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Seismic behaviour of Seismic-Resilient Steel Moment-Resisting Frames equipped with Damage-Free Self-Centring Column Bases

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Abstract

Recent destructive seismic events have underlined the need for increasing research efforts devoted to the development of innovative seismic-resilient structures able to reduce seismic-induced direct and indirect losses. For steel Moment Resisting Frames (MRFs), the inclusion of Friction Devices (FDs) in Beam-to-column Joints (BCJs) has been widely investigated as a viable solution to provide both high local ductility and energy dissipation capacity. However, it has been demonstrated that, although using FDs efficiently protects the BCJs' components from local damage, global damage can still be observed in significant post-earthquake residual drifts. This issue has been tackled by several research works, introducing elastic restoring forces able to regulate the structure's Self-Centring (SC) capability, having the main advantage of ensuring both the energy dissipation capacity and the SC behaviour of the structure.

However, although considerable attention has been given to define innovative technologies for BCJs, further research is still needed to define innovative configurations for Column Bases (CBs), which play a fundamental role in the seismic performance of steel MRFs, and their protection is paramount for the achievement of the structural resilience. In this context, an innovative Damage-Free Self-Centring Column Base (SC-CB) has been recently experimentally developed at the University of Salerno. It consists of a rocking column splice joint where a combination of FDs and PT bars with disk springs dissipates the seismic energy and promotes the connection's SC behaviour. Component tests of an isolated SC-CB specimen showed a good and stable flag-shaped hysteretic behaviour, demonstrating the advantages of this technology in terms of improved SC and energy dissipation capabilities.

The present thesis investigates the seismic behaviour of seismic-resilient steel MRFs equipped with SC-CBs through different methodologies. Firstly, the thesis proposes a robust design methodology of the SC-CB based on analytical formulations, discussing its assumptions and limitations. Then, an experimental study of a SC-CB prototype is reviewed, and two modelling strategies (*i.e.,* simplified and advanced) are developed and validated against the experimental results. Successively, a Finite Element (FE) parametric analysis is conducted in ABAQUS to investigate the relevant parameters affecting the global and local behaviour of the joints while providing additional recommendations to improve the design methodology. Besides, extensive numerical simulations are conducted in OPENSEES to investigate the seismic performances of several case-study perimeter MRFs equipped with the SC-CB connections through Incremental Dynamic Analyses (IDAs) and fragility curves. Lastly, an experimental campaign on a large-scale two-storey steel structure equipped with BCJs endowed with FDs and the proposed SC-CBs is carried out by adopting the Pseudo-Dynamic (PsD) procedure. In addition, a simple repairing methodology, consisting of loosening and re-tightening all the high-strength pre-loadable bolts of the FDs, is proposed and analysed to evaluate the effectiveness in terms of residual drift reduction during repair. The results of this thesis highlight the effectiveness of the SC-CBs in drastically reducing the residual drifts of steel MRFs below the acceptable drift limits while not affecting the peak response and in protecting the first-storey columns from damage. In addition, the outcomes of the thesis provide a large set of data for the validation process of simplified and advanced models, giving insights into the use of the adopted SC-CB connections while defining the boundaries of the investigated parameters for their application. Finally, results also demonstrate the repairing methodology's considerable benefits in terms of repairability, functional recovery, and seismic resilience.