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Robustness of timber structures in seismic areas

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ABSTRACT

Major similarities between robustness assessment and seismic design exist, and significant information can be brought from seismic design to robustness design. As will be discussed, although some methods and limitations considered in seismic design can improve robustness, the capacity of the structure to sustain limited damage without disproportionate effects is significantly more complex. In fact, seismic design can either improve or reduce the resistance of structures to unforeseeable events, depending on the structural type, triggering event, structural material, among others. Based on a case study, the influence of redundancy and ductility on the seismic behavior and robustness of a long-span timber structure is assessed.

1. Introduction

Some of the properties sought in the seismic design of buildings are also considered fundamental to guarantee structural robustness. Moreover, some key concepts are common to both seismic and robustness design. In fact, both analyses consider events with a very small probability of occurrence, and consequently, a significant level of damage is admissible. As very rare events, in both cases, the actions are extremely hard to quantify. The acceptance of limited damage requires a system based analysis of structures, rather than an element by element methodology, as employed for other load cases.

As for robustness analysis, in seismic design the main objective is to guarantee that the structure survives an earthquake, without extensive damage. In the case of seismic design, this is achieved by guaranteeing the dissipation of energy through plastic hinges distributed in the structure. For this to be possible, some key properties must be assured, in particular ductility and redundancy.

The same properties could be fundamental in robustness design, as a structure can only sustain significant damage if capable of distributing stresses to parts of the structure unaffected by the triggering event.

Timber is often used for primary load-bearing elements in single storey long-span structures for public buildings and arenas, where severe consequences can be expected if one or more of the primary load bearing elements fail. The structural system used for these structures consists of main frames, secondary elements and bracing elements. The main frame, composed by columns and beams, can be seen as key elements in the system and should be designed with high safety against failure and under strict quality control. The main frames may sometimes be designed with moment resisting joints between columns and beams. Scenarios, where one or more of these key elements fail should be considered at least for high consequence buildings. Two alternative strategies may be applied: isolation of collapsing sections and, provision of alternate load paths [1]. The first one is relatively straightforward to provide by deliberately designing the secondary structural system to be less strong and stiff. Alternatively, the secondary structural system and the bracing system can be designed so that loss of capacity in the main frame does not lead to the collapse. A case study has been selected aiming to assess the consequences of these two different strategies, in particular, under seismic loads.

2. Earthquake design

Similarly to other seismic design codes, the EN 1998-1:2004 [2] state that, in order to obtain structures resistant to earthquakes, the following aspects must be considered: structural simplicity; uniformity, symmetry and redundancy; bi-directional resistance and stiffness; torsional resistance and stiffness; diaphragmatic behavior at the storey level; and, adequate foundations.

A clear and direct path for the transmission of the seismic forces is available in simple structures, while uniformity allows the inertial forces created in the distributed masses of the building to be transmitted via short and direct paths. Redundancy allows a more favorable redistribution of action effects and widespread energy dissipation across the entire structure. A basic goal of a seismic design is the establishment of diaphragmatic action of the horizontal load bearing systems and the connection (anchorage of the diaphragms) to the vertical load bearing components (walls or

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