Performance of concrete in real fires

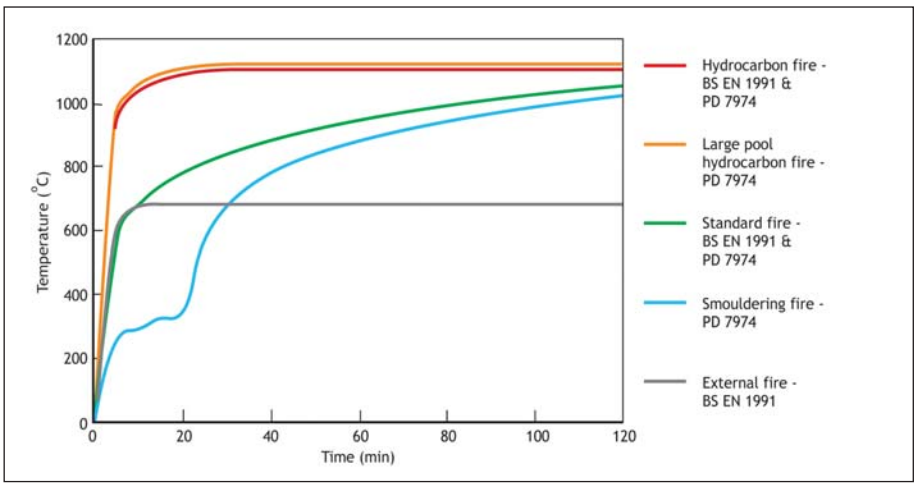
Liverpool Echo Arena car park fire.
(Photos: Merseyside Fire & Rescue Service.)

Over the past two years there have been two very extensive fires in concrete buildings in the UK. Overall, these concrete structures maintained their stability during the fires, although it is likely both buildings will be demolished. ***Tony Jones*** *of* ***MPA–The Concrete Centre*** *looks in further detail at the fires and discusses the performance of the structures. These fires show that concrete's inherent fire performance often exceeds the minimum required by regulation and this is an important factor for the safety of those around buildings that are on fire. But are these regulations adequate?*

In structural design, fire is considered as an 'ultimate limit state', in that the aim is only to avoid collapse for a defined period and there is no requirement for the structure to be serviceable (usable) after the fire.

In addition to structural resistance, concrete elements that form compartments are also required to satisfy integrity and insulation criteria that are, again, defined in terms of time. The periods of time used to define the performance are based on the time in a standard furnace test with a prescribed temperature time – curve.

Real fires do not behave like the standard curve and so the actual performance in real fires may bear no resemblance to the period of resistance calculated on the basis of the standard fire. This means that often concrete structures, which are non-combustible, are fully repairable after fires.



Classification of fire types in relation to temperature, according to BS EN 1991[2] and PD 7974[3].

Grenfell Tower fire

The Grenfell Tower fire was a human tragedy. This makes it even more important that we learn from the events that occurred. While the fire burnt for days, after the first 12 hours, the fires were generally local and associated with local sources of fuel. Even during the first 12 hours, the fire moved through the building, so structural elements generally did not see intense fire for the whole of this period.

According to Approved Document B[1], structural elements within a modern building similar to Grenfell would be required to have a 120-minute fire resistance in the standard test but would also require sprinklers. As stated above, this 120-minute period does not necessarily define the time to failure in a real fire; however, there are methods that enable the fuel load from the contents and the physical properties of a room to be used to give an equivalent fire. Calculations indicate that for Grenfell (excluding the contribution of the cladding and any gas) the equivalent fire was between 90 and 120 minutes. Hence, the requirement of the Approved Document should be sufficient for the structure to withstand burnout of the contents providing there is no contribution to the fire from

Above and below: From a structural stability point of view the Liverpool Echo Arena car park appears to have performed better than expected.

the construction elements themselves. The burning cladding added to that fire load, as would any combustible structure. However, in the case of Grenfell, where much of the additional fuel was burnt outside the building, equating the actual fire to 120 minutes in a standard fire seems reasonable.

The compartment walls and the core walls above level 11 were 200mm thick. Using current design methods this would give a fire resistance of 120 minutes. The slabs, however, were only 200mm thick with a 50mm screed and their design fire resistance would have been 90 minutes based on a reasonable assumption for the cover to the reinforcement. Due to the height of the tower, the columns were significantly bigger than they needed to be for fire and had a fire resistance of 180 minutes. Therefore, the walls are likely to have seen a fire of an equivalent duration to their design resistance and the slabs probably saw a fire in excess of their design resistance. While there was extensive spalling, there was no collapse of any floor plates.

The structural collapse of a building such as Grenfell would have put at risk the lives of anyone remaining in the building, those fighting the fire and those of any residents remaining in the adjacent buildings. A collapse may also have compromised the nearby underground railway. This demonstrates that, while there is rightly a focus on escape from such buildings, the consequences of a structural failure and the impact on those around the building should not be overlooked.

Liverpool Echo Arena car park

The fire at the Liverpool Echo Arena car park on New Year's Eve 2017 destroyed up to 1400 cars[4,5]. Again, the fire burnt for far longer than expected but, in this case, the temperatures would have resembled those in a hydrocarbon fire and therefore would have been much hotter than the standard fire. Research on multi-car fires shows that temperatures in excess of 1100°C can be reached[6]. Approved Document B requires car parks of this type to be designed for 15 minutes resistance in the standard fire. The concrete slab structure was designed for 60 minutes resistance simply because the structural requirements provided this. In addition, the escape cores are understood to have been designed for 120 minutes. No equivalent standard fire duration has been calculated for this fire due to its nature but it is very likely that it was more onerous than a standard 120-minute fire.

The rib slab of the car park was approximately 80mm thick, giving the required 60 minutes fire resistance. There were reports of burning puddles of fuel on the slab and it is perhaps not surprising that this slab failed between ribs in a number of places. However, in general, the ribs – which would also have had only a 60-minute fire rating – performed relatively well, with only one area of local failure reported. The stair core walls were 170mm thick (giving two hours fire performance) and along with their fire doors performed so well that the inside of the stair cores was undamaged.

Not only was the car park designed for a more severe fire than that required by Approved Document B but also from a structural stability point of view it appears to have performed better than expected by current design Codes. There were adjacent residential buildings within 6m of the car park and the consequences of a collapse would have been significant.

Required fire resistance

The Approved Document B bases the structural fire resistance for high-rise residential buildings on the full burnout of the contents. The required fire resistance should include the contribution of fuel from all the construction products used including the structure. Indeed, even the concept of burnout is questionable where a combustible structure is used. In addition, the structural fire resistance should also consider the consequences of collapse, including the impact on surrounding buildings. In the two fires discussed, the inherent fire resistance and non-combustibility of concrete prevented even greater tragedies. ■

References:

1. HM GOVERNMENT. *Fire safety, Vol.1 – Dwelling Houses. Vol.2 – Buildings other than Dwellinghouses*. The Building Regulations 2010 Approved Document B, NBS/RIBA Enterprises, Newcastle Upon Tyne, 2013.
2. BRITISH STANDARDS INSTITUTION, BS EN 1991. *Eurocode 1: Actions on structures. Part 1-2 – General actions. Actions on structures exposed to fire*. BSI, London, 2002.
3. BRITISH STANDARDS INSTITUTION, PD 7974. *Application of fire safety engineering principles to the design of buildings*. Parts 0–7, BSI, London.
4. STANDING COMMITTEE ON STRUCTURAL SAFETY. *Fire in Multi-Storey Car Parks*. SCOSS ALERT, February 2018, available at: *www.structural-safety.org*.
5. NATIONAL FIRE CHIEFS COUNCIL. *Position Statement. Automatic Water Suppression Systems*. Tamworth, February 2018, available at: *www.nationalfirechiefs.org.uk*.
6. BUILDING RESEARCH ESTABLISHMENT, BD 2552. *Fire spread in car parks*. Department for Communities and Local Government, December 2010, available at: *https://bit.ly/2SAp97G*.