ANNUALIZED EARTHQUAKE LOSS ESTIMATIONS FOR HIGH-CODE BUILDINGS IN ISTANBUL

U. Hancilar¹, K. Sesetyan² and E. Cakti³

ABSTRACT

15% of the buildings in Istanbul’s current building inventory are tagged as mid- and high-rise, high-code buildings assuming that they were designed in accordance with the provisions of Turkish Earthquake Resistant Design Code (1998). They are reinforced concrete (RC) moment-resisting frame type structures with minimum five up to nineteen floors, constructed in 2000s. In this study, we perform spectral capacity based damage assessments under probabilistic ground motions for different return periods for the estimation of annualized earthquake losses (AEL) and loss ratios (AELR) associated with post-2000 buildings in the city. Damage analyses are realized for three different building capacity and fragility models. Probabilistic loss curves for each model are developed and estimated AELs and AELRs are compared.

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15% of the buildings in Istanbul's current building inventory are tagged as mid- and high-rise, high-code buildings assuming that they were designed in accordance with the provisions of Turkish Earthquake Resistant Design Code (1998). They are reinforced concrete (RC) moment-resisting frame type structures with minimum five up to nineteen floors, constructed in 2000s. In this study, we perform spectral capacity based damage assessments under probabilistic ground motions for different return periods for the estimation of annualized earthquake losses (AEL) and loss ratios (AELR) associated with post-2000 buildings in the city. Damage analyses are realized for three different building capacity and fragility models. Probabilistic loss curves for each model are developed and estimated AELs and AELRs are compared.

Extended Abstract

In this study, we present annualized earthquake loss (AEL) and annualized earthquake loss ratio (AELR) estimations by alternative damage models, i.e. capacity and fragility functions, for high-code buildings in Istanbul. Probabilistic loss curves for each model are developed and the resulting AELs and AELRs are presented.

The latest building inventory of Istanbul compiled by the Istanbul Metropolitan Municipality [1] comprises 0.005-degree regular grids and contains about 180,000 buildings constructed in 2000s, which are tagged as mid- and high rise, high-code buildings. Those buildings are reinforced concrete (RC) moment-resisting frame type structures with minimum five up to nineteen floors. It is assumed they were designed in accordance with the provisions of Turkish

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Earthquake Resistant Design Code (1998) [2]. Breakdowns of the numbers of buildings considered in damage analyses are 120,161 and 60,257 for mid-rise (5 to 8 floors) and high-rise (9 to 19 floors) classes, respectively.

Damage analyses are realized under site-specific, probabilistic ground motions for eight return periods, i.e. 100, 225, 475, 750, 975, 1,500, 1,975 and 2,475 years. Ground motion computations for the same grid resolution as of the building inventory rely on the probabilistic hazard assessment model by Sesetyan et al. (2016) [3] which incorporates an area source model with all recently compiled data on seismicity and active faulting, a set of recently developed GMPEs for both active shallow crustal and subduction regimes as well as $V_{s,30}$ data obtained from micro-zonation study conducted in IMM-2009 [2].

For each ground motion input, three sets of damage analyses by alternating fragility and capacity functions are conducted: i) Expert judgment based capacity and fragility functions as of the study of Probable Earthquake Losses for Istanbul (IMM-2009); [2]; ii) High-code seismic design level structural capacity and fragility functions for RC frame building typologies provided in HAZUS-MH MR4 (2004) [4]; and iii) Structural capacity and fragility functions for code complying RC frames derived through nonlinear dynamic analyses by Hancilar and Cakti (2015) [5]. Adopted capacity and fragility curves for each building class are presented in Fig.s 1-3.

Structural damage and direct monetary loss estimations are computed with ELER (Earthquake Loss Estimation Routine) software package [6, 7 and 8] that implements spectral acceleration-displacement based damage estimation similarly to HAZUS methodology [4]. In the computation of direct economic losses, we only take into account the cost to replace or to repair the building’s structural system. For the building classes under consideration, we calculate buildings’ values based on official unit construction costs for different building classes provided by the Ministry of Environment and Urbanization [9]. We rely on the same loss ratios as used in the IMM-2009 study: 10%, 40%, 80% and 100% for slight, moderate, extensive and complete damage states, respectively.

AELs and AELRs are calculated as suggested by FEMA P-366 [10]. Probabilistic loss curves are presented in Fig. 4. Estimated AELs and AELRs are compared in Table 1. While IMM-2009 model produces the lowest AEL and AELR, the estimations by HAZUS-MH MR4 model are double of them and Hancilar&Cakti (2015) model falls in between.

![Figure 1. Capacity curves for mid- and high-rise buildings.](image-url)
Figure 2. Fragility curves for mid-rise (5 to 8 floors) buildings.

Figure 3. Fragility curves for high-rise (9 to 19 floors) buildings.
Table 1. Comparison of estimated AELs and AELRs.

<table>
<thead>
<tr>
<th>Model</th>
<th>AEL (USD Million)</th>
<th>AELR</th>
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<tbody>
<tr>
<td>IMM-2009</td>
<td>55.2</td>
<td>0.0006</td>
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<tr>
<td>HAZUS-MH MR4</td>
<td>112.6</td>
<td>0.0012</td>
</tr>
<tr>
<td>Hancilar&amp;Cakti (2015)</td>
<td>91.9</td>
<td>0.0010</td>
</tr>
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References