Design for Extreme Events – Progressive Collapse

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Summary

The current position concerning design against progressive collapse is summarised and the need to move from a prescriptive approach to a quantitative analytical framework is explained. Necessary and desirable features of such a framework are presented. Reference is made to an approach currently under development at Imperial College London that includes all of these features.

Keywords: Buildings, Failure, Progressive Collapse, Robustness, Structural Design

1 Introduction

The Institution of Structural Engineers defines Structural Engineering as:

- "Structural Engineering is the science and art of designing and making, with economy and elegance, buildings, bridges, frameworks and other similar structures so that they safely resist the forces to which they might be subjected".

Three features are highlighted:

- Safety
- Economy
- Elegance

Of these the prime concern must be the first – only the Structural Engineer has the specific knowledge needed to ensure that structures are designed to fulfil the required strength criteria; an unsafe structure, no matter how economical in construction or how elegant in appearance, is clearly unacceptable.

Within the Limit States Design Framework used almost universally nowadays safety is normally related to the Ultimate Limit State i.e. conditions with a suitably small probability of being attained during the life of the structure. The type of structure, the variability of the loading, quality of the construction, confidence in understanding of the structural behaviour etc, all influence the exact way in which the various design requirements are set up and the methods used to effect the design process.

Occasionally, however, a structure will be subject to events outside the normal expectation, or, more particularly, beyond the normally defined set of design requirements. Major earthquakes, bomb blasts or other terrorist actions and accidental explosions are all examples of such an event. One particular consequence of an event of this type is that it may trigger a progressive collapse of the structure. For the purposes of this paper progressive collapse is defined as failure of the whole or a substantial part of the structure as a direct result of some initial local damage. Turning this

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around, structures should be capable of absorbing some limited damage without this triggering consequences that are disproportionate to the initial event. Well known examples of progressive collapse are the Ronan Point failure of one corner of a system built apartment block in London some 40 years ago that was initiated by a gas explosion (1) and the complete collapse of the Twin Towers following aircraft impacts on 9/11 (2).

This paper will review approaches to progressive collapse currently employed in design, will compare these with both the underlying mechanics of the phenomenon and the approach to "conventional" design, will suggest that more fundamental treatments of progressive collapse are required and will assess the extent to which recent research is addressing these issues.

2 Conclusions

The need to align design against progressive collapse more closely with the philosophy and procedures utilised in conventional structural design has been discussed. Necessary and desirable features for a quantitative framework for assessment, intended to replace the current prescriptive approaches, have been identified. The essence of the approach currently being developed at Imperial College London, that addresses all of these requirements, has been presented as one way of making the transition.

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