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Experimental analysis of seismic resistant composite steel frames with dissipative devices

Carlo A. Castiglioni [a,*], Alper Kanyilmaz [a], Luis Calado [b]

[a] Politecnico di Milano, Structural Engineering Department, Piazza Leonardo da Vinci, 32, 20133 Milano, Italy
[b] Department of Civil Engineering and Architecture of Instituto Superior Técnico, Technical University of Lisbon, Av. Rovisco Pais 1, 1049-001 Lisbon, Portugal

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ABSTRACT

This article presents the results of the experimental research performed at Politecnico di Milano, within the project Fuseis. The research project aims at developing innovative types of seismic resistant composite steel frames with dissipative fuses. In case of strong seismic events, damage will concentrate only in these fuses, without observing any significant damage in the structural elements such as steel beams, columns and reinforced concrete slab of the structure. After the seismic event, the repair work will be limited only to replacing the fuses. Four full scale tests are implemented in order to evaluate the performance of a composite steel frame with fuse devices under seismic actions in terms of moment rotation behavior of the joints, global energy dissipation, storey drift and frame stability.

1. Introduction

Steel structures in seismic zones are designed for stiffness, strength and ductility. Stiffness is required for limitation of damage of non-structural elements and reduction of the second order effects. Strength is required for a safe transmission of the acting forces and moments. Ductility under cyclic loading leads to the dissipation of the input seismic energy and results in a reduction of the seismic forces. The demand for strength is therefore closely connected to the provision of ductility. By means of inelastic deformation in the structure, the latter may result in a considerable reduction of the acting seismic forces.

Obviously, not the entire structure shall exhibit uncontrollable inelastic deformations during a strong earthquake. Such deformations are associated with damage and shall be limited into specific zones, the dissipative zones. For that reason, the elements of the dissipative zones are weaker than their connections and the adjacent members. The latter are designed for higher forces and moments according to capacity design criteria. Table 1 shows an evaluation of the existing conventional structural systems and the new system that is proposed in this study with respect to stiffness, ductility, and reparability [1]. Strength is not evaluated since it is accepted that all systems, if properly designed, are able to resist the acting effects. It can be seen that conventional systems have advantages and disadvantages. Moment resisting frames are ductile but usually flexible. Concentric braced frames are stiffer but less ductile due to buckling of braces. The properties of eccentric braced frames are something between the other two types.

Above descriptions and the experience show that unlike accidental loading, earthquakes lead frequently to damages in *large* extent. For instance, the large number of beam-to-column connection failures observed in moment resisting frames after Northridge (USA, 1994) and Kobe (Japan, 1995) earthquakes caused very high repair costs [2]. After these events, some new solutions for moment resisting frame connections have been implemented introducing weakened areas near the beam ends where the plasticity is concentrated. An example to these solutions is the Reduced Beam Section (RBS), introduced by Plumier [3]. Experiments carried out by Pachoumis et al. [4] and by Yu and Uang [5] showed that with this solution it is possible to successfully dissipate energy and concentrate plasticity, however simple and cost effective reparability of the damaged parts of the structure still remained as a problem. It is therefore advisable to develop structural systems that are simple to *repair*, i.e. to introduce the *reparability* as a new property.

Furthermore it has to be pointed out that, in reality, "steel structures" rarely exist by themselves (eventually just in the case of industrial buildings). Most often, in the case of high-rise buildings, housing, as well as commercial buildings, the steel beams support reinforced concrete slabs and usually behave as composite members. In this case, damage to the steel members results in damage in the reinforced concrete slabs and in the finishes, so that repair works will be increased together with the related costs.

From other engineering disciplines, e.g. mechanical, electrical and automobile or aircraft engineering, it is well known that the best way of repairment is the complete replacement of a damaged part with a new one. Such a strategy could be also envisaged in civil engineering, especially for buildings in seismic areas that are more susceptible to damage for the reasons described above. Like bumpers in cars that

* Corresponding author. Tel.: +39 02 2399 4355.

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