ArupFire

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LONG SPAN COMPOSITE BEAMS SUBJECTED TO FIRE

Effects of Fire on Lateral Stability

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INTRODUCTION

Analysis of highly complex structural forms in fire can bring value to a design framework and highlight potential design issues.

As part of a commercial analysis of a high-rise office building a lateral buckling failure mechanism was observed in the long span cellular floor beams. This type of failure had not been observed in similar buildings and hence a parametric study was initiated to discover the root cause.

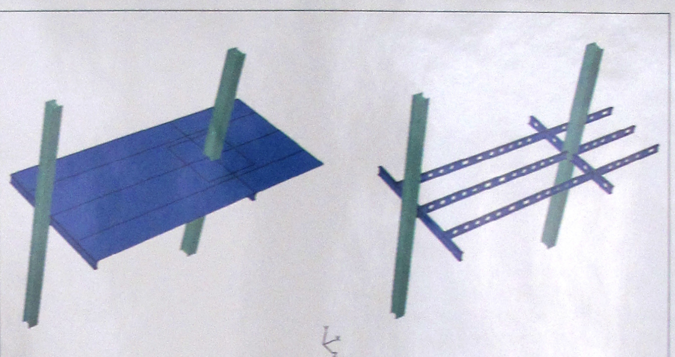
BACKGROUND

This poster demonstrates a significant failure mechanism identified through advanced analysis.

The building under consideration is a proposed high-rise office tower in the City of London. The study concentrated on a portion of the floor system, chosen as a representative worst case for detailed investigation.

A general reduction in structural fire protection from 2 hours to 90 minutes had already been agreed and this study was designed to investigate the possibility of intermediate secondary beams being left unprotected.

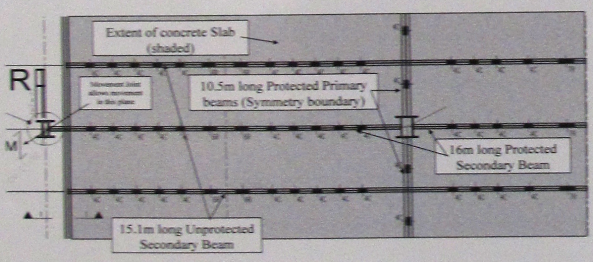
Provided that structural robustness can be proven, this kind of layout can reduce maintenance needs and increase overall building sustainability by reducing the provision of energy intensive materials. A significant cost saving can also be realised by reducing labour and material needs



Model Considered (with and without slab)

Structural Fire Protection

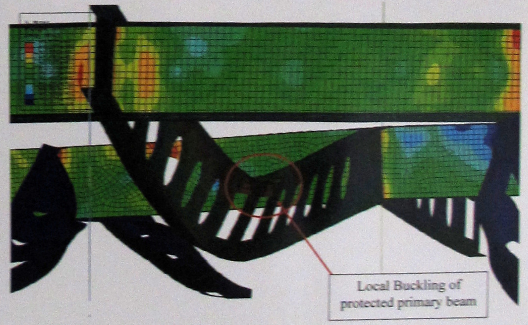
The structural fire analysis of the model was primarily intended to assess the robustness of the floor system assuming a reduced level of structural fire protection compared to code requirements. In this case, primary and secondary beams attached to columns were provided with 90 minute protection while intermediate secondary beams were left unprotected.
It has been shown in a number of recent analyses of tall office buildings that this type of fire protection layout is a safe and efficient alternative to “code compliant” generic solutions. The analysis presented here was conducted in order to gain an understanding of the response of the building to fire under this engineered structural fire protection scheme. Such detailed knowledge of the building would not be gained from merely applying standard fire protection. The analysis utilized cutting edge modelling techniques and the latest **ABAQUS FEM** software.



Structural Response

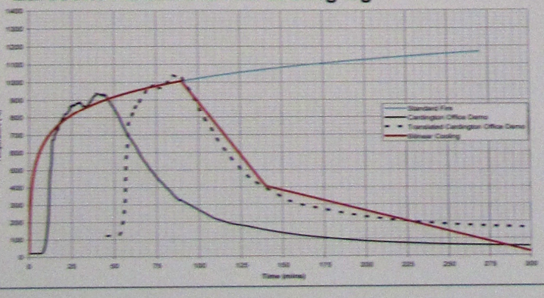
The primary response identified by the analysis is the significant lateral deformation of the protected primary beam, as indicated below which shows the deformed shape of the beam at the onset of failure. Local buckling of the top flange and upper web are also evident.

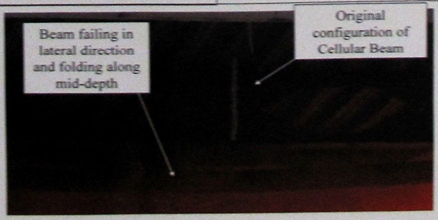
This behaviour occurred towards the end of the heating phase, starting at approximately 45 mins into the design fire. At this point, the temperature of the bottom flange was approximately 375°C while the web was at 400°C. This temperature is significantly lower than the temperature that a beam would normally be expected to fail (Usually 620oC). The resulted in twisting of the entire protected beam which led to failure of the connections between the beams and the megaframe (external perimeter) column, and subsequently collapse of the floor system.



Design Fire

- Severe full floor involvement
- Bi-linear cooling considered more realistic than Eurocode Parametric Fire cooling leg





A similar mechanism identified during the Mokrsko structural fire test

Parametric Study

Model	Parameter	Detail Changed	Result
1*	Web thickness	Protected secondary beam web thickness increased from 12 to 14mm	Fails
2*	Increased protection to steel	Thickness of fire protection on protected secondary beams increased by 10%	Fails
3	Holes in web	Central rectangular holed filled	Fails
4	Top flange temperature	Trapezoidal Deck voids assumed filled	Fails
5	Rebar location	Rebar moved to slab mid-depth to reduce temperatures	Fails
6	Secondary beam location	Unprotected secondary beams moved to equalize slab spans to 3.5m each.	Fails
7	Mid-span stiffener	Stiffener included at the mid-span of the protected secondary beam.	Fails
8	**Bottom flange width**	**Width increased from 200mm to 300mm (flange thickness reduced to 16mm to maintain original overall section area)**	**Stability maintained**

Note: * - The detail altered was incorporated in all following models.

OUTCOME & CONCLUSIONS

Detailed structural fire analysis can provide significant value with regard to robustness in the design of unique buildings.

A parametric study was conducted on a section of a unique high-rise office building that was indicating a lateral failure mechanism. The analysis indicated that the root cause of the instability was related to the depth of the sections combined with the relatively narrow flanges.