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Seismic behavior of RC building structures designed according to current codes

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ABSTRACT

Earthquakes which recently occurred in highly populated regions show that existing buildings constructed without appropriate seismic resisting characteristics may constitute as an important source of risk and may cause economical loses and casualties. It is recognized the progress of the knowledge in earthquake engineering in the last decades. In this paper, two 6 irregular storey buildings were studied consisting of frame structures, representative of the common practice in Portugal, i.e. designed without considering earthquake actions. Push-over and non-linear time history analyses were done, with non-linear 3-D models in longitudinal and transverse directions. The building responses were analyzed in two different levels: global and local. For the global response analyses: max displacement, inter-storey drift (IS drift), floor rotation for each storey and base shear were compared. For local response four columns were chosen and the variation of axial load in terms of base shear and drift as well as the biaxial demand was considered. The result shows that most variation of axial load happens in corner, facade-X, facade-Y and centre column respectively. It is noteworthy that by increasing the initial axial load the biaxial demand decreases. The seismic vulnerability was analyzed for earthquake of different return periods, and the seismic demands were compared with limit proposed in international codes and conclusion are drafted in terms of safety. The vulnerability assessment based on seismic codes clearly shows that the building 2 presented a better performance with low inter-storey drifts. The main goal of this study is considering the application and methodology for the seismic assessment of existent real buildings. In fact this is an important topic, to understand the seismic vulnerability of certain particularities in existing buildings to assure that the common observation can be applied for a prototype building, especially irregular ones. Also one of the major observations in this study is the comprehension of the effect and importance of biaxial loading in columns and the influence of the axial load variation, relating the position of the columns in plan and in height.

1. Introduction

Strong ground motions in the past decade in the densely populated area made great impacts on many buildings specially those designed according to older codes, and revealed that these structures are seismically vulnerable. Several devastating earthquakes, particularly the 1989 Loma Prieta and the 1994 Northridge earthquakes in California, the 1995 Kobe earthquake in Japan, the 2009 L'Aquila and the 2012 Emilia Romagna in Italy, and the 2011 Lorca earthquake in Spain have caused significant damage on the buildings. There are some reasons that show why the structures are practically vulnerable during past earthquakes such as: inadequacy of previous seismic codes and guidelines [1], low standards of construction due to inattention to local detailing [2] and quality control with high variation in material properties [3]. The capacity of the columns is one of the important factors to evaluate the seismic performance of reinforced concrete (RC) buildings. Recent investigation shows that the response of RC members subjected to axial loads combined with biaxial bending moment is recognized as a research topic among researchers for buildings [4]. To achieve this goal, non-linear analyses could be used to evaluate the safety of a structure designed according to the existing design codes. Previous researches have illustrated the trend of seismic performance of reinforce concrete (RC) buildings. Kim and Kim [5] evaluated the seismic demand of reinforce concrete special moment-resisting frame according to IBC 2003. The performance of RC building according to Eurocode 8 was investigated by Panagiotakos and Fardis [6]. Chaulagain et al. [7] conducted a numerical investigation on the seismic performance of four-storey RC buildings. Rodrigues et al. proposed an experimental and numerical simulation to represent the non-linear response of reinforced concrete members due to biaxial bending combined with a constant axial load [8–10]. Varum et al. [11] evaluated numerical tools for the assessment and redesign of concrete buildings capable of estimating the optimum distribution of strengthening needs for a specific performance objective.

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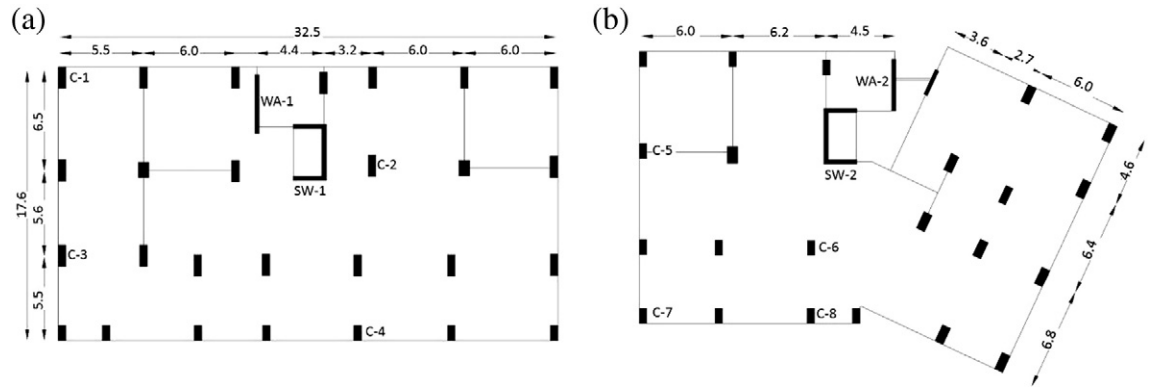

Fig. 1. Geometry of building structure. (a): building 1, (b): building 2.

Table 1
Dimension of column cross-section (dimensions are in cm).

Storey	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8
1st	30 × 60	30 × 80	25 × 80	30 × 60	25 × 80	30 × 80	60 × 30	30 × 65
	14 Φ 20	16 Φ 18	18 Φ 20	12 Φ 20	16 Φ 22	14 Φ 20	12 Φ 20	12 Φ 18
2nd	25 × 60	25 × 60	25 × 60	25 × 60	25 × 60	25 × 70	25 × 50	25 × 60
	12 Φ 18	12 Φ 18	12 Φ 18	12 Φ 18	12 Φ 18	14 Φ 18	12 Φ 18	12 Φ 18
4th	25 × 50	25 × 60	25 × 60	25 × 50	25 × 60	25 × 70	25 × 50	25 × 50
	12 Φ 16	12 Φ 16	12 Φ 16	12 Φ 16	12 Φ 16	14 Φ 16	12 Φ 16	12 Φ 16

Kueht and Hueste [12] evaluated a numerical modeling on the seismic performance of a four-storey RC frame designed by the 2003 International Building Code (IBC). Kotronis et al. [13] proposed a strategy to simulate the non-linear behavior of two RC wall specimens designed according to the French code PS92 and the Eurocode 8, respectively. A constitutive model for predicting the cyclic response of RC structures using a smeared crack approach with orthogonal fixed cracks was studied by Ile and Reynouard [14]. Mazza [15,16] conducted a numerical investigation and structural testing to evaluate the seismic vulnerability and retrofitting of the town hall of Spilinga with an L-shape plan built in 1960. The structural safety assessment procedures based on Eurocode 8 in RC structures are proposed in the study of Romao et al. [17]. There have been several investigations on the seismic performance of RC frames in other countries. The research interest in the 3-D earthquake actions in building irregularities subjected to biaxial bending combined with axial force in the columns is well recognized. The effects of the biaxial loading and its importance in the column response, in terms of the strength degradation and reduction of the ductility capacity are proposed by previous researchers [18]; nevertheless, further studies have to be addressed. For simulation of the biaxial cyclic behavior of RC members with axial load, several modeling processes are proposed, however it is obvious that the available biaxial models are not developed enough to be utilized in practice.

In this research two existing irregular RC buildings which are designed with the previous codes of Eurocode 8 are selected and proposed for non-linear analyses. The main objective of this research is focused on the performance of the existing building in two different levels: global and local. The building responses are analyzed in terms of max

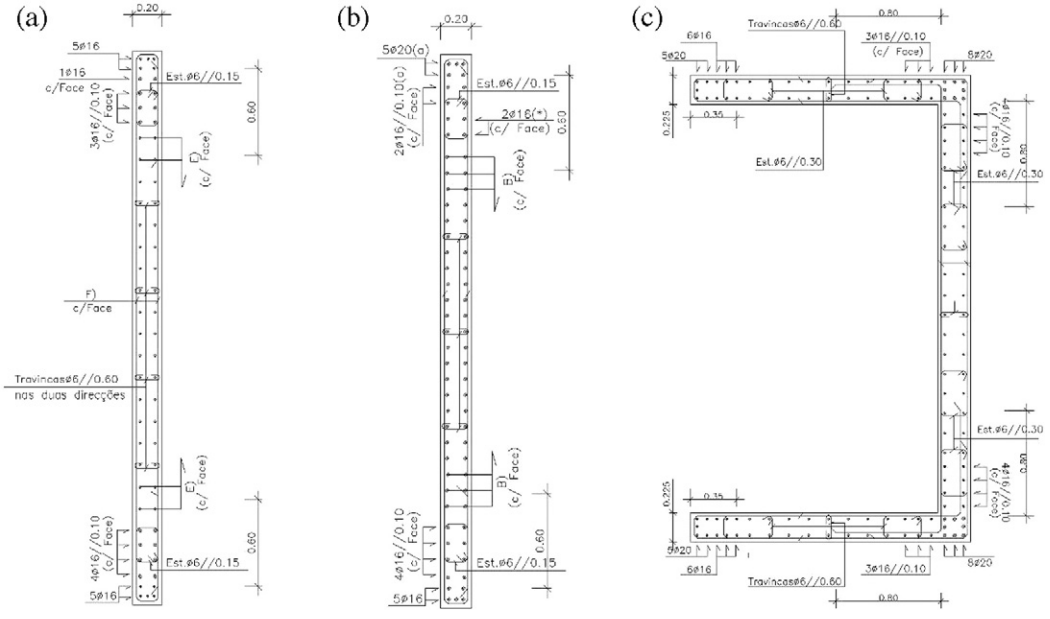

Fig. 2. Shear walls details: (a): WA-1, (b): WA-2, (c): SW-1.