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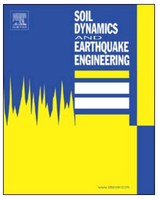

On the seismic response and damping capacity of low-rise plane steel frames with seesaw system

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ABSTRACT

This paper summarizes estimated seismic response results from nonlinear inelastic seismic analyses of low-rise plane steel frames equipped with a seesaw system in which linear viscous dampers have been applied. More specifically, considering for each frame three different configurations of the seesaw system and two different orientations of columns, seismic response results involving height wise distributions for peak interstorey drift ratios (IDR), peak residual interstorey drift ratios (RIDR) and peak floor accelerations (PFA) have been obtained. Moreover, peak seismic demands in columns and in the steel plates of the seesaw are found. Results in terms of modal damping ratios are also provided for all frames and seesaw configurations examined. From the results presented, it can be concluded that the seesaw system provides a very attractive solution for typical low-rise steel frames offering significant damping capacity and reduction of their seismic response.

1. Introduction

The seesaw system, originally proposed by [9,10,11,12], consists of a pin-supported seesaw, two spiral strand ropes (cables) with turnbuckles that intersect from the edges of the seesaw and a couple of dampers installed vertically on the seesaw. Fig. 1 displays a steel frame equipped with a seesaw system, whereas variations of this system regarding its installation type as well as the kind of dampers used (fluid viscous, viscoelastic, slit) can be also found in literature [9,10,23]. Applications of cables as braces for seismic retrofit of frames have been presented in [7,14,15] but without employing a seesaw member.

From the numerical and experimental investigations performed by [9,10,11,12], it has been concluded that the seesaw system can effectively control the dynamic behavior of steel frames and significantly reduce their seismic response. However, the level of this seismic response reduction depends on several factors, e.g., the properties of the spiral strand ropes, the type of their end connection, the dampers used and the height and width of the seesaw. The latter dimensions are directly associated with the stroke of the damper and the inclination angle of the spiral strand ropes, respectively.

Spiral strand ropes are made of galvanized wires helically spun around a strand core. The strength of the wires as a result of thermal and mechanical treatments is between 1770 and 1960 MPa. They usually possess a modulus of elasticity of about 100 MPa and a large ultimate elastic elongation. Strands combined to form larger units are called bundles, while combined bundles form a cable. The cross sections of strands varies, as shown in Fig. 2, and affects the properties of the strand rope [22].

The behavior of strands and cables under dynamic and repeated loading has been thoroughly studied by, e.g., [1,5,6,20,21], taking into account contact (friction) effects between individual wires, localized bending close to the end connection (anchorage) points, fatigue performance, damping as well as the effects of spinning, compaction, prestressing and corrosion. The reduction of the minimum breaking force of strands and cables due to their end connections, is shown in Fig. 3 [22], and can be up to 20%. The design tensile strength of strands and cables taking into account the effects of compaction, spinning and end terminations can be calculated using relevant standards, e.g., [2].

Focusing on their nonlinear hysteretic (seismic) behavior, cable (wire ropes) exhibit pinching and, thus, they have a reduced energy dissipation capacity. This pinching effect is attributed to the slackness of the cables (wire ropes) when the direction of seismic motion changes from forward to backward. A slacked cable (wire rope) cannot contribute to load bearing until it becomes taut (straight). To improve the seismic behavior of cables (wire ropes), researchers have proposed prestressing, incorporation of damping devices or of shape memory alloys and slack free connections ([16] and references therein). In this work, a small prestressing is introduced to the spiral strand ropes (cables) in conjunction with the addition of linear viscous dampers on the seesaw. This way, the energy dissipation of the seesaw system is expected to be improved.

This paper summarizes estimated seismic response results from

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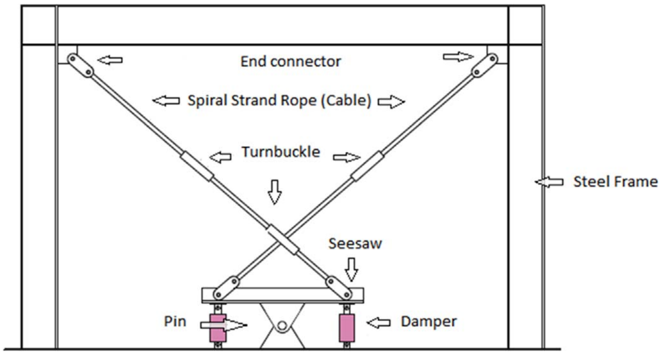

Fig. 1. A steel frame with the seesaw system.

nonlinear inelastic seismic analyses of steel frames equipped with the seesaw system. More specifically, three different configurations of the seesaw system and two different orientations of columns have been considered in a set of plane low-rise steel frames and their seismic responses in terms of height wise distributions to peak interstorey drift ratios (IDR), peak residual interstorey drift ratios (RIDR) and peak floor accelerations (PFA) have been obtained. Moreover, peak seismic demands in terms of: i) axial and shear forces and end rotation in columns, and ii) axial and shear forces and bending moment in the steel plates of the seesaw are computed. The effectiveness of the linear viscous dampers and the spiral strand ropes used is checked on the basis of their allowable strength values provided by their manufacturers. In cases of failure for either the viscous damper or the strand rope or both, the aforementioned seismic response and demands results are re-calculated by re-designing the viscous damper and/or the strand rope. Finally, modal damping ratios for all frames and seesaw configurations examined are calculated employing the damping identification procedure developed by [17,18].

From the results found, it can be concluded that the seesaw system provides a very attractive solution for typical low-rise steel frames and may effectively substitute the common steel braces. The spiral strand ropes of the seesaw system are always in tension and hence buckling problems are eliminated.

2. Seismic analyses of low-rise plane steel frames

2.1. Steel frames with seesaw system

The set of low-rise (1-, 3- and 6-storey) plane steel frames studied

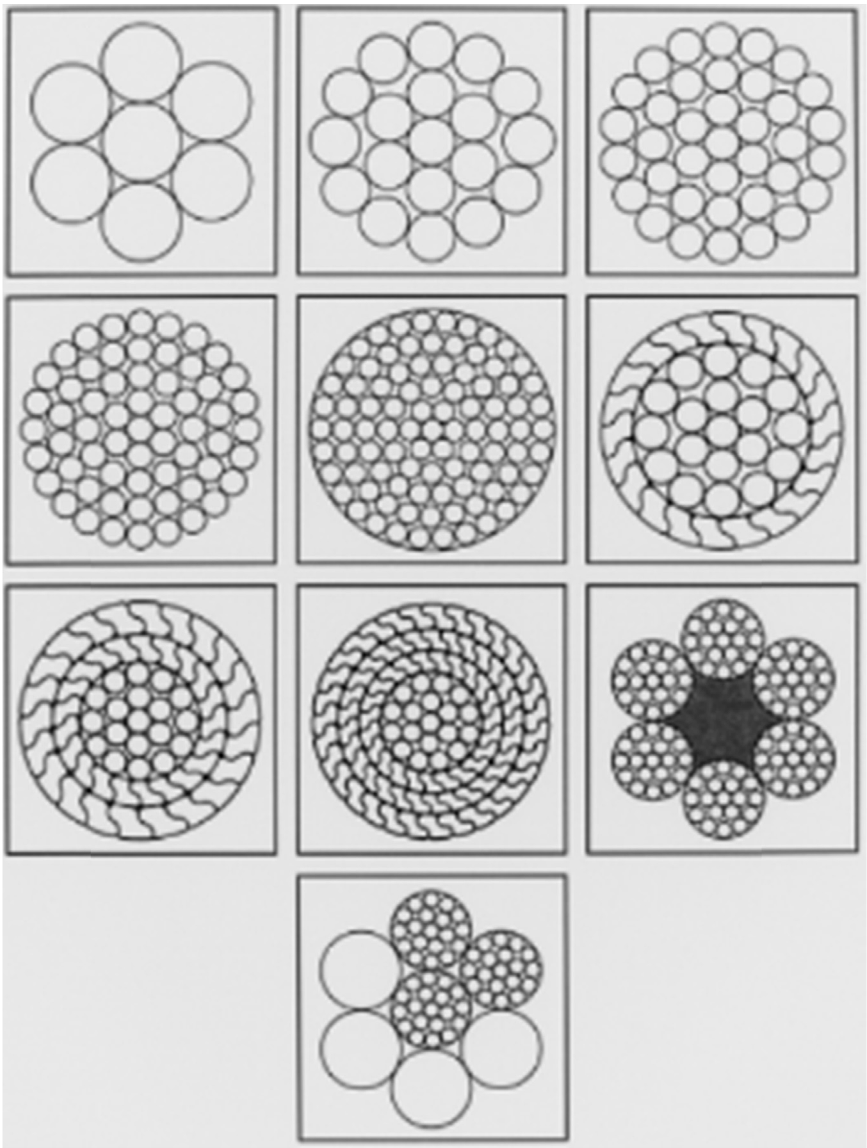

Fig. 2. Cross sections of strands (after [22]).