Theoretical and Experimental Analysis of Dissipative Beam-to-Column Joints in Moment Resisting Steel Frames

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RINGRAZIAMENTI

Concludere questa tesi significa per prima cosa giungere al termine di questi tre anni sicuramente belli, anche se non sempre sereni, di esperienza di dottorato. Il rammarico con cui si lascia alle spalle quanto vissuto fin qui, per continuare la propria vita lavorativa verso nuovi obiettivi, è enorme.

Il ringraziamento più grande voglio rivolgerlo alle persone con cui mi sono ritrovato ogni giorno a condividere tutto (dal laboratorio ai pranzi frugali). Un particolare ricordo va a Riccardo e Fabio, colleghi del gruppo di ricerca, con cui ho trascorso gran parte di questo periodo e senza i quali non avrei mai conseguito questo obiettivo. Mi rende felice e per questo mi fa piacere menzionare Saverio e Francesco, compagni di stanza, ma prima di tutto amici. E' doveroso ringraziare, con grande stima e riconoscenza, il Prof. Gianvittorio Rizzano e il Prof. Vincenzo Piluso, che hanno rappresentato per me un punto di riferimento, ma anche un meraviglioso esempio di come si possa essere persone prima ancora che valenti accademici.

In questo momento non posso non pensare a mia madre e mio padre che, ormai, non sopportano più di vedermi curvo su libri di cui non riescono a comprendere nemmeno il significato del titolo. Infine Manuela, presenza costante cui devo molto di quanto sono riuscito a costruire in questi ultimi tre anni e senza la quale forse non ce l'avrei fatta ad essere qui a mettere questo punto.

Knowledge without follow-through is worse than no knowledge

(Charles Bukowski)

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CHAPTER 1 – INTRODUCTION

1.1 Scope of the study

Before seismic events of Northridge (Los Angeles, 17 January 1994) and Hyogoken-Nanbu (Kobe, 17 January 1995) MRFs were supposed to be the most reliable seismic resistant systems due to the high number of dissipative zones that are able to develop Before these earthquakes, especially in United States, MRFs were realized, generally, by adopting fully welded connections, which, at the time, were retained to perform better compared to other joint typologies. In addition, the economic advantages deriving from the adoption of field fully welded connections, strongly influenced choices of building owners' and, as a result, led to the adoption of this joint typology in almost all pre-Northridge steel MRFs. After Northridge earthquake, even though the loss of life was limited, the unexpected amount of damages occurred in structures adopting as seismic resistant system welded Moment Resisting Frames put into question the role played by welded connections on the whole structural behavior.

Therefore, after the seismic events, two strategies were identified to improve behavior of fully welded connections. The first one is related to the improvement of the welding technique, usually strengthening the critical area subjected to fracture. The second one is based on the possibility of concentrating the energy dissipation in the beam, reducing the bending resistant area of beams by properly cutting the flanges in a zone close to beam-to-column connection. This weakening approach is commonly called RBS. A new design approach, which has been the subject of many studies in last decades, has gained growing interest in last years. In fact, Eurocode 8 has opened the door to the idea of dissipating the seismic input energy in the connecting elements of beam-to-column joints. It has been recognized that semi-rigid partial strength connections can lead to dissipation and ductility capacity compatible with the seismic demand, provided that they are properly designed by means of an appropriate choice of the joint component where the dissipation has to occur.

In this work, the attention is focused on this last approach. The first part of the work is descriptive and deals with the historical development and, in general, with the seismic behavior of Moment Resisting Frames. In the same chapter general concepts concerning the component method, as introduced by last version of Eurocode 3, are given. Finally, the influence of the joint behaviour on main characteristics of partial strength and/or semi-rigid MRFs is evaluated by properly accounting for existing literature. Third chapter deals with an experimental analysis on the cyclic behaviour of classical partial strength beam-to-column joints. The main scope of the experimental campaign is to show how to control the dissipative behaviour of joints by properly designing the weakest joint component and by over-strengthening the other connecting elements. Therefore, a design procedure is pointed out and the comparison among the results obtained by cyclic tests is presented in terms of energy dissipation capacity. In addition, by monitoring during the experimental tests both the whole joint and the single joint components it is shown that the energy dissipated by the joint is equal to the sum of the energy dissipated by the joint components. This result assures that the first phase of the component approach, i.e. the component identification, has been properly carried out and that interaction between components under cyclic loads is negligible. Chapter 4 represents the continuation of the work carried out in previous chapter. In fact, on the base of the obtained results, the goal is to provide a mechanical cyclic model for the prediction of the overall joint behaviour, starting from existing literature models. Hence, a state-of-the-art review is first presented and then, model employed to set up a computer program devoted to the prediction of the cyclic behaviour of steel beam-to-column joints is shown. In particular, cyclic model adopts Kim & Engelhardt model for shear panel, Cofie & Krawinkler model for Panels in Tension and Compression and Piluso et al. model for the prediction of the T-stub behavior. Finally, in chapter 5, an innovative approach to improve the seismic behavior of bolted beam-to-column joints, which are affected by strength and stiffness degradation, is presented. The development of a dissipative device representing the application of ADAS concept to T-stubs, is detailed. First, a mechanical and finite element model able to predict the whole force displacement curve of the so-called hourglass T-stubs are set up. Next, an experimental analysis aiming to compare the hysteretic behaviour and the dissipative capacities of rectangular and dissipative T-stubs is carried out. Finally, as a consequence of the study of the joint component, a further experimental analysis concerning the application of such devices to partial strength beam-to-column joints is presented and the results, in terms of moment-rotation curve and energy dissipation capacity, are discussed and compared to those obtained by the cyclic testing of classical joints.