Fire Resistance and Repair of Earthquake Damaged Structures

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Mission

To develop a comprehensive earthquake and fire research programme based on exploiting the complementary strengths of the collaborating institutions.

http://www.see.ed.ac.uk/fire/UKIERI.html

With increasing urbanization and industrialization earthquakes represent an ever greater risk to life, livelihoods and to the sustainability of India's rapid development. In built-up areas, especially major cities with tall buildings and extensive gas mains, this risk is compounded by post earthquake fires. The consequences of the fires can be more severe than the original seismic event (e.g. San Francisco 1906, Great Kanto 1923, Kobe 1995) as the fighting of fires may become impossible (given over-stretched emergency responders and damaged water mains). This project will be the first international effort towards initiating this important research in the country.

Objectives

- Developing a detailed understanding of the mechanics of the response of earthquake damaged structures (primarily reinforced concrete frames) subjected to fire (through small and large scale testing and developing computational models)
- Understanding the mechanical behavior of structural materials subjected to elevated temperature after having sustained local mechanical damage beyond usual yield and fracture limits and to develop constitutive laws for programming into computational models (through lab testing of structural materials and computational models)

- Developing mathematical models for determining the reliability of structural components and structures subjected to compound seismic and fire loading, which account for the uncertainties associated with the loading and damage estimation, to enable realistic quantification of performance
- Proposing design and retrofitting alternatives using modern materials and methods

Work packages

1. Large scale or "global" behavior of whole structures or sub-assemblies

Research on the behavior of real buildings in fire has highlighted that structural resistance to fire depends strongly on the level of redundancy (availability of multiple load paths). Therefore structural fire resistance cannot reliably be estimated by only assessing the resistance of individual structural members to fire, as is broadly the current practice internationally. In most cases this practice leads to safe designs. However, as the design methods are not based on true behavior and provide resistance only by "coincidence", which of course is neither quantifiable nor reliable (as dramatically illustrated by the catastrophic collapses of 3 tall buildings on September 11, 2001 in the terrorist attack on the WTC complex New York). This is the situation regarding fire resistance of "undamaged structures". There is no current guidance at all on fire resistance of earthquake damaged structures. This project will help extend the seismic design philosophy which dictates that "building structures be able to resist major earthquakes without collapse but with some structural damage", to fire, and to understand how this modifies global behavior and what new mechanisms of structural failure or collapse are found, thence enabling development of new design methodologies and alternatives to prevent them.

2. Smaller scale or "local" behavior at the level of material and structural connections

Global structural collapses may represent a systemic failure of the whole structure resulting from a truly "global" mechanism however this usually represents an upper-bound. Often the roots of failure lie in "progressive" propagation of "local" failure initiated at the material or joint/connection level. In seismically active zones structural details and joints or connections are designed to be sufficiently ductile so that despite damage, structural continuity is maintained during deformation cycles in order to avoid the initiation of progressive collapse. In this project we will consider the effect of fire on the damaged material (reinforced concrete & steel) and joints/connections. This will produce constitutive models for damaged material and local models of connections at elevated temperatures to enable more accurate analyses of global behavior and collapse mechanisms.

3. Analysis of uncertainty due to random nature of loads and resistance to quantify the reliability of structural designs for resistance to compound earthquake and fire loading

Methods for time variant reliability analysis based on intelligent Monte Carlo simulations, extreme value theory, and response surface models will be combined with nonlinear finite element modeling of structural behavior under combined effects of earthquake and fire loads. The treatment of fire induced loads and models for partially damaged structures within a probabilistic framework calls for development of new modeling strategies.

4. Assessment of design alternatives taking advantage of modern repair and strengthening technologies to provide the required structural resistance

The feasibility of advanced FRP (fibre-reinforced plastic) composites and cement based systems will be investigated for repair of earthquake and fire damaged structures and as a retrofit option for structures assessed to have inadequate resistance. FRP will need to be fire protected if future fire resistance is also required, cement based repair systems containing polypropylene and steel fibres are expected to be attractive in this context.