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DAMAGE IDENTIFICATION OF SMALL HOUSES IN DIFFERENT SEISMIC REGIONS

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Abstract: *Comparison of seismic resistance capacity of masonry structures with site dependent seismic demand is presented. Five building types are selected and subjected to the analysis. Push-over analyses have been performed assuming non-linear behaviour of individual walls. Five different damage grades have been identified starting with first crack on a wall up to the total collapse of the structure.*

Keywords: Seismic risk assessment, damage identification, push-over analysis, non-linear analysis.

1. Introduction

Although design analyzes can be linear in seismic codes, such as response spectrum (RS) methods, while in practice the situation is in many cases much more complicated to be described only by RS analysis. The RS method does not provide accurate information about critical cross-sections or the type and extent of damage a structure may suffer after an earthquake. The degrees of damage are described quite clearly in (Lang, 2002; Lang, 2004; Okada, 2000). Many studies have been carried out (Corsanego, 1994; Okada, 2000; Giovinazzi, 2004; Kegyes-Brassai, 2007), etc. focusing on the vulnerability of existing buildings. Vulnerability is expressed by functions or parameters that can be obtained either by statistical studies of damaged buildings in earthquake-affected areas or by simulations using numerical or analytical methods. This paper uses simulations using a combination of numerical and analytical methods according to (Lang, 2002) and (Lang, 2004). Computer code was prepared to perform these simplified push-over analyzes on small masonry (or concrete) buildings. Conditions and results in different regions of Central Europe and Central America were compared.

2. Seismic vulnerability

The seismic vulnerability of selected small houses is expressed in such a way that for the relevant buildings located in a specific area, the degree of their damage after an earthquake is calculated, and accordingly, the house buildings are classified into five categories of damage, starting with the lightly damaged building. (DG1) to the level (DG5) representing the complete destruction of the building (Fig. 4).

2.1. Central Europe

Typical family houses in Central Europe region are assumed, where the seismic risk map is taken, e.g. for Slovakia (Fig. 1a) according to (NA STN EN1998-1, 2005) or (Madarás, 2008). The PGA in selected region close to the city Trnava reaches values up to 1.1 ms^{-2}. Structural types were selected according to catalogue projects (Euroline, 2012).

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The most ordinary types of buildings in the region are unreinforced masonry buildings. Evaluating objects with significant building populations for the selected area is more interesting than the assessment of individual buildings. Vulnerability functions of existing buildings are established with regard to its earthquake response.

2.2. Central America

One of the countries most affected by seismicity is Mexico (Fig. 1b). Maximum peak ground acceleration in Mexico reaches the value of 5.6 ms^{-2}. This value is five times larger than in Central Europe. The seismic risk is much higher; much higher consequences are expected.

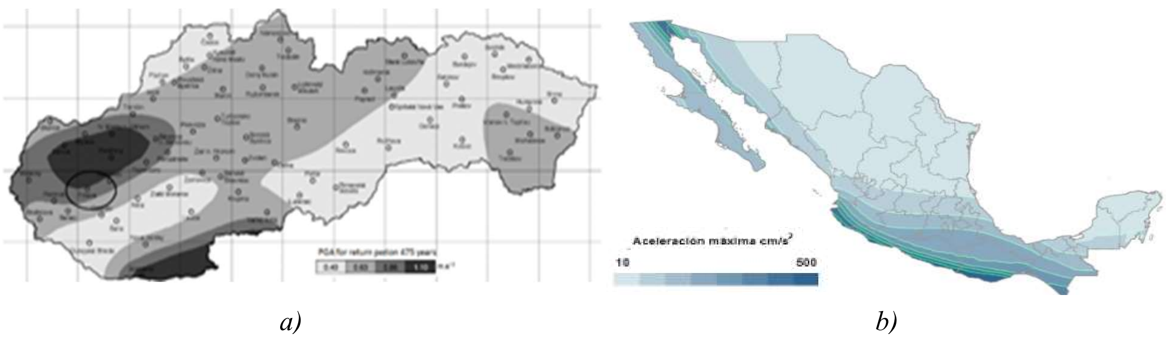


Fig. 1: Seismic risk maps: a) Slovakia (STN EN 1998-1, 2012), b) Mexico.

2.3. Typical small houses

Five typical family houses often built in Central Europe (Fig. 2) and Mexico (Fig. 3b) were selected. Constructions from Fig. 2 have the same wall systems (Fig. 3b) as the houses assumed according to Fig. 3a. Family houses are built mainly in villages in the region of Central Europe, and in America this type of house is common everywhere in cities, but also in villages. In Central Europe, the region in Slovakia near the city of Trnava was selected, in Central America - the state of Mexico, it is the most important area of the southern coast of the Pacific Ocean. There is constant seismic activity on the coast of Guerrero and Oaxaca, several seismic events in this area have led to earthquakes with significant acceleration in the center of the country. The 1985 and 2017 earthquakes in this region saw the collapse of many buildings and significant damage to buildings and houses.

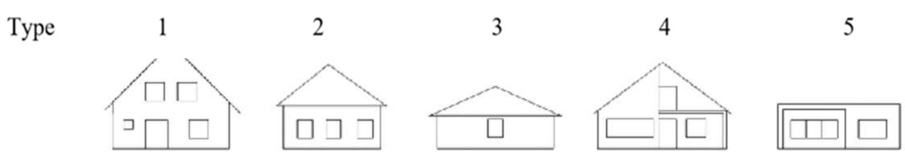


Fig. 2: Five selected types of houses in Europe - Slovakia with plan view according to Fig. 3b.

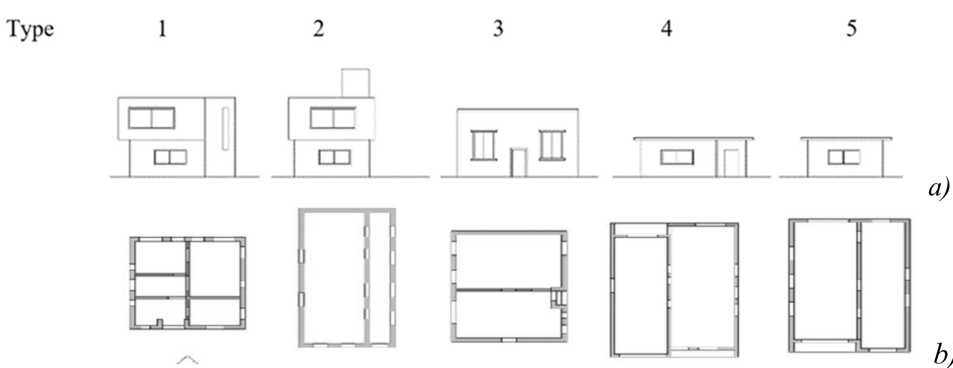


Fig. 3: Typical houses constructed in region Mexico a) and b) wall system in plan view.

2.4. Damage description

Five damage categories (Fig. 4) have been introduced according to (Okada, 2000).

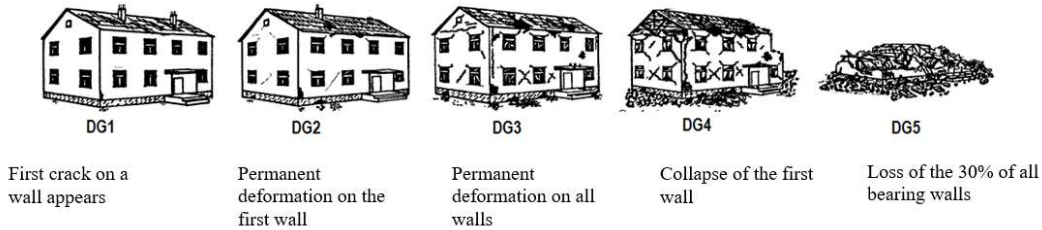


Fig. 4: Damage grades according to Macroseismic Intensity Scale 1998 (Okada, 2000).

3. Analysis

Simplified non-linear push-over analyses have been used. Details of the quasi non-linear solution based on seismic demand and capacity comparison are described in (Lang, 2002) and (Sokol, 2013). The entire process is automated using a prepared computer code. First, it is necessary to identify all structural walls. It is essential is to assess the behavior of the structural system (if the wall acts like a frame or wall system). The capacity curves of individual walls and their bilinear approximations are summing up to get the relationship between total shear forces V_s vs. top displacement Δ, so that is possible to obtain the capacity curve of the structure (Fig. 5), where the damage grades (DG1 to DG5) can be easily identified.

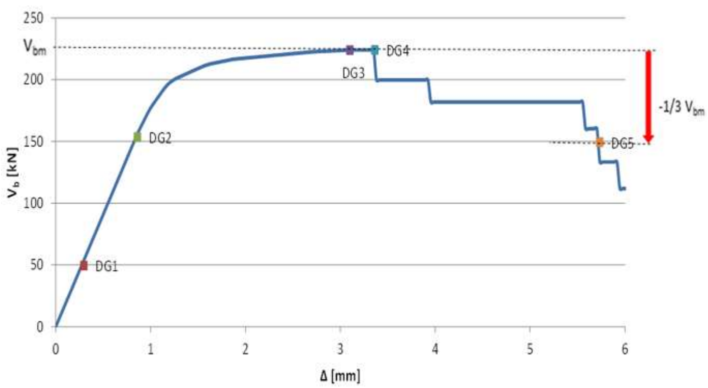
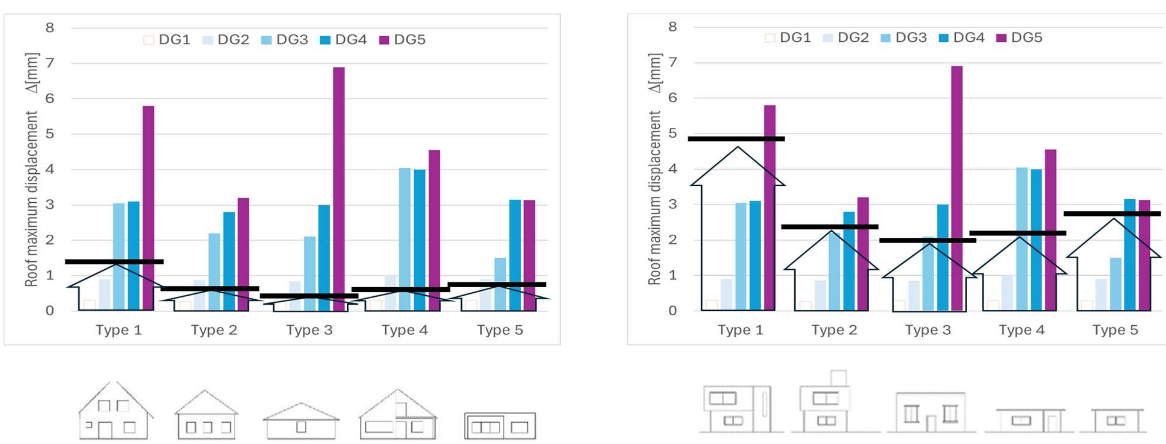


Fig. 5: Capacity curve of structure (Sokol, 2013).

4. Seismic risk assessment

Using analysis automation, we can create simple risk scenarios assessment for a region (Fig. 6).



a) Slovakia (PGA = 1.1 m.s^{-2}, soil category C) b) Mexico (PGA = 5.6 m.s^{-2}, soil category C)

Fig. 6: Seismic performance of typical small houses.

Horizontal bold line (in Fig. 6 drawn in black at the top of a house scheme) represents the seismic displacement demand expressed in mm. If one of the five blue columns representing structural capacity ends under this line it means the corresponding damage grade has already been reached, e.g. for the house (Type 1) in Slovakia the damage grade DG2 Fig. 6a has been reached while the same type in Mexico can offer by damage grade DG4 Fig. 6b. In Slovakia an earthquake can affect such amount of buildings where 20 % of population live (Fig. 6a). In the rest of Slovakia even smaller damages are expected, because of the smaller value of design ground acceleration. From all selected types only masonry multi storey building (Type 1) can suffer from damage grade DG2 which is the permanent deformation of first structural wall. No collapse is threatened.

The damage scenarios for different structural types of buildings in Mexico are shown in Fig. 6b. Earthquake can affect 90 % of Mexican population. In Mexico all types of assumed buildings can suffer from severe damages, starting with DG 3 (Permanent deformation on all walls) up to DG 5 (Loss of the 30 % of all bearing walls).

5. Conclusions

The most common types of simple masonry constructions were selected according to available statistical data. The quasi-nonlinear response of these buildings was analyzed. The most vulnerable regions of Slovakia and Mexico according to seismic risk maps were taken into account. Earthquake demand was compared with structural capacity. The vulnerability of five selected building types was presented, including a description of the damage scenario. Family houses in Slovakia will not be greatly affected by the earthquake, expect small cracks on the walls. On the other hand, most Mexican single-family homes are at risk of more serious damage, possibly ending in collapse.

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