Steel's Fire Performance Under Scrutiny

The ability of structural steel to withstand major fires is under scrutiny. The latest findings of the US-based National Institute of Standards and Technology into the collapse of the World Trade Center coupled with the recent collapse in fire of the perimeter steel columns of the Madrid Windsor Torre building question the performance of structural steel in fires in high rise buildings, reports Anna Scothern, Head of Performance at The Concrete Centre.

The collapse of the World Trade Center towers following the terrorist attacks of September 11th 2001 resulted in the death of 2,749 people, over 350 of which were fire fighters and emergency response personnel. The National Institute of Standards and Technology (NIST) has conducted a major building and fire safety investigation into the factors that contributed to the collapse of the buildings. Its findings confound the original belief that one of the main factors of the structural steel failure was the high temperature of the aviation fuel fires. According to NIST, the fire load was due to the office contents and not the aviation fuel, the majority of which was dissipated and vaporised in the initial impact and explosion. It was this impact of the aircraft that triggered the resultant structural steel failure by dislodging the fireproofing. This was followed by the failure of the connections which resulted in external column instability and progressive collapse.

Particularly damning for the steel frame is that, according to NIST, the building design of the towers was robust with sufficient redundancy. So this was a robust steel frame that failed to withstand an office loading fire. American and European clients are now demanding high rise buildings to be designed to survive complete burnout.

Initial investigations into the recent fire that devastated the Windsor Torre in Madrid again highlight the problem of steel's performance in fire. Failure was limited to the perimeter steel frame whereas the internal concrete frame survived complete burnout with no collapse.

The fire which started on the 21st floor of the 32-storey building quickly spread due to lack of fire stops between the curtain wall façade and the concrete floor slabs. Designed and built in the 1970s, the tower was built using traditional methods of design. Extensive refurbishment was under way at the time of the fire. Part of the refurbishment programme was to bring the building's fire standards up to date with the installation of a range of active fire prevention and resistance measures.

Failure of the structure happened with the collapse of the steel perimeter columns which resulted in the floor slabs collapsing as the edge support was taken away. The massive concrete transfer slab at the 20th floor prevented further progressive failure. However, as the debris fell the cladding below was smashed and the fire spread to lower floors.

The height of the tower and extent of the blaze meant that firefighters could only mount a containment operation. The fire was eventually put out after 26 hours. Preliminary investigations have found that thanks to the concrete slab at the 20th floor and the inherent fire resistance of the central concrete columns and core the building remained standing with the structural failure being confined to the perimeter steel section.

The structural concrete performed extremely well demonstrating once again the robustness of traditional methods of construction. However, the intensity of the fire proved too much for the perimeter steel frame. It is understood that sprinklers were being installed but this is an example of what can happen when sprinklers fail to contain the initial fire. American data collected following the WTC fires show that 1 in 6 sprinklers fails in actual fires.

The scrutiny on steel's ability to withstand major fires comes at a time when the performance of reinforced concrete structures during fires has been fully vindicated by the BRE in its report "Fire Safety of Concrete Structures: Background to BS8110 Fire Design". The report found that in many cases the presumed periods of concrete fire resistance is very conservative. The BRE report investigated the background to methods for establishing the fire resistance of reinforced concrete

Windsor Torre during deconstruction.

structures specified to BS8110. In particular, it examined and revisited the original research and test results that underpin the tabulated data.

The research brought together a body of information that covers test results and research carried out over a number of years. With the passing of time there was a concern that much of the important work supporting the development of codes and standards could have been lost if it was not published. It was felt that there was a need to collate and assess all the relevant information to ensure that the important lessons from the past were recorded and used to help define the strategy for a new generation of codes and standards. To this end, the research focused on the original research and tests underpinning the tabulated data in BS8110 in order to assess the relevance of the prescriptive approach to modern concrete construction.

The research found that the experimental results used as data for developing the tabulated approach to BS8110 fully supported the provisions of the code in relation to assumed periods of fire resistance. Furthermore, the research found that these provisions are in many cases very conservative as they are based in the assumption that structural elements are fully stressed at the fire limit state and take into account the spalling characteristics of concrete.

Not only does the BRE report clearly demonstrate that evidence from the concrete performance in real fires over a number of years prove that the tabular approach has been effective. It also suggested that the conservatism of the existing data means that further research would potentially result in even greater construction and cost economies for concrete structures.

The prescriptive approach of individual elements of BS8110 will continue to be popular despite the increasing adoption of the whole building performance-based approach of the Eurocodes. The research carried out by BRE is important not only because it fully validates the fire resistance of concrete by highlighting the conservatism of the prescriptive approach but also because by doing so it proves the relevance of the historic tabulated data for future high rise and low rise buildings.

The concrete industry is not resting on its laurels. Research continues across Europe, America and Japan to develop bespoke concrete mixes able to withstand the most intense fires, for example those experienced in tunnels where the temperature can reach 1350°C. Design guidance is being developed for the new generation of fire Eurocodes and research continues to develop a better understanding of the robustness of concrete buildings in fire.