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Influence of modelling assumptions in the expected loss evaluation of a precast industrial building

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Abstract

The economic losses arisen in the industrial sector after the Emilia earthquakes in 2012 highlighted the importance of conducting reliable seismic assessment analyses on the existing industrial building stock in order to ascertain both safety and potential losses associated to seismic events. To accomplish to such task, an accurate representation and quantification of the actual vulnerabilities in such buildings is required and reliable structural models need to be adopted.

The paper investigates how various assumptions and levels of sophistication in finite element modelling affect the results in terms of economic losses, herein assumed as the reference decision variable. After the definition of the main seismic vulnerabilities of precast industrial buildings typical of the Italian territory, different types of finite element models are adopted and non-linear time history analyses conducted; in particular, the reinforced concrete fork at the top of the column is modelled in different ways, also considering the seismic retrofit.

Appropriate fragility curves under selected engineering demand parameters are defined and provided within the Performance Based Earthquake Engineering methodology developed at the Pacific Earthquake Engineering Research Center for the assessment of the expected losses under a scenario-based earthquake. The influence of the modelling assumptions in the seismic risk estimate is evaluated. The results indicate that for the considered case study and in the absence of loss of support, simplified single-column models are suitable to estimate the expected losses.

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Keywords: Precast connections; Industrial buildings; Beam-to-column joint; Performance-based earthquake engineering.

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1. Introduction

During the last decade, extensive research was conducted on the effect of earthquakes in terms of damage and economic losses on the affected buildings. Among these studies, the most applied framework is the probabilistic Performance Based Earthquake Engineering method developed at the Pacific Earthquake Engineering Research Center (PEER-PBEE methodology). The PEER-PBEE methodology allows estimating the performance of structures in seismic zones in terms of direct and indirect losses (typically downtime, economic losses, and casualties) and it is subdivided into four main steps: the hazard analysis, the structural analysis, the damage analysis, and the loss analysis [1]. The outcome of the loss analysis is a loss curve, which is obtained by applying the total probability theorem to the combination of all four phases. Through the calculation of such integral, it is possible to obtain the annualized expected annual loss of the considered building or facility. Simplified loss estimations are also available [2-3].

The application of the PEER-PBEE methodology allows evaluating the influence of the rate of recovery costs associated to non-structural elements (or secondary elements) and/or the contents of the building. Especially in the industrial field, the monetary value of the facilities, the activities, and the internal installations could be significant. Let us think about the damages suffered by many companies in the Emilia-Romagna region (Italy) following the seismic sequence in 2012 (Fig. 1). Most of the observed damage is closely related to the lack of seismic provisions, being those structures not designed according to modern seismic codes [4-6]. The main vulnerabilities, which caused both local and global collapses, are related to the inefficiency of the horizontal load transfer mechanism between precast elements and to the displacement and rotation compatibility among structural elements and between structural and non-structural elements [7-10].

a.  b. 

Fig. 1 (a) Damage caused by the collapse of the roof in a RC precast industrial building in Emilia, 2012 (b) failure of the fork at the top of the column due of the out-of-plane stress of the beam.

The structural layout of the precast concrete structures considered in this paper, typical of industrial and commercial buildings in the Italian territory, is made of cantilever columns pin-connected [11, 12] to pre-stressed RC beams spanning in one direction, which support pre-stressed concrete roof elements spanning in the transverse direction. The columns are placed inside cup footings or connected to the foundation by means of mechanical devices or grouted sleeves solutions [13, 14]. The paper considers how different modelling assumptions influence the results in terms of expected Economic Losses (EL); the assessment is carried out following the PEER-PBEE methodology. The vulnerable elements are considered in terms of fragility curves at selected damage states. Various finite element models are considered and non-linear time history analyses are conducted. The EL are calculated through the Performance Assessment Calculation Tool (PACT) freely available as a result of the ATC- 58 project [15].