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Abstract

ROBUSTNESS AND SEISMIC BEHAVIOUR OF STRUCTURES EQUIPPED WITH TRADITIONAL AND INNOVATIVE BEAM-TO-COLUMN CONNECTIONS

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Moment Resisting Frames are structures that withstand seismic actions by the bending of girders, columns and connections. Their main source of stiffness and lateral strength is given by the flexural resistance of members and connections, and the seismic energy dissipation capacity and ductility, is provided by the formation of a high number of dissipative zones which can be located in beams, columns or joints depending on the applied design philosophy. Classically, framed structures are designed to possess strong columns, weak beams and full strength rigid connections, so that the earthquake input energy is dissipated through the plastic engagement of the end of beams and of the end of columns of the first storey. The aim of the PhD thesis is to investigate the possibility of using innovative beam-to-column joints characterised by an appropriate stiffness under service loads but which are able to provide a high energy dissipation under seismic event and to confer a suitable robustness in case of a column loss due to exceptional events. According to the traditional strategy for the seismic design of building structures, in case of frequent and occasional seismic events whose return period is comparable with the life cycle of structures, the earthquake input energy has to be completely dissipated by means of viscous damping. Therefore, the hysteretic energy is equal to zero because, for such seismic events, the structure has to be designed to remain in elastic range. Conversely, in case of rare and very rare seismic events whose return period is about 500 years and even more, most of the earthquake input energy is dissipated by hysteresis, but leading to severe plastic excursions and related structural damage. Such structural damage has to be compatible with the ductility and the energy dissipation capacity of structures, because, even though structural damage is accepted, collapse prevention has to be assured and the safeguard of human lives has to be guaranteed. To this scope a reliable prediction of nonlinear structural behaviour during severe seismic events is required, which represents an extremely difficult task. Although many nonlinear analysis programs exist, the accuracy of their results depends on the assumptions made in the characterization of member stiffness. Therefore, experimental research remains the most reliable means of assessing seismic performance and is crucial to the development of new analytical models and design methods. Quasi-static testing can provide information on the nonlinear behaviour of members or subassemblies, but it is often difficult to relate the imposed force or displacement histories to those that might occur during an earthquake. These static methods are therefore, primarily used to calibrate analytical models or to compare the relative performance of a variety of similar structural details.

Starting from the above considerations, in this work, the possibility of using steel frames with innovative bolted connections has been analysed with the aim of providing the structure of supplemental damping devices by means of properly detailed beam-to-column joints. In particular, in order to overcome the drawbacks of the traditional and passive control design strategies, the aim of the work is the development of a new design strategy whose goal is the design of connections able to withstand frequent and occasional seismic events but also destructive earthquakes such as those corresponding to rare and very rare events without any damage. In addition, with reference to structural robustness, has been underlined that, because of the specific behaviour of beam-to-column connections equipped with friction pads, significant benefits are in the catenary action resulting, as example, in case of a column loss due to blast loading or impact loading. The development of this design strategy is also the subject of the FREEDAM project, which is an RFCS project, granted by the European Community.

Six main chapters will be included within the PhD thesis.

Chapter I contains general introduction explaining the behaviuor of the Moment Resisting frames, their classification and the influence on their behaviour of the beam-to-column connections. Moreover, the origin of the studied problem and the objectives of the presented work have been explained

Afterwards, the attention is focused on the design procedures of full-strength and partial-strength beam-to-column connections. In particular, in ***Chapter 2*** general concepts concerning the component method, as introduced by last version of Eurocode 3, are given and a design procedure of the full-strength full-ductility joints has been proposed and validated through the comparison with the results obtained by means FEM analyses performed in ABAQUS 6.13 software.

Chapter 3 provides the results of an experimental programme consisting of 63 specimens, developed at the STRENGTH laboratory (STRuctural ENGineering Testing Hall) of the University of Salerno, devoted to know with a sufficient level of accuracy the value of the bolts' preloading and the value of the static and dynamic friction coefficients of the friction material employed in FREEDAM connections. A design procedure of the friction beam-to-column connections has been proposed and followed in the designing of the two specimens typologies tested at the STRENGTH laboratory.

Chapter 4 deals with the experimental investigation of the behaviour of the FREEDAM joints. Preliminarily, the design of the specimens and the description of the experimental layout have been reported. Therefore, the results obtained by cyclic tests is presented and it is pointed out how the typology of the hysteresis loops is mainly governed by the weakest joint component.

In the second part of the thesis the seismic response and the structural robustness of the frame where the friction connections have been adopted, have been analysed and compared to the performance of the same MRF equipped with a traditional double split tee connection (partial strength joints) and with the dobgone connection (full strength joints) whose cyclic response have been experimentally analysed in the past years at the University of Salerno. In particular, aiming to evaluate the seismic response of the structures by varying the beam-to-column joint detail, in ***Chapter 5*** an accurate modelling of the structure and, in particular, of the beam-to-column connections is reported; considering eight ground motion records, the Inelastic Dynamic Analyses (IDA) have been performed by means SeismoStruct v.2016 software and the results have been presented.

Finally, in ***Chapter 6***, in order to evaluate the robustness of the earthquake resistant moment resistant frame analysed in chapter 5 under seismic load, the pushdown analyses of the structures by varying the beam-to-column connections have been performed in SAP 2000 computer program.

To this scope, the beam-to-column joints described in the previous chapters preliminarily the component method for predicting the whole moment-rotation curve of the joint has been modified in order to account for the development of axial forces and to introduce the ultimate deformation of the single joint components.