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Numerical and experimental behaviour of a full-scale RC structure upgraded with steel and aluminium shear panels

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ABSTRACT

In current paper the problem of seismic upgrading of existing reinforced concrete structures by means of metal shear panels is examined. Firstly, according to both a preliminarily experimental–numerical evaluation of the bare RC structure performance and analytical relationships, an ideal steel panel configuration has been defined and secondly refined FEM models have been implemented in order to check the reliability of the proposed design procedure. Finally, based on the achieved numerical results, the effectiveness of the applied devices has been proved by full-scale experimental tests, which confirmed in both cases the significant improvement of the original building features.

1. Introduction

The seismic upgrading of RC buildings represents a remarkable interest topic in the field of Seismic Engineering. In fact, recent earthquakes showed that such structures are particularly vulnerable to the effects of both frequent and rare quake motions [1]. Common damages occurred into RC buildings during past earthquakes varied from soft-storey mechanisms to columns collapse – often determined by the lack of confining action exerted by stirrups – from shear cracking into shear walls to beam-to-column joints failure (see Fig. 1) [2]. Therefore, the necessity to set-up and develop adequate intervention techniques able to both safeguard the human lives and to reduce possible damages into structures, has been particularly advertised in the scientific community. Such a tendency has been acknowledged in many European Countries, as for instance in Italy, where, due do the tragic consequences of a recent earthquake (2002), a new technical code has been promulgated [3]. At the light of the above issues, the use of innovative and reversible techniques plays a fundamental role for retrofitting existing RC structures. These techniques are based on either the reinforcement of existing elements, so to improve the local structural behaviour, or the introduction of new components, aiming at increasing the global response of the building [4]. Epoxy-resin injections, steel plates jacketing and the use of fibre-reinforced polymers (FRPs) belong to the first intervention category, which does not foresee any change in the global behaviour of the building. Conversely, dissipative elements undergoing large plastic deformations and contemporarily able to reduce plastic engagement of the main structural members, can be effectively used as global level techniques. Among the latter intervention systems exploiting both the effectiveness and the economy of metallic elements, the use of metal shear panels represents an innovative design system which, differently from bracing systems that have been already widely studied and designed according to the recent anti-seismic codes, deserves a deeper attention.

Such devices possess several advantageous prerequisites, such as both the limited weight and the reduced hindrance space in comparison to RC shear walls, the ease of insertion and the significant structural contribution offered in terms of strength, stiffness and energy dissipation capability.

Metal shear panels were firstly used in 1920s as cladding panels, without having any structural purpose [5]. The initial applications were based on the use of corrugated sheeting and sandwich panels which were connected to a supporting frame by means of steel bolts, rivets or spot welds [6], providing a significant increase of the seismic performance at the serviceability limit state [7]. Subsequently, steel shear plates connected to an external frame were used as lateral load resisting system [8], they being based on either the use of special connections [9] or by adopting appropriate stiffeners configurations [10]. The evolution of the metal plate shear walls behaviour has led to a different classification of these devices within two main typologies, namely compact shear panels, realised with either stiffened plates or plates made of low-yield strength

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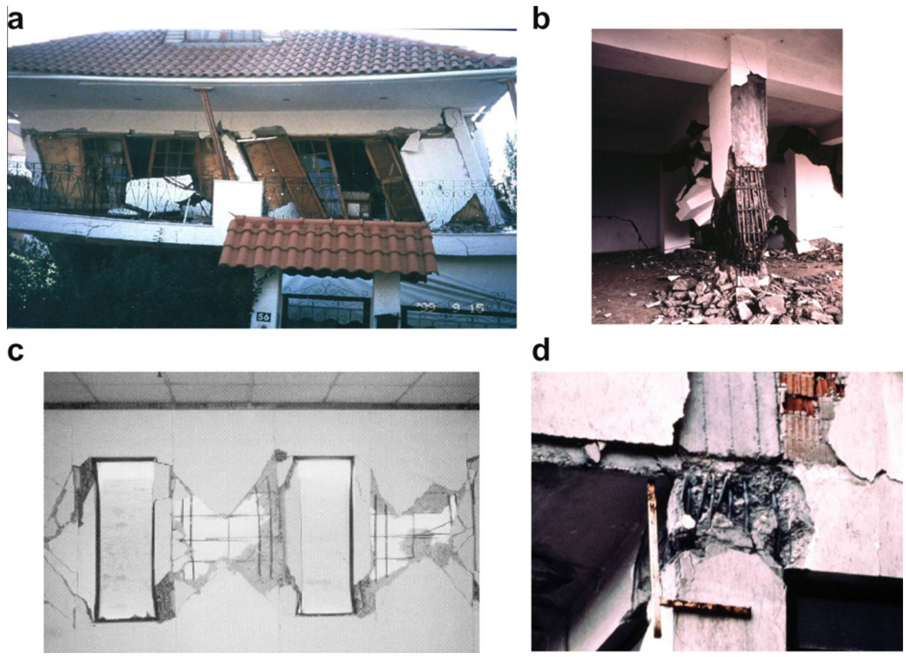

Fig. 1. Damages occurred into RC buildings under earthquakes: (a) soft-storey mechanism; (b) column failure; (c) cracking of shear walls; (d) beam-to-column joint collapse.

metals (LYS steel or pure aluminium) [11], and slender shear panels, made of thin steel plates connected to the members of a surrounding steel frame by means of either welded or bolted connections (Fig. 2) [12]. Compact shear panels have a good energy dissipation capability, they being characterised by stable and large hysteretic cycles due to the occurrence of buckling phenomena in the plastic field only (Fig. 2a). On the contrary, slender shear panels have a poor hysteretic behaviour with pronounced pinching effects due to buckling phenomena occurring in the elastic field (Fig. 2b). Nevertheless, the fabrication simplicity of slender metal plates suggests their employment as passive control devices of structures. In this framework, while compact shear panels have been strongly used in USA and Japan within new and existing buildings, slender shear panels have been widely studied and applied in Canada, but they have been hardly ever employed for seismic retrofitting purposes. For this reason, the main target of the current paper is to

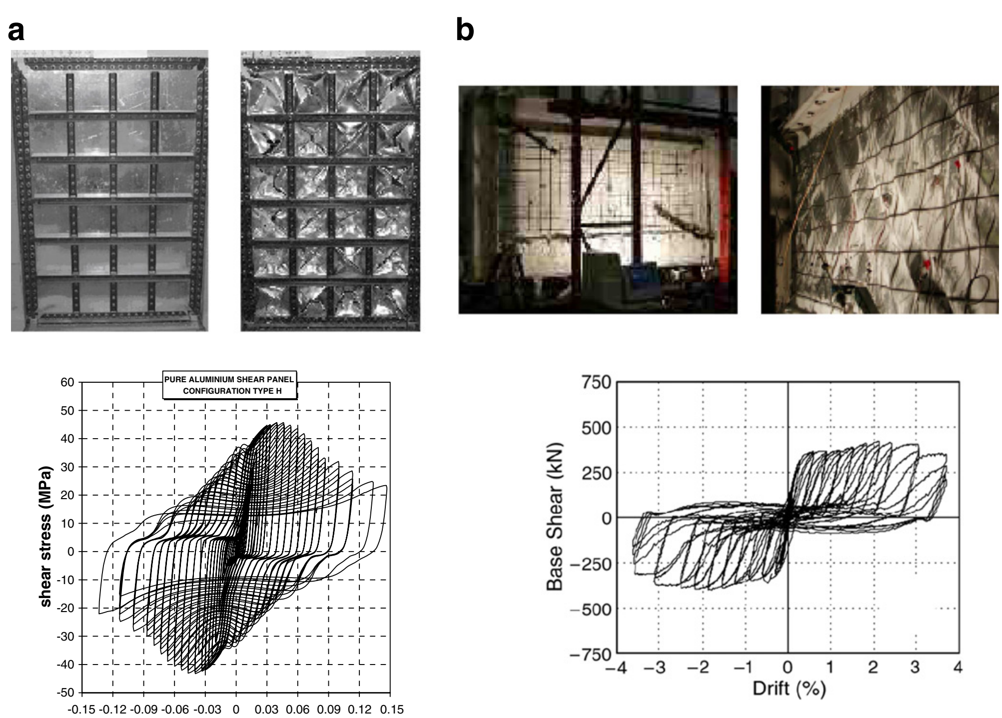

Fig. 2. Experimental cyclic tests on compact pure aluminium (a) [11] and slender steel (b) [12] shear panels.