REUSE OF WASTE TYRE FIBRES FOR FIRE SPALLING MITIGATION

DR SHAN-SHAN HUANG

LECTURER, UNIVERSITY OF SHEFFIELD

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Concrete Spalling in Fire

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Concrete Spalling in Fire

Mont Blanc tunnel after fire
Source: www.phys.tue.nl/

Channel Tunnel fire
Source: www.phys.tue.nl/

Spalling of a building under construction
Source: www.panoramafactory.net

State of the Art

- First observation in 1854
- **No** common view on the causes
- **No** standard test method
- **No** guaranteed prevention measure
- **No** prediction model for use in design

Why still so many 'NO's?

- **An extensive list of influencing parameters**
- **Spalling risk increases as:**
  1. Increased concrete compressive strength
  2. Increased in-service stress condition
  3. Increased in-service moisture content
  4. Certain fire exposure regimes (faster heating)
  5. Certain sizes/thicknesses/shapes of structural elements (larger elements)
  6. Fresh concrete slump or slump flow (i.e. self-consolidating, pumped, etc)
  7. Certain methods of manufacture (e.g. precast, pre-stressed concrete)
  8. Absence of PP fibres (fibre dose, diameter, aspect ratio)
  9. Absence of steel fibres (fibre dose)
  10. Certain types of cement
  11. Certain types and shapes of aggregates and their gradation
  12. Certain other concrete admixtures or supplementary cementing materials (e.g. fly ash, silica fume, water reducers, air entraining agents, etc)
  13. Certain internal reinforcement types, ratios, geometries

Why still so many ‘NO’s?

- An extensive list of **influencing parameters**
- Difficult to obtain test data of adequate quantity and consistency to support systematic, statistically reliable and efficient studies
- The rapid **evolution of concrete** material itself
    - Modern concretes are more vulnerable to spalling

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Research Needs

- **No** common view on the causes
- **No** standard test method
- **No** guaranteed prevent measure
- **No** prediction model for use in design
- **Concentration on prevention**

Polypropylene Fibres

“*Explosive spalling is unlikely to occur when the* ***moisture content*** *of the concrete is* ***< 3%*** *by weight*”

“*Include in the concrete mix more than* ***2 kg/m³*** *of monofilament* ***propylene fibres***”

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Reuse Tyre Polymer Fibre?

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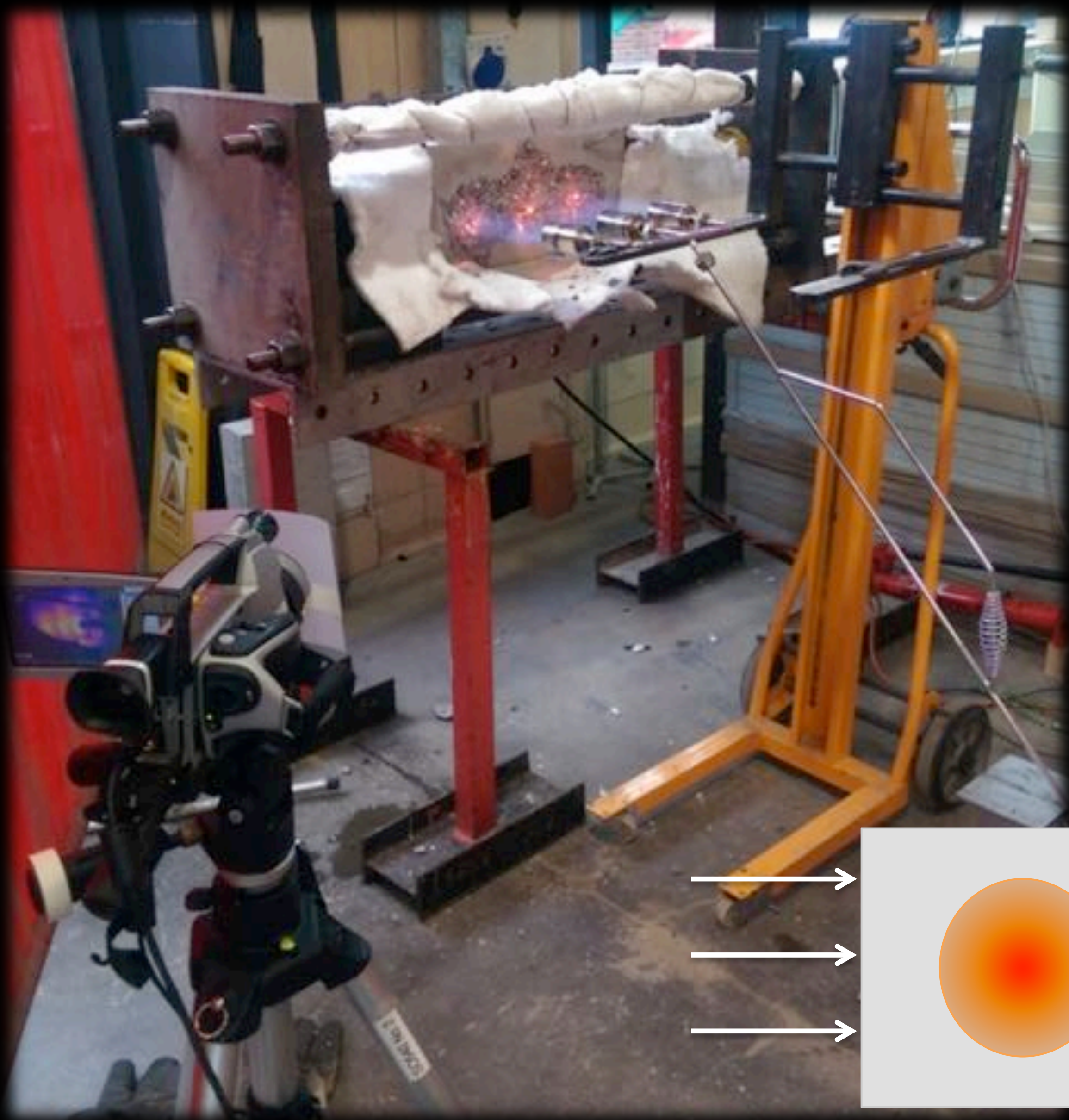
Preliminary Testing

12 cubes

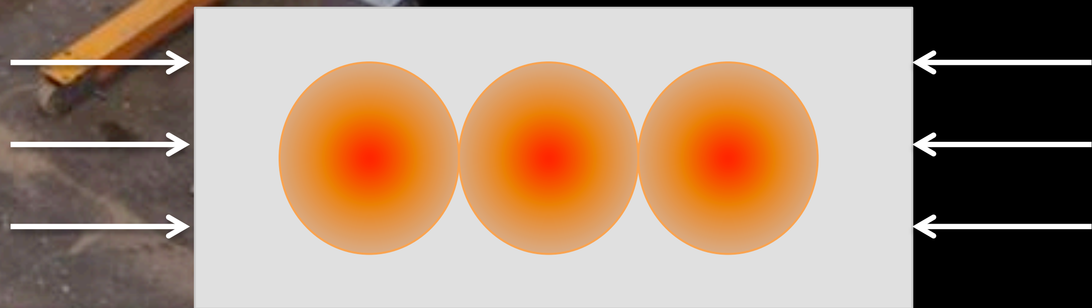
- 6 plain concrete - 2 spalled
- **6 with RTPF (7 kg/m^3) - NO spalling**

Slab Tests – Series 1



12 slabs

- 3 plain concrete
- 3 with 1 kg/m^3 RTPF
- 3 with 2 kg/m^3 RTPF
- 3 with 7 kg/m^3 RTPF



Mix Design

Strength ≈ 70 MPa

PFA	99	kg/m^3
10 mm agg.	1281	kg/m^3
Fine agg.	734	kg/m^3
Water	168	kg/m^3
Superplasticizer	4	kg/m^3
RTPF	1, 2 or 7	kg/m^3

Fibre Processing

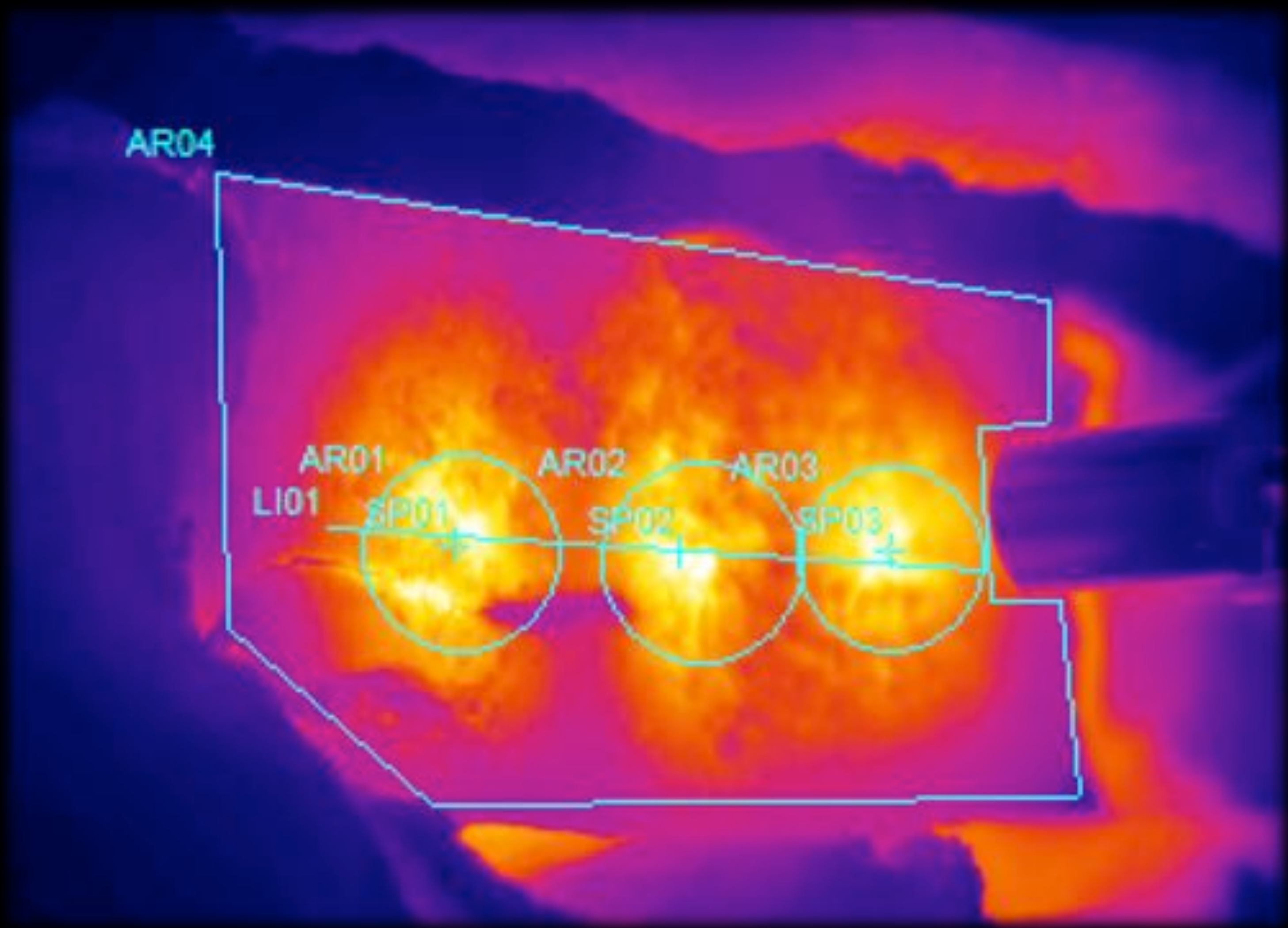
Fibre Processing

Fibre Processing

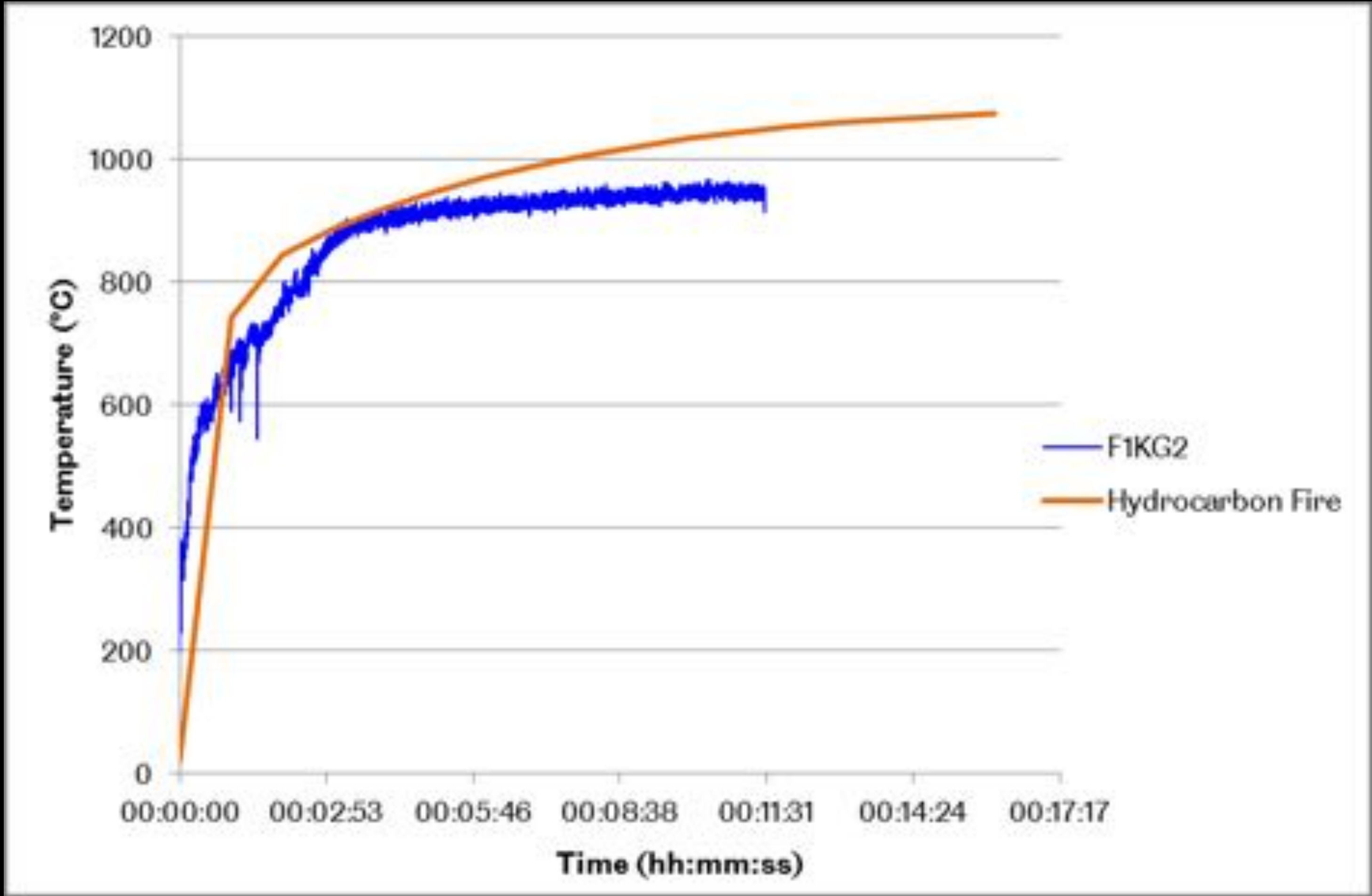
Raw Material | 4.75mm Sieve | 1.18mm Sieve | 0.042 mm Sieve | Collection drawer

Visible Fibres in Wet Concrete

Surface Temperature Measured by Thermal Imaging Camera

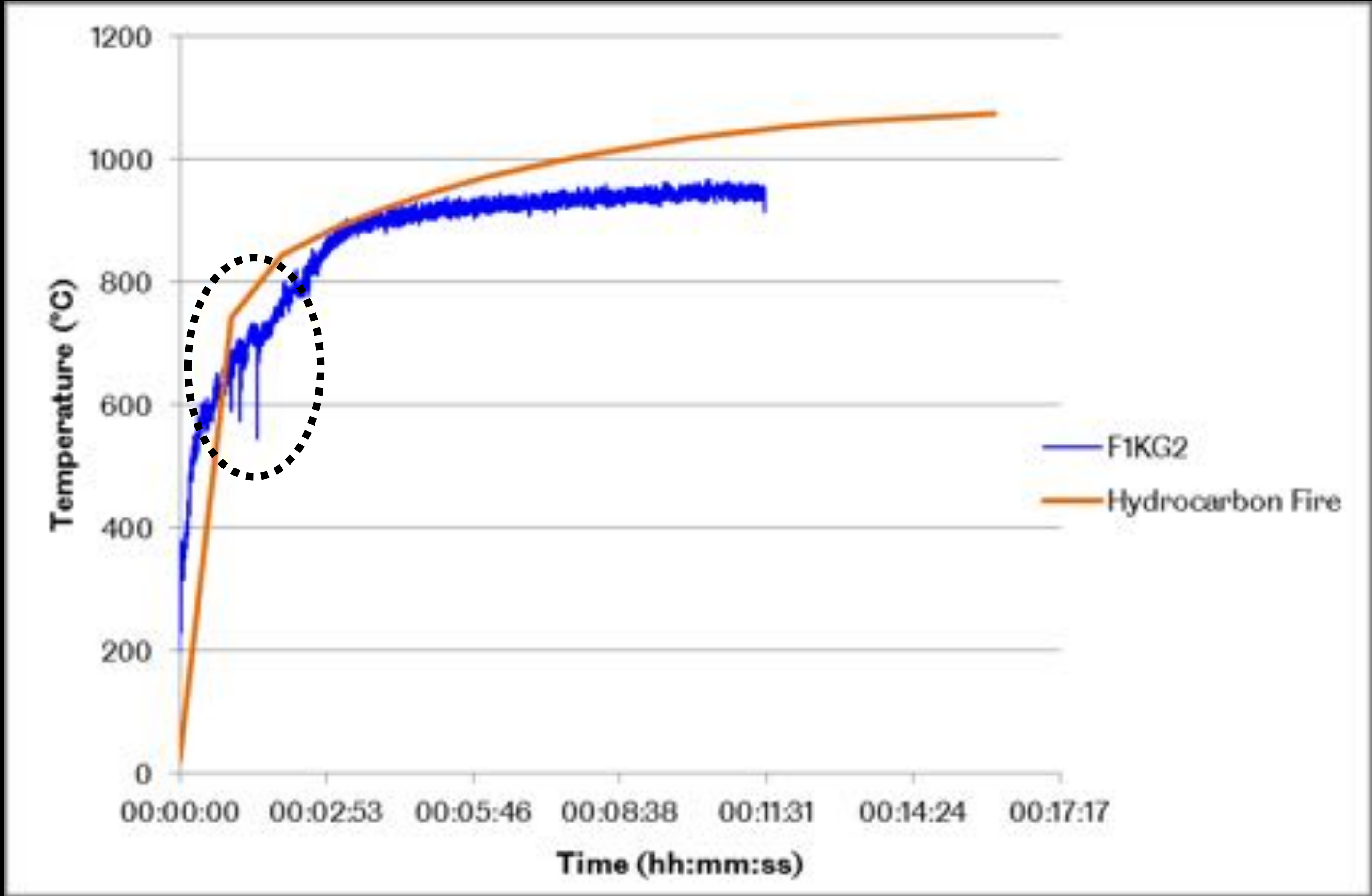


Surface Temperature vs. Hydrocarbon Fire



Slab Tests – During Heating

Surface Temperature vs. Hydrocarbon Fire



Slab Tests – During Heating

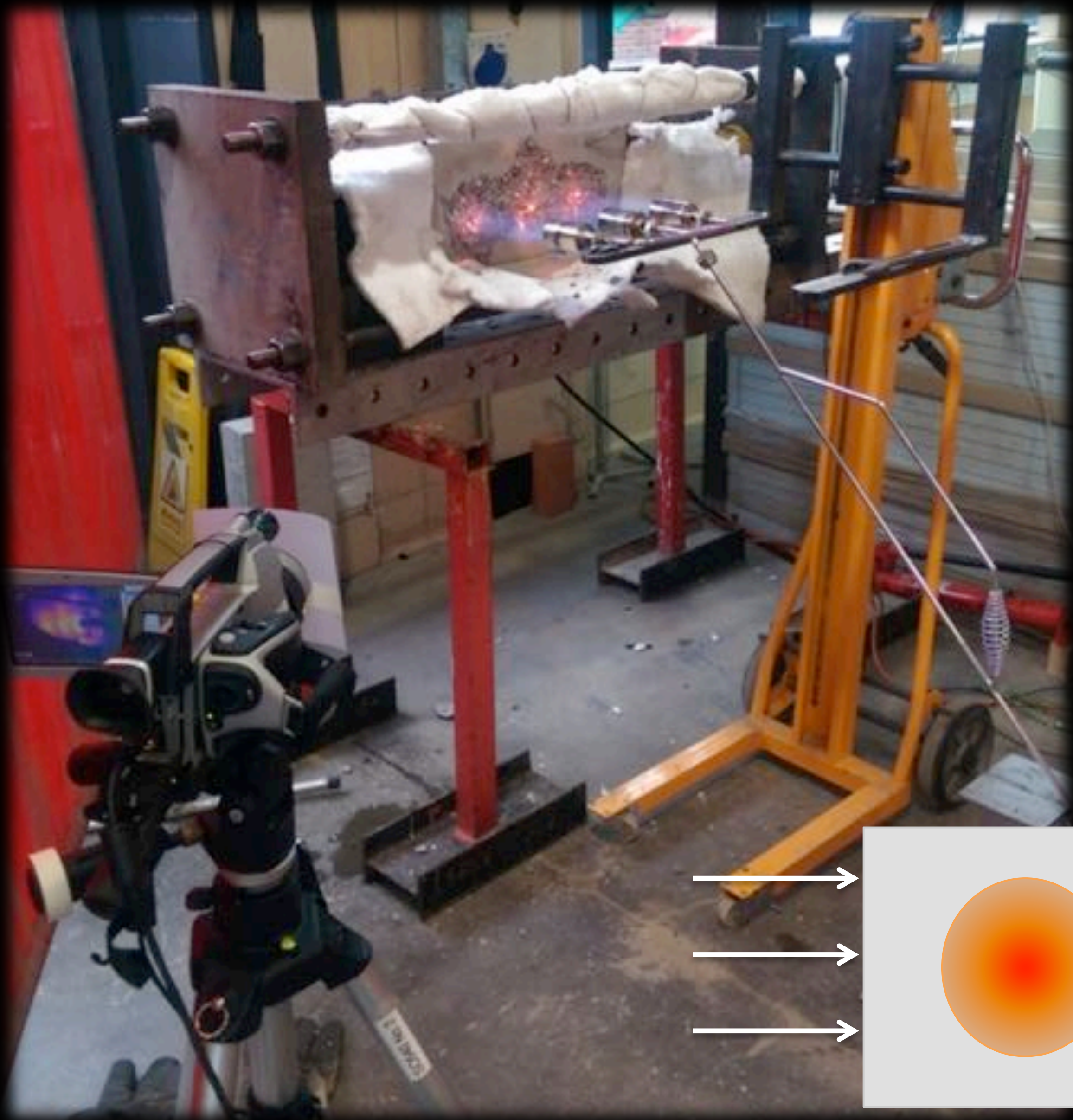
Slab Tests, Series 1 - Aftermath

Plain Concrete	1 kg/m^3 RTPF	2 kg/m^3 RTPF	7 kg/m^3 RTPF
		Damaged specimen prior to fire loading	
			
			

Slab Tests - Series 1

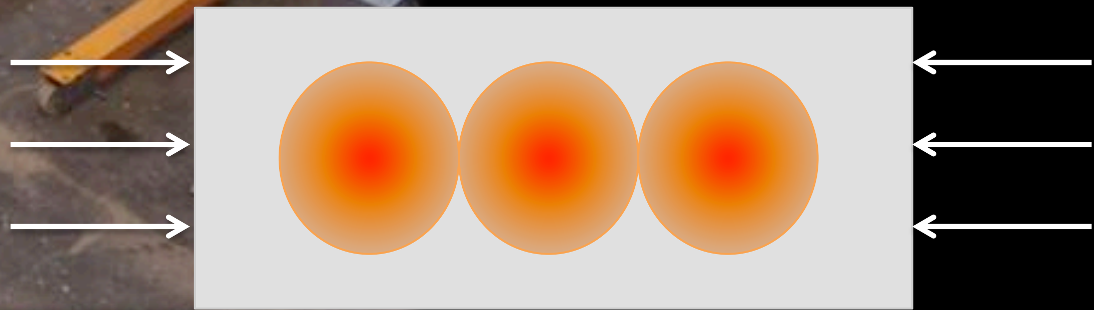
	Spall?	Time Taken to Spall (mm:ss)	Cube Strength (MPa)	Moisture Content (%)
P1	Yes	00:30	69	2.2
P2	No	-	70	2.1
P3	Yes	00:24	68	2.2
F1KG1	No	-	65	2.9
F1KG2	Yes	01:00	68	2.9
F1KG3	Yes	00:49	67	3.2
F2KG1	-	-	68	3.2
F2KG2	No	-	67	2.9
F2KG3	No	-	67	3.0
F7KG1	No	-	65	3.4
F7KG2	No	-	65	3.3
F7KG3	No	-	65	3.3

Slab Tests – Series 2



12 slabs (with steel mesh)

- 3 plain concrete
- 3 with 40 kg/m^3 RTSF
- 3 with 40 kg/m^3 RTSF & 2 kg/m^3 RTPF
- 3 with 40 kg/m^3 RTSF & 5 kg/m^3 RTPF



Reused Tyre Steel Fibre (RTSF)

Slab Tests, Series 2 - Aftermath

Plain Concrete	40 kg/m^3 RTSF	40 kg/m^3 RTSF + 2 kg/m^3 RTPF	40 kg/m^3 RTSF + 5 kg/m^3 RTPF
			
			
			

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Slab Tests, Series 2

	Spall?	Time Taken to Spall (mm:ss)	Cube Strength (MPa)	Moisture Content (%)
P1	Yes	01:12	70	3.0
P2	Yes	00:41	70	3.0
P3	No	-	70	3.0
SF1	No	-	73	2.8
SF2	No	-	73	2.8
SF3	No	-	72	2.8
SF2PF1	Yes	01:07	66	2.7
SF2PF2	No	-	67	2.7
SF2PF3	No	-	66	2.7
SF5PF1	No	-	68	2.7
SF5PF2	No	-	68	2.7
SF5PF3	No	-	68	2.7

Encouraging Results

12 cubes

- 6 plain concrete - 2 spalled
- **6 with RTPF (7 kg/m^3) - NO spalling**

12 slabs (Series 1; no steel mesh)

- 3 plain concrete – 2 spalled
- 3 with low RTPF dose (1 kg/m^3) - 2 spalled
- **6 with medium & high RTPF doses (2 & 7 kg/m^3) - NO spalling**

12 slabs (Series 2; with steel mesh)

- 3 plain concrete – 2 spalled
- **3 with RTST – NO spalling**
- **6 with RTSF-RTPF blends - 1 spalled lightly**

What's Next?

H-TRIS @ University of Edinburgh

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Engineering and Physical Sciences Research Council

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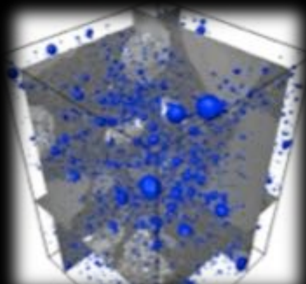
For Detailed Understanding of Spalling

- Phase changing of RTPF at high temperature
- X-Ray CT - Monitor fibre melting, heat-induced microstructure changes (e.g. changes in porosity and pore network structure) & crack/damage formation
- Permeability testing (Oxygen permeability cell)



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STRUCTURES IN FIRE FORUM

Thank you!

Shan-Shan Huang *s.huang@shef.ac.uk*

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