Seismic Damage Assessment for Thin-walled Reinforced Concrete Buildings in Urban Areas In Peru

J. Velásquez¹, S. López², C. Rodríguez³, J. Acero³, G. Ponce⁴

¹Professor, Dept. of Civil Engineering, Pontifical Catholic University of Peru
²Master Student, Dept. of Civil Engineering, Pontifical Catholic University of Peru
³Lecturer, Dept. of Civil Engineering, Pontifical Catholic University of Peru
⁴Professor, Dept. of Civil Engineering, Catholic University of Santiago de Guayaquil (Ecuador)
Seismic Damage Assessment for Thin-walled Reinforced Concrete Buildings in Urban Areas in Peru
Perú is constantly subjected to severe earthquakes due to its close location to the ring of fire.
Thin-walled reinforced concrete dwellings have been built in Peru very commonly since the 90s. However, many problems have been reported during the construction process and we cannot predict their performance.

Typical Ductility-Limited Shear Wall Building (DLSWB) in Peru
This paper shows a probabilistic methodology for the development of fragility curves in single-family dwellings. These curves are generated by a Monte Carlo simulation technique and for 2 types of buildings.
ESTIMATION OF THE SEISMIC VULNERABILITY
Type 1: 2-story 3-block building and T1 layout considers a 2-story building composed by three attached blocks

Type 2: 3-story 1-block building T2 layout consists of a single 3-story independent block. These are the most common layouts offered by the housing market since the 90s
Synthetic signals were obtained randomly with the program SIMQKE (Vanmarke and Gasparini 1976), considering that their response spectrum is compatible with the elastic design spectrum of the Seismic Peruvian Code.

Response spectra generated by SIMQKE for synthetic signals for PGA of 0.45g

Synthetic signals for PGA of 0.45g on rigid soil.
The structural parameters considered for the DLSWB are the compressive strength of the concrete $f'_c$ and the yield stress of the reinforcing steel $f_y$. 

*Mean = 480.7 MPa, Std.Dev = 25.1 MPa, Number = 100*

*Mean = 22.6 MPa, Std.Dev = 4.1 MPa, Number = 100*
The damage states were defined under the guidelines of FEMA 356 (2000) and ASCE 41-06 (2007), and were complemented with experimental results from previous research that reflect the characteristics of the construction process, the quality of the employed manpower and the typical wall dimensions.

Table 1. Damage states for Limited-Ductility Shear Wall Buildings (DLSWB).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IO</th>
<th>LS</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear strain in coupling beams</td>
<td>0.005</td>
<td>0.010</td>
<td>0.020</td>
</tr>
<tr>
<td>Rotation of the plastic hinge region located at the base of the walls (rad)</td>
<td>0.002</td>
<td>0.004</td>
<td>0.008</td>
</tr>
<tr>
<td>Maximum interstory drift ratio</td>
<td>0.25%</td>
<td>0.375%</td>
<td>0.50%</td>
</tr>
</tbody>
</table>

IO: Immediate Occupancy  LS: Life Safety  CP: Collapse Prevention
At the laboratory of the PUCP, a total of 9 tests were carried out for natural scale ductility-limited shear walls (2.00 x 0.10 x 2.40 m) with conventional reinforcement with the purpose of studying their seismic performance.
The model of the structure was considered as a group of these calibrated elements, properly modelled in the tests. Therefore, the responses obtained against the seismic demand should be acceptable.
DEVELOPMENT OF FRAGILITY CURVES
For each model analyzed, the history of drifts was obtained and the maximum drift was extracted.

Response of drifts in time, using Perform 3D
The histogram of the maximum drifts for each level of seismic intensity is calculated to obtain the cumulative probability distribution.

### Valores definidos para cada nivel de comportamiento

<table>
<thead>
<tr>
<th>Número</th>
<th>Parámetro</th>
<th>IO</th>
<th>LS</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Distorsión máxima de entrepiso (%)</td>
<td>0.25%</td>
<td>0.375%</td>
<td>0.50%</td>
</tr>
</tbody>
</table>

Distribución de probabilidad acumulada de daño - Tipología 2
With the discrete damage states for MDL houses and by adjusting to a lognormal function, fragility curves are obtained.

- For a probability of exceedance of 50%, fragility curves for Type 1 building (2-story 3-block) show a very wide range of pseudo-accelerations between Slight Damage and Extensive Damage (1.9g to 4.6g).
- This is due to the fact that these buildings have only 2 stories and the 3 blocks attached to each other might cause the delay the stiffness degradation and strength loss due to the assembly of the building.
The fragility curves for the Type 2 building (3-story 1-block), for a probability of exceedance of 50%, show a smaller range of pseudo-accelerations between Slight Damage and Extensive Damage (3.2g to 4.4g). These walls are slender because the ratio between height and length is around 2. This might be the reason of the delay of the flexure failure. However, once this failure begins stiffness degradation and strength loss rapidly accelerates.