Real Fires/Real Structures

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Real Fires/Real Structures

- What do we design for
- How do concrete structures behave in real fires
- How that behaviour compares to what we design for
- What are the fundamental properties of concrete that enable it to behave in this way

Two Significant fires in concrete buildings

- Grenfell – 23 storey residential building
- Liverpool Arena carpark
- Both retained structural stability through fires that appeared to exceed design requirements.
- What can we learn about the performance of concrete in fire from these examples.
- What can be inferred about the likely performance of other materials.

Building Regulations

- Building Regulation 8 states that Regulation B *"….shall not require anything to be done except for the purpose of securing reasonable standards of health and safety for persons in or about buildings…"*
- Regulation B3 –(1) *"The building shall be designed and constructed so that, in the event of fire, its stability will be maintained for a reasonable period."*

"Reasonable"

- To allow means of escape to be effective
- To resist the spread of fire between buildings
- Approved Document -B adds reducing the danger to people in the vicinity and impact of collapsing structure on other buildings.

Approved Document B2

Do the Fire Resistance periods in AD B meet the outcomes required by the Regulations?

Block of flats, More than 30m high 120 minutes (Sprinklered)

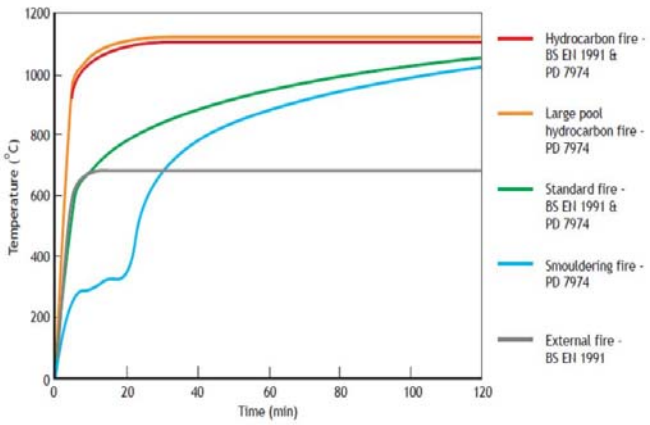
Open sided car park less than 30m high 15 minutes

Table A2 **Minimum periods of fire resistance**

Purpose group of building	Minimum periods of fire resistance (minutes) in a:					
	Basement storey [1] including floor over		Ground or upper storey			
	Depth (m) of a lowest basement		Height (m) of top floor above ground, in a building or separated part of a building			
	More than 10	Not more than 10	Not more than 5	Not more than 18	Not more than 30	More than 30
1. Residential:						
a. Block of flats – not sprinklered	90	60	30*	60**†	90**	Not permitted
– sprinklered	90	60	30*	60**†	90**	120**
b. Institutional	90	60	30*	60	90	120#
c. Other residential	90	60	30*	60	90	120#
2. Office:						
– not sprinklered	90	60	30*	60	90	Not permitted
– sprinklered [2]	60	60	30*	30*	60	120#
3. Shop and commercial:						
– not sprinklered	90	60	60	60	90	Not permitted
– sprinklered [2]	60	60	30*	60	60	120#
4. Assembly and recreation:						
– not sprinklered	90	60	60	60	90	Not permitted
– sprinklered [2]	60	60	30*	60	60	120#
5. Industrial:						
– not sprinklered	120	90	60	90	120	Not permitted
– sprinklered [2]	90	60	30*	60	90	120#
6. Storage and other non-residential:						
a. any building or part not described elsewhere:						
– not sprinklered	120	90	60	90	120	Not permitted
– sprinklered [2]	90	60	30*	60	90	120#
b. car park for light vehicles:						
i. open sided car park [5]	Not applicable	Not applicable	15*+	15*+ [4]	15*+ [4]	60
ii. any other car park	90	60	30*	60	90	120#

What is the Fire Resistance?

- The structural element is tested under a defined temperature time curve
- The temperature time curve does not intend to match reality
- The temperature time curve does not consider any contribution to the fire of the material being tested.
- Not all materials respond the same to variations from the standard fire test.



Grenfell

- Fire started early hours of the 14th June 2017
- Primary fire spread through cladding
- "… the fire was burning at a level of severity that would significantly impact on the fire resistance of the structure for between 9 and 12 hours."

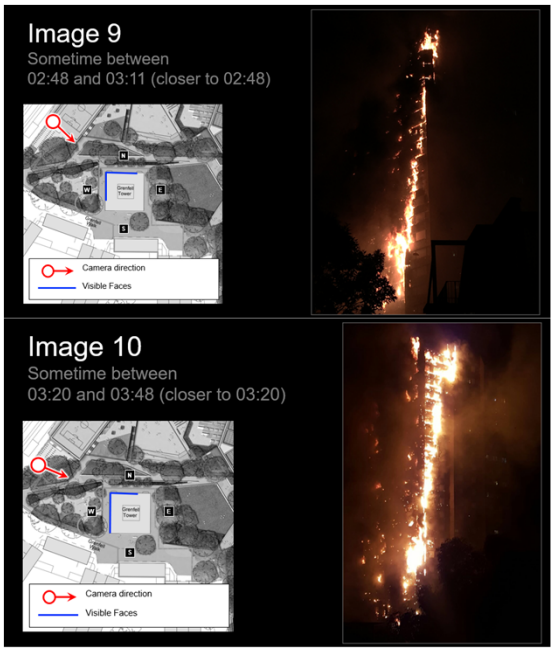
Source: Grenfell Tower Inquiry / Dr Barbara Lane report

"Leaked" Draft BRE report.

- "Had modern standards of fire resistance been provided, in BRE's opinion, given the severity of spalling to concrete including exposure of reinforcing steelwork, it is likely that the tower would have collapsed whether fully or partially"
- Collapse would have further impacted the safety of occupants but also impacted those *about* the building in neighbouring residences, those on the London underground, and the Emergency services.
- This conclusion required testing for a modern concrete building.

Time Equivalence (PD6688-1-2)

- Fire load for a "dwelling"
- Properties of enclosure.
- Ventilation.
- Between 90-120 minutes fire.
- But what about cladding?



Source: Grenfell Tower Inquiry / Professor Luke Bisby Presentation

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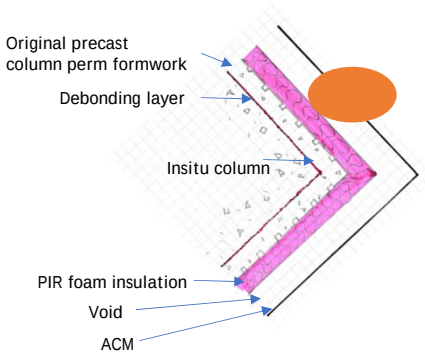
Impact of cladding Fire on Structure



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Fire Resistance to EN1992-1-2.

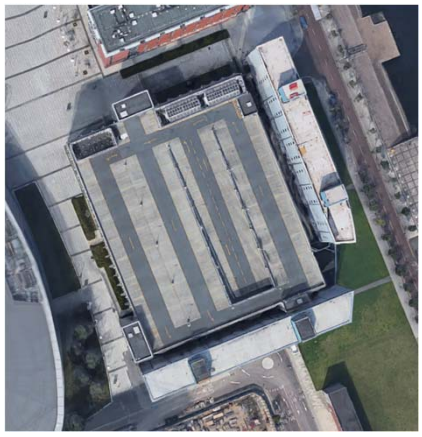
- Slab 200mm thick (50mm Screed) assumed 25mm cover – 90 minutes.
- Core Walls, 200 thick above level 11 - 120 minutes
- Party Walls, 200 thick 120 minutes minimum
- Columns 700x700 – 180 minutes
- Spandrel beams ?? – 90 minutes.

Grenfell

- Structure survived burn out,
- Surprisingly the fire is not predicted to be more sever for a concrete structure than required by current building regs.
- Actual Structure would not satisfy current building regs
- Current design approaches for new concrete buildings would be expected lead to similar/better performance.

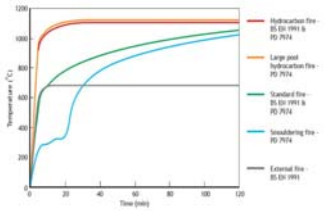
Liverpool Arena car park

- 8 Floor Open Sided Car Park
- Apartment blocks approximately 6m away.
- AD B would require 15mins Fire resistance increasing to 30 minutes for elements forming means of escape.
- Original design understood to be 60 minutes for slabs and 120 minutes to walls.



The Fire

- 1150 Cars destroyed
- Research has shown that multi vehicle fires develop fire in excess of 1100 degrees.
- It has been reported that the fire burnt for 120 mins before the Fire fighters decided the fire was too intense to fight and reverted to protecting adjacent properties. Reports of smoke coming from the building up to 10 hours after the start of the fire.



The Structure

- Fire significantly greater than the design Fire in AD B, and greater than the design of the floor slabs.
- Failure of thin slab between ribs
- Only one local area of Floor failure
- Stair Core walls Protected Stairs
- No Significant collapse that could have endangered adjacent buildings/fire fighters.

Why

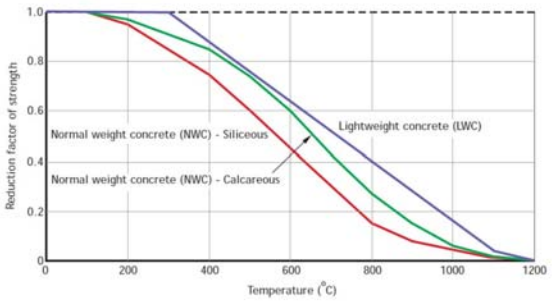
- Inherent fire resistance of concrete:
  - Slab between ribs circa 80mm thick gives 60 mins
  - Rib beam 60 mins
  - Beams >120 mins.
  - Columns >120 mins
  - Core walls 120 mins

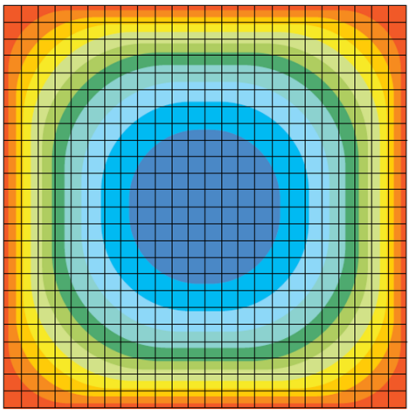
Real fires

- Grenfell burnt for significantly longer than the equivalent standard fire. Given the predicted fire load, temperatures must have been lower than the standard fires
- Liverpool Arena was a rapid and significantly more intense fire than AD B required the structure to be designed for.

Concrete in fire

- Concrete does not burn
- Concrete does not melt
- Concrete does not give off noxious fumes
- Concrete retains its strength
- Concrete provides good insulation against heat





Concrete

Timber

$d_{\text{char,n}} = \beta_n t$

Where
t=time

Cross-laminated timber (CLT) - performance in real fires

"Fire safety design in modern timber buildings", Deeny et al, The Structural Engineer, January 2018.

- Tests on isolated samples of CLT demonstrate traditional charring
- However full scale compartment fires behave very differently.
- Delamination occurs and this contributes more fuel to the fire, the freshly exposed surface then combusts again "cyclical burning".
- The CLT more than doubled the fire load – i.e. the fire load from the structure was as great as that from the timber cribs used to set the fire.
- If the structure is contributing significant fuel to the fire design for burn out becomes problematic.

Fire Resistance

- Given the previous 2 slides is the standard fire test appropriate to compare the performance of Concrete and Timber structures in Fire?

Fire Resistance of Car Parks

- BD 2552 DCLG 2010
  - research in 1968 on pre-1960-s cars showed that fire spread beyond the first car was unlikely.
  - New tests demonstrated ease of fire spread between modern cars.
- Prior to the 1968 car parks had 1 hour resistance, reduction to 15 minutes enabled unprotected steel frame construction.

Fire Resistance of Car Parks

- Do we think that a car park designed for 15 minutes fire resistance in unprotected steelwork would have been appropriate for this car park adjacent to residential blocks?

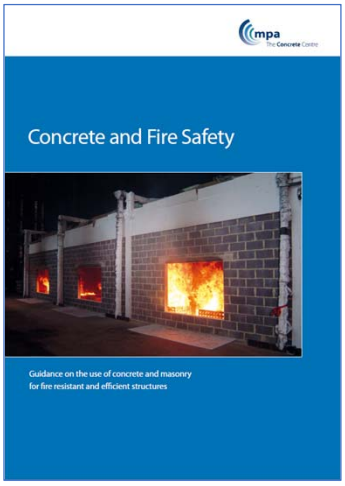
Conclusions

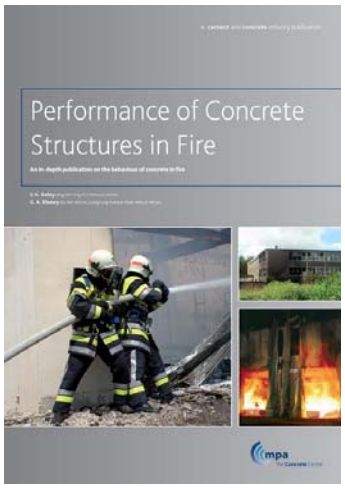
- 2 concrete buildings performed well in severe fires.
- They Survived burn out – if they had collapsed there would have been further very significant implications.
- Burn out should be explicitly considered in AD B where the consequences of collapse are significant.
- Regardless of the above Designers should consider the implications of collapse.

Conclusions

- Fire Resistance requirements of Car Parks requires updating to reflect the make up of modern Cars.
- How do we assess tolerance to fires that are different to the standard fires
- Not clear how other materials would perform but the use of the fire resistance test on its own should be examined.

Resources





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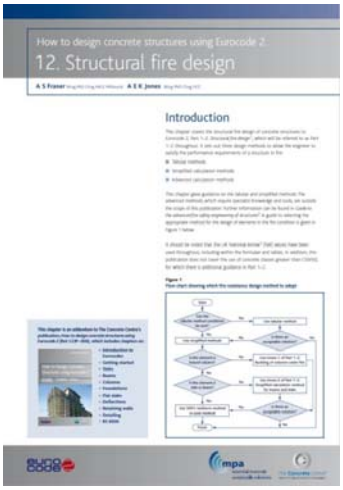

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