specimen)
- α_f = 25W/m^2°C;
- ε_s = temperature dependant (Papoloski and Liedquist);
- upper limit thermal conductivity, λ,
- **New concrete specific heat capacity model** ; and
- **Gap conductance** between the steel tube and concrete core as suggested by Ghojel.



- Average error **±50°C for all tests**

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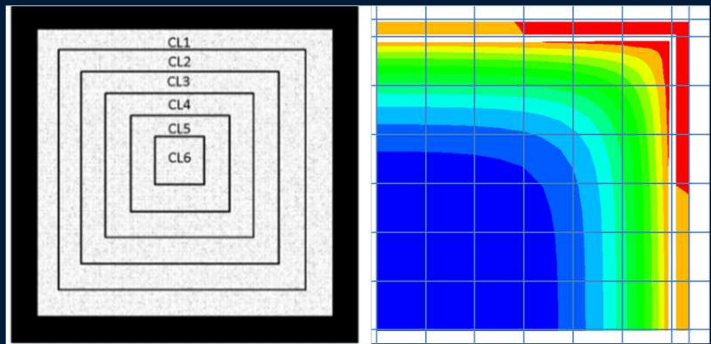
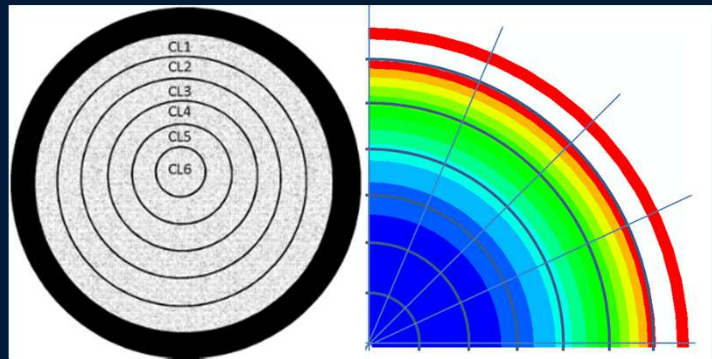
Fire resistance predictions

- Four exemplar columns from database of over 380+ furnace tests
- **Fire resistance predicted** using **EC4 Annex H**
  - Obtain **temperature profile**
  - Calculate **load capacity** (Assume $\varepsilon_a = \varepsilon_c = \varepsilon_{tot}$; $N_{fi,Rd} = N_{fi,cr} = N_{fi,pl,Rd}$)





Example	C/S	d or b	t_w	L	$N_{fi,Rd}$	$N_{fi,Rd} / N_{Rd}$	Observed		Predicted	
							FR	ϑ_a	FR	ϑ_a
		mm	mm	m	kN		mins	°C	mins	°C
1	C	273.1	5.6	3.81	574	0.26	112	960	117	1008
2	C	168.3	4.8	3.81	218	0.23	56	896	55	854
3	S	350	10	3.6	4560	0.54	51	749	45	726
4	S	160	3.6	3.6	820	0.48	25	670	29	676

Thank you for your attention
Any questions?

Contact:

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Link to full **PhD thesis**:
www.era.lib.ed.ac.uk/handle/1842/8298

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