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Seismic loss-of-support conditions of frictional beam-to-column connections: hazard disaggregation effects

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ABSTRACT

The evaluation of the loss-of-support conditions of frictional beam-to-column connections using simplified numerical models describing the transverse response of a portal-like structure is presented in this paper considering the effects of the seismic-hazard disaggregation. Real earthquake time histories selected from European Strong-motion Database (ESD) are used to show the effects of the seismic-hazard disaggregation on the beam loss-of-support conditions. Seismic events are classified according to different values of magnitudes, epicentral distances and soil conditions (stiff or soft soil) highlighting the importance of considering the characteristics of the seismic input in the assessment of the loss-of-support conditions of frictional beam-to-column connections.
A rigid and an elastic model of a frame of a precast industrial building (2-DoF portal-like model) are presented and adopted to find the minimum required friction coefficient to avoid sliding. Then, the mean value of the minimum required friction coefficient with an epicentral distance bin of 10 km is calculated and fitted with a linear function depending on the logarithm of the epicentral distance. A complete parametric analysis varying the horizontal and vertical period of vibration of the structure is performed. Results show that the loss of support condition is strongly influenced by magnitude, epicentral distance and soil conditions determining the frequency content of the earthquake time histories and the correlation between the maxima of the horizontal and vertical components. Moreover, as expected, dynamic characteristics of the structure have also a strong influence. Finally, the effect of the column nonlinear behavior (i.e. formation of plastic hinges at the base) is analyzed showing that the connection and the column are a series system where the maximum force is limited by the element having the minimum strength. Two different longitudinal reinforcement ratios are analyzed demonstrating that the column strength variation changes the system response.

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1. INTRODUCTION

Single storey precast industrial buildings are widely used for their fast construction time and relatively low construction costs. Moreover, this structural typology guarantees standardization of spatial organization and structural layouts permitting a substantial reduction in the number of standard sizes for components and structural members. Nowadays, with reference to Europe, one-storey industrial precast concrete buildings are the most common type to be found at industrial enterprises and constitute 75-80% of total industrial construction. Precast industrial buildings are very efficient under dead and wind loads. Differently, in the case of seismic events with strong horizontal and vertical actions, they show all their vulnerabilities. These structural deficiencies referring to all the structural and non-structural elements were observed during the recent devastating earthquakes in China (2008 and 2010), New Zealand (2011), Japan (2011), Turkey (2011) and Italy (2009 and 2012). The main problem of these structures is related to the inefficient mechanical behavior of beam-to-column connections in which the shear transfer usually relies on friction.

A precast structure is an assemblage of precast elements which, when suitable connected together, form a 3D framework capable of resisting to the dead and live load (Elliott, 2002). Precast concrete buildings are located in many important countries such as Italy (Dassori et al., 2001), Turkey (Sezen et al., 2000; Posada et al., 2002) and China (Zhu et al., 2015). The typical structure used as industrial building is a single story frame composed of precast concrete elements (Figure 1): two foundation systems, two columns and one beam. A roof system (purlins and roof slabs) and precast infill elements complete the buildings. One-story industrial buildings were characterized by long-span roof beams, which provided large open areas needed for manufacturing (Dassori et al., 2001). The buildings are usually rectangular. Transverse bay widths usually ranges from L=10 to 30m, and longitudinal bay widths (frame spacing) ranges from I=6 to 14 m and storey heights also ranges from H=4 to 9 m.

The foundation is usually realized using precast socket foundations. The columns are modeled as base-fixed cantilever columns (inserted in precast socket footings) with precast beams placed on top of them featuring simple supported behavior loading roof systems of different typologies. In both precast columns and beams, concrete is of the highest quality due to their production and casting in a controlled environment. Bar diameters commonly used are 8 and 10 mm for column stirrups, 10 and 12 mm for beam stirrups and anti-crack bars and from 16 mm up to 40 mm for main flexural bars. The beam supports the roof system that is usually made with secondary beams (purlins) supporting roof slabs and/or roof windows.

The main difference between a normal concrete structure and a precast one is the presence of joints that strongly affect the mechanical behavior. In fact, this type of buildings is usually made by the superposition (i.e. joining) of structural element to obtain precast portal frames. In many countries (USA, New Zealand, Japan, Australia, etc.), rigid connections are preferred for beam-column joints, while in Europe (Italy, Greece, Spain, Portugal, Slovenia, etc.) and elsewhere (Turkey, Armenia etc.), simple

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