HORIZON 2020

Novel braced frame for earthquake resilience

Sprawozdania

Informacje na temat projektu

CBF-EQRES

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Strona internetowa projektu

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Periodic Reporting for period 1 - CBF-EQRES (Novel braced frame for earthquake resilience)

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Podsumowanie kontekstu i ogólnych celów projektu

The project has addressed the problem of fast repair of buildings after a strong earthquake. It also addressed the problem of progressive collapse in steel buildings when a vertical element, such as a column, is suddenly lost, for example due to explosion, accidental impact etc.

Steel buildings designed according to current Codes of Practice (for example, Eurocode 8) experience extended damage after an earthquake. This damage is often difficult to repair. As a result there are significant socio-economic losses due to the repair cost and excessive downtime. There is also the major problem of residual deformations, and if they are significant, it may be financially more viable to demolish a building rather than repair it after a strong seismic event. Progressive collapse of a building due to a loss of column is a rare event but it may have devastating consequences, including numerous fatalities. It is therefore important to design buildings that are able to recover fast from strong earthquakes, i.e. with increased resilience, and to mitigate the consequences of progressive collapse.

Objectives:
1. To develop a seismic resistant steel frame that can drastically reduce the residual deformations of a steel frame after a strong seismic event, and to limit damage to easily-replaceable structural elements, the so-called sacrificial devices.
2. To develop novel structural details to design or retrofit vulnerable steel beam-column joints for increased safety against progressive collapse due to an abnormal event, such as a sudden column removal.
3. To design and assess, both experimentally and numerically, the structural behaviour of the sacrificial devices, and fine-tune their properties to meet the design targets.
4. To evaluate the seismic performance and resilience of concentrically braced frames equipped with such devices.
5. To evaluate the progressive collapse resistance of nominally-pinned joints equipped with the above novel structural details for progressive collapse mitigation.

Prace wykonane od początku projektu do końca okresu sprawozdawczego oraz najważniejsze dotychczasowe rezultaty

R) RESEARCH ACTIVITIES

1. A novel steel concentrically-braced frame (CBF) configuration was proposed. The novel typology makes use of stainless steel pins (SSPs) as sacrificial devices, and their inherent material properties in order to reduce the residual deformations of a building after an earthquake. The SSPs are placed in series with braces, and they are bolted so that they can easily be replaced in case they are damaged. In addition, the inherent high post-yield stiffness of the devices reduces substantially the residual displacements of a building after an earthquake.
2. Selection of a realistic prototype multi-storey building to serve a a case-study building. The building was designed using the proposed CBF configuration.
3. Experimental evaluation of the SSPs, under both cyclic and monotonic loading (component tests). The component tests confirmed that the SSPs have excellent cyclic fracture capacity, (relevant to earthquake loading) and are able to sustain many cycles before fracturing. In addition, the SSPs have excellent deformation and fracture characteristics under excessive monotonic loading (relevant to loss of column loading).
4. Based on the results of the component tests, a second novel configuration was proposed, this time

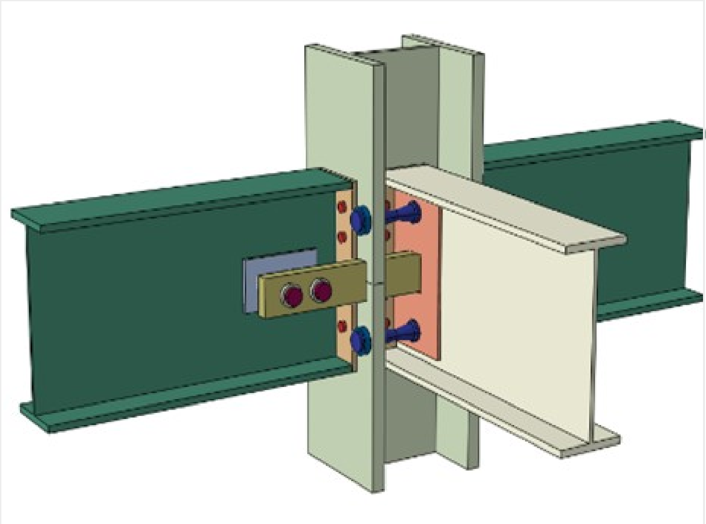
with the objective to mitigate the devastating consequences of progressive collapse. The second novel typology makes use of the SSPs, taking into account their excellent monotonic displacement capacity. The proposed configuration places the SSPs strategically so that they do not interfere with the initial design of a building due to ordinary loads (e.g. permanent and wind loads). In such way, the design of a building for gravity loads do not interfere with the design of the building for progressive collapse mitigation, thus the traditional design is not complicated.
5. The second novel typology was evaluated experimentally in the Structures Lab. Static and dynamic tests simulating a sudden loss of column scenario were conducted. The results demonstrated the effectiveness of the proposed joint to mitigate the devastating consequences of progressive collapse.
6. The seismic performance of the CBF was evaluated using sophisticated numerical simulations. The prototype building, equipped with the novel seismic details, was modelled in the OpenSEES software. Nonlinear dynamic analyses showed that the proposed seismic-resistant frame can achieve high resilience standards after a strong earthquake.
7. The robust joint was further studied using advanced numerical simulations. In particular, the static and dynamic tests have been both modelled in the Abaqus finite element software and the models were able to reproduce the experimental behaviour with good accuracy. A series of parametric analyses were then performed to generalise the results to a wider range of geometris and loading scenaria.

Innowacyjność oraz oczekiwany potencjalny wpływ (w tym dotychczasowe znaczenie społeczno-gospodarcze i szersze implikacje społeczne projektu)

Resilience after a strong seismic event is a modern topic in earthquake engineering. The project has proposed and validated, both experimentally and numerically, a novel structural typology with cost-effective structural details that limit the damage to a reparable level and, thus, permitting a rapid return to usual occupation of a steel frame that has experienced a strong earthquake. Furthermore, solutions to the problem of vulnerability of steel joints to progressive collapse have been limited so far to strengthening of conventional joints. This project goes beyond the state of the art in progressive collapse mitigation by proposing and validating, both experimentally and numerically, a novel joint configuration that can efficiently arrest progressive collapse in steel buildings, does not interfere with the conventional joint design, and can be applied to both new designs and to retrofitting existing vulnerable buildings.

The underpinning body of research resulted in a set of design guidelines for the proposed configurations for multi-hazard mitigation in steel buildings, backed up by experimental evidence and advanced numerical analyses. The results are or will be published to international high-impact scientific journals, and will be presented in international conferences.

Potential codification of the results and implementation of the proposed typologies in practice will have the socio-economic impacts of avoiding fatalities in the case of an extreme event such as a sudden loss of column, minimising financial losses after a rare earthquake, and creating a more sustainable construction sector by avoiding building demolition.



The proposed joint for progressive collapse mitigation

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