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STUDY OF THE BEHAVIOUR OF STEEL AND COMPOSITE STRUCTURES IN FIRE-AFTER-EARTHQUAKE EVENTS

Summary

The objective of the project is the study of the behaviour of steel structures in the case of fire after seismic events. Normally, the design of structures according to the current codes is performed independently for the seismic and thermal actions. Many theoretical and experimental studies have been published in the last 20 years about the seismic behaviour of structures. The scientific knowledge in this field has been incorporated in the recent seismic regulations in Europe and elsewhere. Moreover, considerable research effort has been devoted during the same period to the study of the behaviour of steel and composite structures at elevated temperatures. Recently, the research interest has been extended beyond the behaviour of materials and structural members at elevated temperatures, to the overall behaviour of real structures. To this purpose, large-scale experiments have been performed at European level (e.g. the Cardington full-scale building fire tests). These studies have led to the identification of additional mechanisms through which the structures may resist the design loads at elevated temperatures. Much of this research has been consolidated in the latest versions of design rules against fire (see part 1.2 of all the structural Eurocodes).

Despite the above mentioned progress in the research on both earthquake and fire response, the research on the combined effect of seismic and thermal actions on structures started only very recently. The damage of fire resulting after an earthquake event has been witnessed by the international community after the major earthquakes in recent years (Northridge 1994, Kobe 1995, Chile 2010, Tohoku 2011), being not covered by any design code. More specifically, fire design codes make the assumption that at the beginning of the fire event, the structure is intact and that all the measures for fireproofing are active (fire coatings, paints, sprinkler systems, etc.). However, this assumption is not valid when the structures are damaged by seismic events, which are followed by the outbreak of fire. Earthquakes may cause damage to structural and non-structural elements. For the structural components damage means that when the fire event occurs, the structure will be in a completely different state from that which has been considered in the design against fire. On the other hand, damage to non-structural elements due to earthquake, may limit the resistance of structures in fire (e.g. cracking of fireproof cladding, peeling of fireproof painting due to

intense plastic deformation, sprinkler failure etc). Moreover, seismic damage significantly affects the conditions for growth and spread of fire (e.g. breakage of windows allowing free air inflow, blocking of fireproof doors, etc).

The main problem that has to be addressed in this project is the assessment of the structural behaviour at elevated temperatures when the design starting point is a state of permanent damage (permanent deformations, brittle fracture, damage to non-structural members and to fire protection systems), that are supposed to derive from seismic loads. It is expected that the resistance of structures in fire will be reduced, depending on the level of damage caused by the earthquake. For this particular reason, it is appropriate to take into account more than one design earthquakes, in order to link the reduction of the fire resistance to the degree of expected damage and to the return period of design earthquakes. From the above, it is clear that the problem should be formulated within a performance based design framework. The first step of the project would be the study of temperatures resulting in structural members under the ISO fire curve.

The next step is to establish different characteristic fire scenarios for earthquake-damaged structures. Fire is a complex phenomenon that is influenced by many parameters. Some basic parameters that influence the temperature distribution and spread of fire are the geometry of the fire compartment, the fire load and the ventilation conditions. Thus, the investigations will be limited to structures where most parameters are well-defined. One example is office buildings or industrial buildings, where a lot of normative regulations result in similar buildings. To determine the fire scenarios, zone models (such as Cfast or Ozone) will be used. Another important goal of this project is the simulation of the natural fire through computational fluid mechanics in order to take more realistic results about the temperature distribution in the structural members. The simulation will be conducted through FDS. Fluid Dynamics Simulator is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires. Finally, a parametric model will be established to vary the most important parameters within the previously defined range. This will include the heat release rate, geometry of the fire compartment and ventilation conditions (opening of doors and smoke extractors as well as the breaking of windows).

Then, a number of structural models covering all seismic-resistant typologies and designed according to the current seismic and fire regulations will be analysed through non-linear methodology considering different scenarios of fire and earthquake, in order to identify different levels of damage to structural and non-structural elements. The project will finally suggest specific measures through which the structure will be able to survive the combination of both actions. These measures will be codified and design guides for practical applications will be developed.

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