FIRST RESULTS OF FRAGILITY CURVES OF SINGLE STORY,
DOUBLE BAY UNREINFORCED MASONRY BUILDINGS IN LORCA

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Abstract.

After the seism that took place in Lorca, there is a need to study the vulnerability and fragility of the built heritage in this town and other highly seismic towns in Spain.

This article aims to calculate the seismic performance and vulnerability of single story and double bay unreinforced masonry buildings (URM buildings), located in the town of Lorca, Murcia (Spain). This article focuses on the structural vulnerability of the building, excluding urbanistic factors.

The Capacity-Demand Diagram method will be applied in order to calculate the estimated damage due to seismic action. A non-linear static analysis is carried out, applying an increasing displacement in the upper part of the wall up until the structure collapses (pushover) in a three-dimensional model. The seism is considered in the two main directions, characterizing the uncertainty of the parameters of the structural model (geometry and resistance) through distribution functions that will be further explained in the main body of the article.

The capacity curves for the given typology are obtained. By crossing the obtained data with the seismic demand spectrum to deduce the behavior of the given typology in different kinds of earthquakes (from the lower intensity, most common ones to less frequent but more intense ones).

This capacity curve is compared to the demand spectrum of the seism that took place in Lorca on May 11th, 2011 to deduce the performance point of the chosen typology.

From the values of those curves, fragility curves are obtained. These curves are useful when evaluating the seismic risk of this structural typology, and afterwards, when proposing new restoration strategies that offer solutions to the deficiencies detected and specify actions that lessen the seismic risk.

Key words: Structures, Fragility curves, Seismic vulnerability, Masonry buildings, Nonlinear analysis, Lorca.
1 INTRODUCTION

The study of fragility has proven to be a useful tool for the assessment of seismic risk in structures. It can be used for evaluating the probable seismic loses. And allows to decide or propose different methods to reduce the seismic risk. This article uses a 3D model to represent the non-linear behaviour of the given structural typology: single story, double bay URM building type of structures. Later on, the procedure is showed, the capacity and demand spectra are obtained and ultimately the fragility curves.

2 STRUCTURAL TYPOLOGY

Nowadays, in Lorca, the most common building typology is reinforced concrete buildings, it is studied in other publications [8]. However, URM buildings show higher vulnerability indexes both in Lorca [2] as well as in Europe [7]. This article focusses in the M3.1L (according to Risk-UE project’s typology matrix): URM buildings (either stonework or brickwork), wooden slabs, low-rise, 1 or 2 stories, and height 6m and lower. M3.1 typology is the most commonly spread in Lorca up until 1945 [2], when there was no seismic normative in Spain. It is the most common building construction in the old town, and most of them got 0 to 2 degree damage [2]. The study and later layout of capacity and fragility curves for URM buildings are new.

3 STRUCTURAL MODEL

A building in Lorca is chosen, of those we have enough information of (Figure 1). It is a brickwork made, single story, double bay house, that did not suffer significative damage during 2011’s earthquake.

To make this particular building representative of a whole typology, we consider the uncertainty of the parameters of its structural model: its geometry and the resistance of the masonry walls as showed.

3.1 Size of the model

Masonry buildings in Lorca are in the oldest neighbourhoods. The urban layout is closed blocks with housing between dividing walls. In order to bring light into the inner rooms there is a need for an inner courtyard.

We consult Lorca’s cadastre in order to consider the uncertainty of the sizes of the given typology. Different housing dimensions are analysed in three different neighbourhoods in which the buildings are mainly masonry buildings Figure 2.
A wide variety of measurements and façade width, construction length are obtained. They are represented with a blue line in Figure 3 and Figure 4.

The number of case study examples (140) is adapted to this distribution, represented in red columns in both in Figure 3 and Figure 4.

3.2 Material

To characterize the variability of resistances, two representative values are taken ($f_k = 2$ y 4 N/mm²) from the Spanish building code [4]. Currently the study is being conducted about 300 different examples with more materials that the ones used here.

Resistance to mechanical traction is considered to be a $10^6$ of the resistance to compression. The elasticity module is established according to the resistance as $E=1000f_k$.

3.3 Elements

A non-linear analysis is conducted, with an increase on the shifting in the top of the wall until total collapse of the structure (pushover). ANSYS version 18.2 is the software chosen to do the analysis.

The non-linear behaviour is modelled with SOLID65 elements. This element is used for the 3D modelling of walls of unreinforced masonry. The solid is capable of cracking in tension (in three orthogonal directions), crushing in compression. Also, it is capable of plastic deformation, and creep [1].

The studied typology has wooden horizontal structures that, due to the lack of a proper union, cannot be analysed as a stiff diaphragm. So, the model is done without a horizontal structure. Horizontal structures are considered to be done in non-aligned orientations in order to apply the gravity load in the roof.

4 CAPACITY CURVES

Figure 5: Capacity spectra along the x axis. In blue $f_k=4$N/mm² and in orange $f_k=2$N/mm².
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4 Figure 6: Capacity spectra along the Y axis. In blue $f_k=4\text{N/mm}^2$ and in orange $f_k=2\text{N/mm}^2$.

The LM2 RISK-UE’s procedure was followed in order to do the analysis. Capacity curves are obtained for seismic action parallel to X and Y axis (Figure 6 and Figure 6).

From the medium capacity curve in both directions, we can draw the bilinear approximation of the same energy deformation (Figure 7). The following values are obtained: yield point: $S_{dy}=9.63\times10^{-4} \text{[m]}$, $S_{ay}=0.58\text{g}$; ultimate point: $S_{du}=3.13\times10^{-3} \text{[m]}$, $S_{au}=0.79\text{g}$.

4.1 Comparison with the demand spectrum

Capacity and demand spectrum are represented by the spectral pseudo-acceleration (relative to gravity) in the Y axis and pseudo spectral shifting in the X axis (Figure 8 and Figure 9).

Demand spectra are obtained according to the Spanish legislation [5] with the map of seismic acceleration, last version by IGN, 2015 [3]. Four spectra are obtained, according to the earthquake’s return period: 75, 225, 475 and 2475 years.

5 FRAGILITY CURVES AS VULNERABILITY INDICATIVES

The fragility of the typology is a set of curves that are represented in the coordinate axes for that the Y axis represents spectral displacements ($S_d$) and the X axis the chance of finding ($P[D_s=ds]$) or exceeding ($P[D_s>ds]$) a particular damage stage.

Each curve is characterized by the average value of the spectral shifting, $S_{d,ds}$, and the lognormal deviation, $\beta_{Sd}$, determined by ductility ($\mu_u$) as shown in
Table 1.

<table>
<thead>
<tr>
<th>Damage State (ds)</th>
<th>S_{d,ds}</th>
<th>\beta_{Sd}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight</td>
<td>0.7 D_y</td>
<td>\beta_{Sd1} = 0.25+0.07\ln(\mu_u)</td>
</tr>
<tr>
<td>Moderate</td>
<td>D_y</td>
<td>\beta_{Sd2} = 0.20+0.18\ln(\mu_u)</td>
</tr>
<tr>
<td>Extensive</td>
<td>D_y+0.25(D_u-D_y), \beta_{Sd3} = 0.10+0.040\ln(\mu_u)</td>
<td></td>
</tr>
<tr>
<td>Complete</td>
<td>D_u</td>
<td>\beta_{Sd4} = 0.15+0.50\ln(\mu_u)</td>
</tr>
</tbody>
</table>

Table 1: Damage stages according to Risk-UE, shifting in the head and beta value.

Figure 9: Fragility curves

6 CONCLUSIONS

The obtained results may differ from the real response due to the imperfections or flaws of the construction that have not been taken into account.

Seismic behaviour of URM buildings is quite sensitive to the wall’s out-of-plane stiffness.

Parameters published by RISK-UE for fragility curves do not include the studied typology. The obtained results when this investigation comes to an end can be used to complete the ones published within the Risk-UE project for URM buildings.

The structural modelling method introduced in this study can be efficiently applied for the development of fragility curves of URM buildings.

REFERENCES


