Design optimization of high-rise buildings equipped with Shear Link Bozzo devices using the PBSD approach

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Master's degree thesis summary

Over the past decades, the number of applications of earthquake-resistant devices, such as passive control systems, has steadily increased in civil engineering due to their ability to provide higher levels of safety to the structure. As an example, Shear Link Bozzo (SLB) devices, metallic dampers belonging to the family of passive energy dissipation systems, are widely used. These devices are used for new and retrofitted reinforced concrete and steel buildings, especially in America (e.g., Mexico, Perú, Ecuador). This thesis, developed during the Erasmus Traineeship at the engineering company "Luis Bozzo Estructuras y Proyectos S.L." in Barcelona, Spain, deals with the optimization of the structural design of reinforced concrete buildings equipped with Shear Link Bozzo (SLB) devices. The use of SLB devices increases the stiffness of the structure, reducing the interstory drift during an earthquake and providing an additional source of energy dissipation, reducing the structural damage in both structural elements (e.g., beams and columns) and non-structural components. The aim of the study is to highlight the benefits associated with the application of the SLB devices to the seismic structural behavior and, furthermore, to evaluate the advantages of the Performance Based Seismic Design Approach (PBSD) over prescriptive building codes.

Chapter 1 introduces the topic of seismic protection of buildings through the use of various types of dissipation devices. **Chapter 2** deals with passive energy dissipation systems. The basic principles of these devices and their classification are introduced, with a more detailed focus on metallic dampers such as the Shear Link Bozzo devices. **Chapter 3** describes the main features of the SLB devices. The main results of the experimental campaigns of the four SLB generations are presented. In particular, tests concerning the last generation devices, where the ultimate displacement is approximately 60 mm, show a much higher deformation capacity, thus energy dissipation, compared to previous generations. **Chapter 4** is dedicated to the modelling and design methods of SLB. First, the physical and mathematical modelling of the SLB device and the support, generally consisting of decoupled reinforced concrete walls or steel braces, is presented and then the corresponding finite element modelling is described. The design of the dissipator is generally conducted by means of *linear response spectrum analyses* (RSA) with two different methods: the direct iteration method and the inverse interaction method. Nonlinear time history analyses are highly recommended to verify the structural behavior of the building equipped with SLB. **Chapter 5** presents the main aspects of PBSD. This approach allows to make exceptions to specific prescriptive code-based approaches, so the focus of the structural design changes from a prescriptive "check list" of code provisions to a verification of building performance required at multiple seismic hazard levels using linear and advanced nonlinear analyses. Therefore, PBSD stands in contrast to common analysis and design methodologies such as *Equivalent Lateral Force* (ELF) analysis and *Response Spectrum analysis* (RSA) and results very useful especially for high-rise buildings. **Chapter 6** is dedicated to the geometric and mechanical nonlinear modelling of reinforced concrete structures. The various types of models for plastic hinges are introduced, focusing mainly on distributed and concentrated plasticity models, the most frequently used for nonlinear analyses. The importance of P-Δ effects and their influence in the analysis of structures is illustrated, taking as example a simple one-degree-of-freedom structure. Finally, the main theoretical aspects of linear and nonlinear dynamic analyses are introduced, including numerical integration methods and the damping modelling by means of the Rayleigh damping method. **Chapter 7** describes the case study of the thesis: a new high-rise reinforced concrete building located in Acapulco, Mexico. Firstly, the design of the SLB devices is carried out using the direct and inverse iteration methods in order to define the optimal dimensions of the dissipators. Then, the design of the steel reinforcement and the verification of the structure is carried out using the performance PBSD by ensuring that the global and local acceptance criteria of the building codes are met. Finally, a comparison between the bare frame structure and the structure equipped with SLB is made, highlighting the pros and cons of the two proposed solutions. **Chapter 8** is dedicated to the conclusions of the thesis.