GENERALIZED FRAGILITY CURVES FOR EARTHQUAKE INSURANCE PREMIUMS

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submitted by **MELİS AYSUN EKİCİ** in partial fulfillment of the requirements for the degree of **Master of Science in Earthquake Studies Department, Middle East Technical University** by,

Prof. Dr. M. Gülbin Dural Ünver _____________________
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Melih Ersoy _____________________
Head of Department, **Earthquake Studies**

Prof. Dr. Ahmet Yakut _____________________
Supervisor, **Civil Engineering Dept., METU**

Assoc. Prof. Dr. Sevtap Kestel _____________________
Co-Advisor, **Actuarial Sciences Program, IAM, METU**

Examining Committee Members:

Prof. Dr. Ahmet Yakut _____________________
Civil Engineering Dept., METU

Assoc. Prof. Dr. Sevtap Kestel _____________________
Actuarial Sciences Program, IAM, METU

Prof. Dr. Murat Altuğ Erberik _____________________
Civil Engineering Dept., METU

Assoc. Prof. Dr. Alp Caner _____________________
Civil Engineering Dept., METU

Assoc. Prof. Dr. Sabahattin Aykaç _____________________
Civil Engineering Dept., Gazi University

DATE: 20.05.2015

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name : Melis Aysun Ekici

Signature :

ABSTRACT

GENERALIZED FRAGILITY CURVES FOR EARTHQUAKE INSURANCE PREMIUMS

Ekici, Melis Aysun

M.S., Department of Earthquake Studies

Supervisor: Prof. Dr. Ahmet Yakut

Co-Supervisor: Assoc. Prof. Dr. Sevtap Kestel

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Since there are three major earthquake lines on Anatolia which are North Anatolian Fault, East Anatolian Fault and West Anatolian Fault, earthquake is one of the most important issue for Turkey. Following the damages of Kocaeli (1999) Earthquake to our economy, importance of earthquake insurance was understood and therefore Compulsory Earthquake Insurance was put into action. However, for the calculation of insurance premiums which were specified by Turkish Catastrophe Insurance Pool (TCIP), only type of buildings and Earthquake Zones are considered that are not adequate parameters for determining the premiums. In this study, by utilizing fragility curves of the previous studies which were done for Turkish Reinforced Concrete and Masonry buildings, representative curves involving these types of buildings were suggested and new insurance premiums were recalculated by using these curves. In the first part, fragility curves taken from the previous studies were classified according to type of building (Reinforced Concrete Frame, Reinforced Concrete Dual or Masonry) and the height of building (Low-rise, Mid-rise and High-rise). Ground motion parameter is chosen as PGV (cm/s) for the Reinforced Concrete buildings and PGA(g) (m/s^2) for the Masonry buildings. Fragility curves were determined according to Immediate Occupancy, Life Safety and Collapse Prevention performance levels. In the second part, various mathematical methods were applied on classified curves and representative fragility curves were obtained. Finally, by using the representative curves resulting from Lognormal Cumulative Distribution Function, new insurance premiums were calculated for Reinforced Concrete and

Masonry buildings in Istanbul and results were compared with the current premiums of TCIP.

Keywords: Fragility Curves, Generalized Fragility Curves, Insurance Premiums, RC Frame, RC Dual, Masonry Buildings

ÖZ

DEPREM SİGORTA PRİMLERİ İÇİN GENELLEŞTİRİLMİŞ KIRILGANLIK EĞRİLERİ

Ekici, Melis Aysun
Yüksek Lisans, Deprem Çalışmaları Bölümü
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Üzerinde KAF, DAF ve BAF olmak üzere üç büyük fay hattı bulunduğundan dolayı, depremler Türkiye için en önemli katastrofik konulardan birisidir. 1999 Kocaeli Depremi'nin ekonomimize verdiği zararların ardından, deprem sigortalarının önemi anlaşılmıştır ve bundan dolayı Zorunlu Deprem Sigortası uygulamasına geçilmiştir. Ancak DASK tarafından belirlenen sigorta primleri hesabında sadece yapı tipi ve Deprem Risk Bölgesi dikkate alınmaktadır ve bu parametreler yeterli değildir. Bu çalışmada, Türkiye'deki betonarme ve yığma binalar için geçmişte yapılan çalışmalarda bulunan kırılganlık eğrilerinden yararlanılarak, bu yapı tiplerini kapsayan genel eğriler önerilmiştir ve bu kırılganlık eğrileri kullanılarak sigorta primleri yeniden hesaplanmıştır. İlk kısımda, çalışmalardaki kırılganlık eğrileri yapı tipine göre (betonarme ve yığma) ve bina yüksekliklerine göre (alçak, orta ve yüksek katlı) sınıflandırılmıştır. Yer hareketi şiddeti betonarme binalar için PGV(cm/s), yığma binalar için ise PGA(g) (m/s^2) olarak seçilmiştir. Kırılganlık eğrileri, Hemen Kullanım, Can Güvenliği ve Göçme Öncesi hasar düzeyleri kullanılarak ayrıştırılmıştır. İkinci kısımda, sınıflandırılan eğrilere çeşitli matematiksel yöntemler uygulanılarak genel kırılganlık eğrileri bulunmuştur. Son olarak bu yöntemlerden en uygun olan sonucu veren Standart Logaritmik Toplam Fonksiyonu Metodu kullanılarak İstanbul'daki binalar için yeni sigorta prim hesabı yapılmıştır ve sonuçlar güncel DASK primleri ile karşılaştırılmıştır.

Anahtar Kelimeler: Kırılganlık Eğrileri, Genelleştirilmiş Kırılganlık Eğrileri, Sigorta Primleri, Betonarme, Yığma Binalar

To my family…

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CHAPTER 1

INTRODUCTION

Earthquake is one of the most compelling challenges in terms of catastrophic losses in Turkey. By considering history of the movements of active North Anatolian Fault Zone (NAF), inadequate engineering or non-engineering applications during construction of structures caused not only many deaths, permanent physical and psychological injuries of thousands of people but also economic losses for government. Although Erzincan (1992), Izmit (1999) Earthquake and Van (2011) Earthquakes losses show that the seismic danger of NAF is known especially for the last 30 years, immature earthquake insurance is applied to Reinforced Concrete and masonry buildings in Turkey.

To evaluate the risk of Turkish building stock and to determine losses, many academic studies have been done by different researchers for years. In the literature, for the seismic loss estimation, it is common to use fragility curves of buildings. Fragility curves represent the probability of exceeding a damage limit state for a given structure type subjected to a seismic excitation (Akkar et al., 2005). The most common intensity measure types for the curves are peak ground acceleration (PGA), peak ground velocity (PGV), spectral displacement (S_d), spectral acceleration (S_a) and drift ratio. Limit states or damage states can be different according to chosen methodology. For example, in TEC 2007 (Turkish Earthquake Code, 2007) there are three performance states which are Immediate Occupancy, Life Safety, and Collapse Prevention. However, in ATC-13 (Applied Technology Council, 1985) there are five damage states which are Slight, Light, Moderate, Heavy, and Major. Fragility curves for the buildings generally change according to the construction material and height of the building.

However, there is still lack of interest to recalculate earthquake insurance premiums in contrast to extremely good, detailed and unique insurance system of developed countries. The reason of the importance of uniqueness depends on a variety of conditions for each country which can be summarized as geographical, economic, social and cultural diversities. Due to the fact that these diversities, disasters (natural or man-made disasters) and their effects also show variety from country to country and developed countries are aware of these diversities and they create an insurance system by considering economic consequences of these disasters. As it is mentioned above, the most important disaster for Turkey is earthquake but it has an ordinary earthquake insurance which only depends on material type of buildings and seismic zones. According to Compulsory Earthquake Insurance Tariff and Instructions which were created by TCIP (Turkish Catastrophe Insurance Pool, 2013), there are 15 tariff rates depending on 5 risk zones determined by Turkey's Earthquake Regions Map prepared by the Ministry of Environment and Urban Planning and 3 different building styles. The insurance premiums are calculated by multiplying the sum insured with tariff rates which are shown in Table 5.1. However, seismic behavior of buildings is not considered for the calculation of tariff rates. In this study, generalized fragility curves are used to recalculate earthquake insurance premiums.

1.1 Literature Survey

As it is mentioned in the introduction part, several studies have been carried out for Turkey. The recognizable studies about fragility curves for Turkey are listed according to the building types

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1.1.1 Reinforced Concrete Frame Buildings

In the study of Akkar et al. (2005), 32 represented buildings of Turkish Reinforced Concrete frame type having 2- to 5 -stories were obtained. The response of building was idealized as SDOF system response by using FEMA 356 (ASCE, 2000). Nonlinear dynamic analysis was employed. Intensity measure is taken as PGV due to better-correlated data results. Analytical method was conducted to obtain fragility curves, and the probability distribution function was chosen as the standard lognormal distribution. Three performance limits were chosen which are Immediate Occupancy, Life Safety and Collapse Prevention. Calibration was made by using probabilities of exceeding moderate and severe damage states of calculated and observed data of Düzce case for two to five story buildings.

In the article by Ay et al. (2006), 5, 7 and 9 story RC Frame structures were examined. The response of building was modeled as MDOF and pushover analysis and time history analysis were used to find capacities and demand statistics, respectively. The intensity measure was chosen as PGV. The frame structures were classified as poor and superior due to their construction practice and behavior during earthquakes. Analytical method was employed to obtain fragility curves and the probability distribution function was chosen as the standard lognormal distribution.

In the study of Erberik (2008a), typical RC Frame Low-rise and Mid-rise buildings in Turkey, were examined by considering Düzce damage database after Düzce (1999) Earthquake. The response of building was idealized as SDOF system by using FEMA 356. Nonlinear time history analysis was used. Intensity measure type was chosen as PGV. Analytical method was applied to obtain fragility curves, and the probability distribution function was selected as the lognormal cumulative distribution function. Three limit states were used which are serviceability limit state, damage control limit state and Collapse Prevention limit state.

Korkmaz and Johnson (2007) studied the probabilistic approach for the represented 7 story RC concrete frame buildings to define seismic structural behavior. The building was idealized as SDOF system by using FEMA 440 (American Society of Civil Engineers, 2005). Nonlinear pushover and time history analyses were performed. Intensity measure types used are PGA, PGV, and PGD. To obtain fragility curves, analytical method was used, and the probability distribution function is chosen as the standard lognormal distribution by using Hwang's Methodology (Hwang & Jaws, 1989). Only Collapse Prevention limit state was considered.

In the study of Ozmen et al. (2010), vulnerability of 2, 4 and 7 story RC Frame buildings were investigated which were built according to TEC 1975 and TEC 1998 by using fragility curves. The building is modeled as SDOF and nonlinear dynamic time history analysis is used for 96 equivalent SDOF models according to ATC-40 and FEMA 440. Intensity measure type was chosen as S_d. In order to obtain fragility curves, analytical method was implemented, and the probability distribution function was chosen as the standard lognormal distribution. Three limit states were used which are named as Immediate Occupancy, Life Safety and Collapse Prevention.

Kircil and Polat (2006) generated fragility curves for Mid-rise RC Frame buildings in Istanbul. 3, 5 and 7 story buildings were designed according to 1975 version of Turkish seismic code. 2D modeling was used for the response of buildings, and nonlinear dynamic analysis was used to generate fragility curves. Intensity measure type was chosen as S_d, S_a and PGA. To obtain fragility curves, analytical method was applied, and the probability distribution function was selected as the standard lognormal distribution. Three limit states were used which are Immediate Occupancy, Life Safety and Collapse Prevention depending on FEMA 356 and ATC-40.

1.1.2 RC Frame and Dual Structures

In the study of Smyth et al. (2004), benefit cost analysis was performed by using probabilistic methodology for a 5 story representative RC Frame apartment building in Turkey. Nonlinear dynamic analysis was used to generate fragility curves. Intensity measure type was chosen as PGA. To obtain fragility curves, analytical method was conducted, and the probability distribution function was selected as the standard lognormal distribution. There were four performance levels which are slight, moderate, extensive and complete which depends on HAZUS methodology.

1.1.3 Masonry Structures

In the article by Erberik (2008b), in-plane failure modes of Masonry buildings in Turkey was examined by constructing fragility curves to determine damage of buildings after Dinar (1995) Earthquake. Nonlinear static (pushover for capacity) and nonlinear dynamic (time history for base shear demand) analysis were used to generate fragility curves by considering data of past earthquakes. 140 rural type buildings and 69 urban-type Masonry buildings were studied, and they were classified according to the number of stories, load-bearing wall material and regularity in plan. Intensity measure type was chosen as PGA and only failure damage state of the buildings was investigated.

In the study of Ceran and Erberik (2013), fragility curve analysis of Unreinforced Low-rise Masonry buildings with the behavior of in-plane and out of plane was made. In plane behavior determination, damage in Dinar (1995) Earthquake and in out of plane behavior determination, the observed damage in Elazığ (2010) Earthquake were used. Intensity measure type was chosen as PGA. For the calculation of fragility curves, equivalent lateral load method was used. Two limit states were used which are serviceability limit state and ultimate limit state. Calibration was made by using estimated and observed data of Elazığ (2010) Earthquake for Low-rise Masonry buildings.

In the report by D'Ayala and Kishali (2012), FaMIVE procedure was applied to Low-rise Masonry buildings in rural and urban areas of Turkey data of which was taken from METU and relevant Masonry buildings in Turkey (Erberik, 2008b; Erberik, 2010) and resulted fragility curves were compared with METU procedure. The response of buildings was idealized as SDOF system and a combination of the analytical method, expert opinion method, and data collection of past earthquakes were used in the methodology. Intensity measure type was chosen as Sd. In order to obtain fragility curves, probability distribution function was selected as the standard lognormal distribution. Three damage states were used which are slight, structural damage and near collapse.

1.1.4 RC Frame Dual and Masonry Buildings

Erdik et al. (2003), developed earthquake loss for Istanbul by using two different methods which are based on intensities and spectral displacement. Buildings were classified as RC Frame, RC shear wall and Masonry buildings with Low-rise (1-3), Mid-rise (4-8) and High-rise (higher than 8) by considering construction year; pre 1979 and post 1980. ELER (Bogazici University, 2010) was utilized for the generation of fragility curves which has similar methodology with HAZUS methodology. Intensity measure type was chosen as S_d. There were four performance levels which are slight, moderate, extensive and complete which depend on HAZUS methodology.

1.2 Objective and Scope of the Thesis

The aim of this study is to collect the existing fragility curves of the Turkish buildings based on the recent studies done in the literature. These studies are done by using different methods and thereby show different behaviors. They suggest a generalized fragility curves comprehending all Low-rise, Mid-rise and High-rise Reinforced Concrete, Dual and Masonry buildings separately via some statistical methods. This is the first study in the literature done for Turkey to recommend a representative fragility curve comprising the curves of existing studies that used different methodologies. After determination of the generalized fragility curves, adjusted insurance premiums are calculated and compared with the ones TCIP requires.

The organization of the thesis is as follows:

First of all, methods for fragility curves are summarized and then introduction and description of existing fragility curves are presented classified according to the structural system. To extract generalized fragility curves, buildings are divided into three main groups according to material types which are Reinforced Concrete Frame buildings, Reinforced Concrete Dual buildings and Masonry buildings. Moreover, these curves are classified as Low-rise buildings (1 to 3 stories), Mid-rise buildings (4 to 7 stories) and High-rise buildings (higher than 7 stories) due to the heights.

Secondly, by considering these fragility curves, new fragility curves are suggested using three methods; 1) Mean Method, 2) Weighted Coefficient Method and 3) Weighted Lognormal Cumulative Distribution Function Analysis. The first method is simply average of the classified curves. The second method is the average of weighted fragility curves. Weighted coefficients are determined according to the methods utilized in the articles. The last method is to use lognormal cumulative distribution function to find the fragility curves.

Finally, new earthquake insurance premiums are calculated for Istanbul region via proposed fragility curves by using the formulation by Kanda and Nishijima (2004). After that, existing premium amount are compared with calculated premium rates.

Last chapter includes conclusions and summary of the thesis.

CHAPTER 2

FRAGILITY CURVE METHODS

Different methodologies were developed to obtain fragility curves. These are Expert Based Method, Empirical Fragility Curves Method, Experimental Data Based Method and Analytical Method. Expert Based Method depends on expert ideas for determination of damage functions. Empirical Fragility Curves Method is simply the calculation of the fragility curves by using data of past earthquakes. Experimental Data Based Method depends on modeling structures and examining them under scenario earthquakes. Finally, Analytical Method is finding fragility curves by analyzing created models via some analytical methods such as linear method, nonlinear static method etc.

2.1 Expert Based Method

Expert opinion based approach is the method which depends on mean loss or probability of damage forecast of experts for different types of structures and several levels of ground shaking (SYNER-G, 2011). Porter et al. (2007) stated that "There are several methods for eliciting expert opinion, from ad hoc to structured processes involving multiple experts, self-judgment of expertise, and iteration to examine major discrepancies between experts. To properly elicit expert opinion on uncertain quantities requires attention to clear definitions, biases, assumptions, and expert qualifications". Although it is advantageous for being economic and time protective method, judgment based determination of fragility curves is not accepted to be the scientific way. The most detailed study of this approach is developed by ATC-13 to estimate economic impacts from earthquakes in California. Expert-opinion ground motion-damage relationships were presented in the form of damage probability matrices, for 40 classes of buildings by referring 58 experts. Mercalli Magnitude Intensity was chosen as hazard parameter. Another main study is HAZUS Earthquake Loss Estimation Methodology (National Institute of Building Sciences (NIBS), 1999), which was developed by National Institute of Building Sciences (NIBS) in 1997 and funded by FEMA. The selected hazard parameters were spectral acceleration (for nonstructural damage) and spectral displacement (for structural damage).

2.2 Empirical Fragility Curves Method

Empirical fragility curves are generated by using damage database collected from locations of past earthquakes and applying statistical methods to obtain final curves. This method is especially useful for non-engineering structures such as certain Masonry buildings. If structural capacities and soil-structure interactions are considered in calculations, the most realistic fragility curves can be obtained. (SYNER-G, 2011). However, the high possibility of deficient or wrong data resulted from previous surveys of earthquakes may lead to incorrect curves. As an example of this method the most common study is Shinozuka et al. (2001) in which empirical fragility curves were developed as functions of PGA by using bridge damage data mostly depending on 1994 Northbridge and 1995 Kobe earthquakes. The curves were expressed in the form of two-parameter lognormal functions. Moreover, in the recent study of Hancilar et al. (2013), by using land use classes set and building typology classes (material types, number of stories etc.) set of Haiti (2010) Earthquake, empirical curves were generated with the calculation of cumulative standard lognormal distribution function. Totally 6900 buildings were surveyed in the region, and since no data was available for ground motions, they were calculated by using the ground motion prediction equations.

2.3 Experimental Data Based Method

A key aspect of experimental data method is modeling for any kind of structural typologies and examining them under scenario earthquakes to construct fragility curves. This method is useful for element based studies because it is not economic and fast to apply large scaled studies. An example of this is the study carried out by Chong and Soong (2000) in which behavior of freestanding rigid objects against sliding that is created by the help of shaking table is examined. In the experiment, five different acceleration time history values were used horizontally and vertically to develop fragility curves.

2.4 Analytical Method

In the first stage of this method, the structure is modeled, damage distributions are simulated under increasing earthquake intensity and finally fragility curves are developed respectively (SYNER-G, 2011). This method is applicable when there is no data from past earthquakes or experiments. At the present time, mostly computer programs are used for analytical studies. Although it is possible to model any kind of structures, it must be remembered that results significantly depend on definition of elements of structural models and the computation capacity of computer programs or methods that are utilized for calculations. Moreover, realistic selection of earthquake intensity is also important for results. Analytical study may be divided into two main groups which are linear and nonlinear methods for the calculation of fragility curves and each of them can also be sub-classified as static and dynamic methods. For the construction of fragility curves, mostly nonlinear methods are preferred.

The most common nonlinear static method is the capacity spectrum method which is explained in ATC-40. In this process, pushover analysis is used to find capacity curve whose parameters are base shear and lateral displacement obtained by increasing loads until specified roof displacement is obtained. Then, these parameters are converted in to spectral ordinates which are spectral acceleration and spectral displacement by the aid of modal analysis that gives modal shape vectors, modal masses and participation factors referring to ATC-40. For the ease of analysis, structures are mostly converted to equivalent single degree of freedom (SDOF) system instead of calculating multiple degrees of freedom (MDOF) systems. According to Kuramoto et al. (2000), although calculation of displacements for both SDOF and MDOF systems gives similar results for RC and steel regular buildings regardless of number of stories, for irregular buildings, as height increase, difference between MDOF and SDOF also raises which is especially significant for up to 10-story buildings. There are many studies that use this method. For example, in the article Polese et al. (2008), more than 400, 1-story to 7-story RC Frame buildings were examined by using CSM with push over analysis and equivalent SDOF system. Intensity parameter of fragility curves was chosen as spectral displacement (S_d). This method was also used in the article by Güneyisi and Altay (2008), in which fragility curves were developed for 12-story representative office building for Turkey by using 240 artificially created earthquakes with the help of dampers. The selected ground motion intensities were peak ground acceleration (PGA), spectral acceleration (S_a) and spectral displacement (S_d).

Even though CSM is a good way to find fragility functions, it depends on some assumptions. For the detailed studies, Time History Analysis is preferred which is a nonlinear dynamic method. Basically, acceleration, force, moment or displacement is applied in time increments and by considering the response of the structure to time history; eigenvalues are developed referring to Szymanski (n.d.). It is useful for especially tall buildings and irregular buildings. On the other hand, since the high amount of data is needed it is a time-consuming method and also seismic forces may not be reduced due to soil properties, structural properties, and structure type. As an example, in the study of Seyedi et al. (2010), this procedure was used to develop fragility surfaces and fragility curves by using five sets and eight ground motions; for each set spectral displacement (S_d) was used as the intensity parameter.

CHAPTER 3

EXISTING FRAGILITY CURVES FOR TURKEY

In this part, comparison of fragility curves obtained from previous studies is made through plots. First, method to extract the fragility curves is presented, and then the procedure which is employed to harmonize these fragility curves is explained.

3.1 Attainment of Fragility Curves

The existing fragility curves are generally presented in the form of graphs in previous studies. To obtain digital form of these curves a digitizing program "Getdata Graph Digitizer" was used. Basically, these programs digitize scanned graphs and get original (x,y) data. However, for the curves that are not presented in the form of plots, such as the ones in the study of Erdik et al. (2003), the curves were obtained based on the data and the method given in the relevant study.

3.1.1 Classification of Buildings

Buildings are categorized according to their material types, which are Reinforced Concrete and Masonry buildings. Reinforced Concrete buildings have sub-classification pursuant to their structural members which are frame buildings and both frame and shear wall buildings (Dual buildings). Masonry buildings have sub-classification with regard to material type such as brick type (soil brick, hollow clay brick etc.), block type, stone type. In the study Erdik et al. (2003), Masonry buildings was not classified according to material types, therefore, fragility curves taken from Erdik et al. (2003) are subclassified as "General Masonry". Each sub-classification of concrete and Masonry buildings has also further classification considering the height. 1 to 3 story buildings are Low-rise buildings, from 4 to 7 story buildings are Mid-rise buildings and 7 and more story buildings are classified as High-rise buildings.
The classification is made as shown in Figure 3.1.

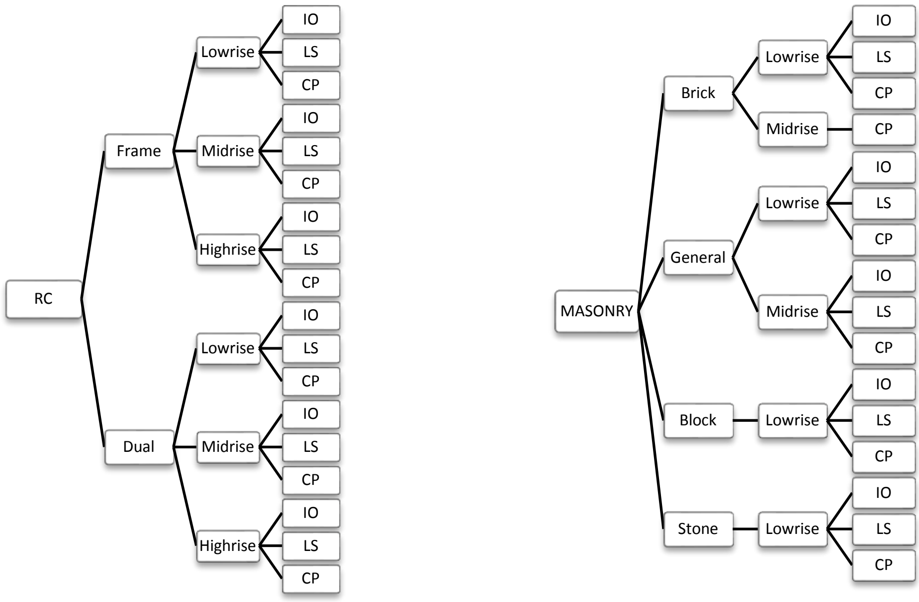

Figure 3.1 Classification of fragility curves taken from the articles

In Figure 3.1, IO, LS and CP represent Immediate Occupancy Performance Level, Life Safety Performance Level and Collapse Prevention Performance Level respectively.

3.1.2 Limit States for Fragility Curves

Since the previous studies employed did not use the same damage limits for the curves, a procedure presented in SYNER-G (2011) is utilized to classify fragility curves accurately for the similar damage state limits given in Table 3.1.

Table 3.1 Comparison of existing damage scales with the HRC damage scale (SYNER-G, 2011)

<table>
<tr><th>HRC</th><th>HAZUS99</th><th>Vision 2000</th><th>EMS98</th><th>ATC-13</th></tr>
<tr><td>None</td><td colspan="4">No damage</td></tr>
<tr><td>Slight</td><td rowspan="4">Slight damage</td><td rowspan="2">Fully operational</td><td rowspan="2">Grade 1</td><td>Slight</td></tr>
<tr><td rowspan="3">Light</td><td rowspan="2">Light</td></tr>
<tr><td rowspan="3">Operational</td><td rowspan="2">Grade 2</td></tr>
<tr><td rowspan="3">Moderate</td></tr>
<tr><td rowspan="3">Moderate</td><td rowspan="3">Moderate damage</td><td rowspan="3">Grade 3</td></tr>
<tr><td rowspan="2">Life Safe</td></tr>
<tr><td rowspan="2">Heavy</td></tr>
<tr><td rowspan="2">Extensive</td><td rowspan="3">Extensive damage</td><td rowspan="2">Near Collapse</td><td rowspan="3">Grade 4</td></tr>
<tr><td rowspan="2">Major</td></tr>
<tr><td>Partial Collapse</td><td>Collapse</td></tr>
<tr><td>Collapse</td><td colspan="4">Collapse</td></tr>
</table>

In this study, 3 limit states were chosen which are Immediate Occupancy (IO), Life Safety (LS) and Collapse Prevention (CP) and the curves, which are in Heavy, Major, Extensive and Collapse damage limit states, are appertain to Collapse Prevention damage state. The Slight damage state is considered in Immediate Occupancy limit state.

3.1.3 Harmonization of Fragility Curves

Previous studies used different ground motion intensities. For the collection of all fragility curves on the graphs, conversion of different ground motion parameters to selected ground motion parameters used the most is needed. For RC Frame and RC Dual Buildings for all heights (Low-rise, Mid-rise, and High-rise), the main parameter is chosen as peak ground velocity PGV (cm/s). For Masonry Buildings, the main parameter is considered as peak ground acceleration PGA (g). Pursuant to the main parameters, there are three types of conversion accomplished which are PGA(g) to PGV (cm/s), S_d (cm) to PGV (cm/s) and S_d (cm) to PGA(g) which are shown below. All these conversions are carried out using formulations and tables based on the method stated in the SYNER-G (2011).

3.1.3.1 PGA to PGV Conversion

The following steps explain how PGA is converted to PGV in order to express fragility curves that are developed using PGA as the ground motion intensity to PGV based curves.

Step 1: For a given site class and for $T = 0.3$, $S_a(0.3)$ and PGA relationship for class B, short-period amplification factor F_{Ai} is found. This is needed because in SYNER-G (2011), formulations are given for only site class B and usage of formulations for the other soil types which specified according to NEHRB Site Classification, this factor is utilized. Thereby, ground motion parameters of fragility curves for different site classes are obtained considering the site class B ground motion parameters as reference. For the conversion, short-period amplification factor F_{Ai} is found from Table 3.2.

Table 3.2 Site Amplification Factors (SYNER-G, 2011)

Site Class B Spectral Acceleration	Site Class				
	A	B	C	D	E
Short Period, S_{AS} [g]	**Short-Period Amplification Factor, F_A**				
≤ 0.25	0.8	1.0	1.2	1.6	2.5
(0.25, 0.50]	0.8	1.0	1.2	1.4	1.7
(0.50, 0.75]	0.8	1.0	1.1	1.2	1.2
(0.75, 1.0]	0.8	1.0	1.0	1.1	0.9
>1.0	0.8	1.0	1.0	1.0	0.9
1-Second Period, S_{AI} [g]	**1-Second Period Amplification Factor, F_V**				
≤ 0.10	0.8	1.0	1.7	2.4	3.5
(0.1, 0.2]	0.8	1.0	1.6	2.0	3.2
(0.2, 0.3]	0.8	1.0	1.5	1.8	2.8
(0.3, 0.4]	0.8	1.0	1.4	1.6	2.4
>0.4	0.8	1.0	1.3	1.5	2.4

In Table 3.2, $S_{AI}[g]$ is one second-period spectral acceleration for site class B and $S_{As}[g]$ is short-period spectral acceleration for site class B. F_{vi} is one second-period amplification factor for site class i and spectral acceleration S_{AI} and F_{Ai} is short period amplification factor for site class i and spectral acceleration S_{AS}.

Step 2: PGA values for class B is found using Equation (3.1) by dividing given PGA values for different soil type (PGA) to site amplification factor F_{Ai} of the soil type. Note that by using Table 3.2 and Equation (3.1), PGA values for each class of soil and for each value of spectral acceleration can be developed.

$$PGA_i = PGA \times F_{Ai} \tag{3.1}$$

Step 3: By using PGA (g) values for site class B, $S_a(0.3)$ and $S_a(1)$ values for class B are obtained by using elastic response spectrum formulation as follows:

$$S_a(0.3) = S_{AS} = 2.5 \times PGA \tag{3.2}$$

$$S_a(1) = S_{AI} = PGA \tag{3.3}$$

Step 4: $S_a(0.5)$ value is calculated by using the following equations:

$$S_a(T) = S_a(0.3) \times \left(0.4 + 0.6 \times \frac{T}{T_A}\right) \quad if\ \ 0 < T < T_A \tag{3.4}$$

$$S_a(T) = S_a(0.3) \quad if\ \ T_A < T < T_{AV} \tag{3.5}$$

$$S_a(T) = \frac{S_a(1)}{T} \quad if\ T_{AV} < T < T_{VD} \tag{3.6}$$

$$S_a(T) = S_a(1) \times \frac{T_{VD}}{T^2} \quad if\ T_{VD} < T < 10 \tag{3.7}$$

As can be seen, $S_a(0.3)$ or $S_a(1)$ depend on building period for the transition periods, T_A, T_{AV} and T_{VD} which are calculated from Equations (3.4) to (3.7). According to SYNER-G (2011), T_{VD} period is assumed to be 10 seconds (i.e. M=7) when moment magnitude M is unknown. Therefore,

$$T_A = 0.2 \times T_{AV} \tag{3.8}$$

$$T_{AV} = \frac{Sa(1)}{Sa(0.3)} \tag{3.9}$$

$$T_{VD} = 10^{[(M-5)/2]} \tag{3.10}$$

Step 5: Finally, by using the correlation between $PGV(cm/s)$ and $SA[0.5]$ (cm/s^{2}) values taken from SYNER-G (2011), PGV values can be obtained as follows:

$$PGV(cm/s) = \frac{SA[0.5](cm/s^2)}{20} \tag{3.11}$$

3.1.3.2 S_d to PGV Conversion

In order to convert Spectral displacement S_d to PGV the following procedure is employed:

Step 1: Since the building period and spectral displacement are given, spectral acceleration, S_a, can be calculated by using conversion equation from $S_d(T_y)$ to $S_a(T_y)$ as follows:

$$S_d(T_y) = \left(\frac{T_y}{2\pi}\right)^2 S_a(T_y) \tag{3.12}$$

In Equation (3.12), S_d, S_a and T_y represent Spectral Displacement, Spectral Acceleration and Elastic Period of the Structure respectively.

Step 2: For a given site class and given building period, T_y, short-period amplification factor for a given site class F_{Ai} is obtained from Table 3.2.

Step 3: By using relationship given in Equation (3.13), spectral acceleration for site class B is found by dividing spectral acceleration for site class i to site class amplification factor F_{Ai}.

$$S_a(0.3)_i = S_{ASi} = S_{AS} \times F_{Ai} \tag{3.13}$$

Step 4: By using $S_a(T)$ values for class B calculated in step 3, $S_a(0.3)$ and $S_a(1)$ values for class B are obtained via elastic response spectrum formulation. $S_a(0.3)$ or $S_a(1)$ are computed (Equations (3.4) to (3.7)) based on T_A, T_{AV} and T_{VD} (Equations (3.8) to (3.10)).

Due to the relationship between $S_a(0.3)$ and $S_a(1)$ for site class B which is shown in Equation (3.2), it is easy to find $T_A = \frac{0.2\times1}{2.5} = 0.08$ using Equation (3.8) and $T_{AV} = \frac{1}{2.5} = 0.4$ using Equation (3.9).

Step 5: After finding $S_a(0.3)$ or $S_a(1)$, $S_a(0.5)$ is calculated from Equations (3.4) to (3.7).

Step 6: Finally, by using the correlation between $PGV(cm/s)$ and $SA[0.5]$ (cm/s^2) values which is given in SYNER-G (2011), PGV values can be obtained by using Equation (3.11).

3.1.3.3 S_d to PGA(g) Conversion

For Masonry buildings all existing fragility curves are chosen to be expressed in terms of PGA, so that conversion from spectral displacement S_d to PGA has been done using the following procedure:

Step 1: Since proper building period and spectral displacement are given, spectral acceleration can be calculated by using Equation (3.12).

Step 2: For a given site class and given building period, T_Y, short-period amplification factor for a particular site class, F_{Ai}, is found by using Table 3.2.

Step 3: Using $S_a(T)$ for site class i calculated in step 1 and F_{Ai} taken from step 2, Sa(T) values for class B are determined by using Equation (3.13).

Step 4: By using $S_a(T)$ values for class B calculated in step 3, $S_a(0.3)$ and $S_a(1)$ values for class B are obtained via elastic response spectrum formulation. $S_a(0.3)$ or $S_a(1)$ are computed (Equations (3.4) to (3.7)) based on T_A, T_{AV} and T_{VD} from Equations (3.8) to (3.10). Due to the relationship between $S_a(0.3)$ and $S_a(1)$ for site class B which is shown in Equations (3.2) and (3.3), it is easy to find $T_A = \frac{0.2\times1}{2.5} = 0.08$ using Equation (3.8) and $T_{AV} = \frac{1}{2.5} = 0.4$ using Equation (3.9).

Step 5: After finding $S_a(0.3)$ or $S_a(1)$, PGA value is obtained for class B by using Equations (3.2) and (3.3).

Step 6: PGA_i value is found by using Equation (3.1).

3.1.3.4 Site Class Comparison Table

As it is stated above, formulations in SYNER-G (2011) are used for only site class B. Modifications to above formulations are also given in SYNER-G (2011) for other NEHRB Site Classifications. However, soil types in the studies employed here depend on local site classes (Z1, Z2, Z3 and Z4) of TEC 2007. To apply the formulas for these site classes, local site classes are converted to equivalent NEHRB Site Classes. Local site classes are converted to site groups in TEC 2007 which is demonstrated in Table 3.3.

Table 3.3 Local Site Classes According to TEC 2007

Local Site Class	**Soil Group and Topmost Soil Layer Thickness (h_1)**
Z1	Group (**A**) soils Group (**B**) soils with $h_1 \leq 15$ m
Z2	Group (**B**) soils with $h_1 > 15$ m Group (**C**) soils with $h_1 \leq 15$ m
Z3	Group (**C**) soils with 15 m $< h_1 \leq 50$ m Group (**D**) soils with $h_1 \leq 10$ m
Z4	Group (**C**) soils with $h_1 > 50$ m Group (**D**) soils with $h_1 > 10$ m

Since the soil depths are not given in the studies, Z1, Z2, Z3 and Z4 are assumed as A, B, C and D. After that, equivalence of site types are found via given Shear Wave Velocities and Soil Descriptions in NEHRB Site Classification (SYNER-G, 2011) and TEC 2007 presented in Table 3.4.

Table 3.4 Soil Type Description (FEMA 1997 and TEC 2007)

Site Class	Soil Description	
	NEHRP (FEMA 1997) **Shear Wave Velocity** **VS,30 [m/s]**	**TEC 2007** **Drift Wave** **Velocity (m / s)**
A	Hard Rock, Eastern U.S. sites only >1500	Massive volcanic rocks, unweathered sound metamorphic rocks, stiff cemented sedimentary rocks >1000
B	Rock 760-1500	Soft volcanic rocks such as tuff and agglomerate, weathered cemented sedimentary rocks with planes of discontinuity 700-1000
C	Very dense soil and soft rock 360-760	Highly weathered soft metamorphic rocks and cemented sedimentary rocks with planes of discontinuity 400-700
D	Stiff soil 180-360	Soft, deep alluvial layers with high ground water level <200
E	Soft soil, profile with > 3m of soft clay defined as soil with plasticity index PI>20, moisture content w > 40% <180	-
F	Soils requiring site specific evaluations -	-

According to Table 3.4, site classes of FEMA (1997) (SYNER-G, 2011) and TEC (2007) are similar.

Based on Table 3.4, for the Z3 type of local site class given in the studies, amplification factor for C type of soil site is used

3.1.3.5 Soil Types for the Converted Intensity Parameters

Since soil types were needed for the parameter conversion according to SYNER-G (2011), the soil types used in the studies employed are listed below in Table 3.5.

Table 3.5 Converted Ground Motion Parameters (GMP's)

Building Class	Article Name	Soil Type	Initial GMP	Finalized GMP
RC Frame	Ozmen et al. (2010)	Z3	PGA(g) (m/s^2)	PGV (cm/s)
	Kircil and Polat (2006)	C	PGA(g) (m/s^2)	PGV (cm/s)
	Erdik et al. (2003)	C	Sd (cm)	PGV (cm/s)
	Smyth et al. (2004)	Z3	PGA(g) (m/s^2)	PGV (cm/s)
RC Dual	Smyth et al. (2004)	Z3	PGA(g) (m/s^2)	PGV (cm/s)
Masonry	Erdik et al. (2003)	C	Sd (cm)	PGA(g) (m/s^2)
	D'Ayala and Kishali (2012)	Z4	Sd (cm)	PGA(g) (m/s^2)

3.2 Comparison of Fragility Curves with Observed Data of Kocaeli (1999) Earthquake

Bilal (2013) derived Damage Probability Matrices (DPM) for Reinforced Concrete and Masonry buildings in the central districts of Bolu, Düzce, Kocaeli and Sakarya regions by utilizing damage assessment forms prepared by General Directorate of Disaster Affairs for Kocaeli (1999) Earthquake. Damage ratios were expressed in the form of MMI (Modified Mercalli Intensity) values. Bilal (2013) also found relationships between felt intensity (MMI) and instrumental ground motion parameters for Turkey (PGV (m/s) and PGA (m/s^2)). Fragility curves of previous studies are compared with damage ratios of Bolu, Düzce, Kocaeli and Sakarya regions which are in the form of MMI (Bilal 2013) in order to see how these curves fit the real data. For comparison, harmonization of data is made by using relationship formula between felt intensity (MMI) and PGV and PGA relationship (Bilal 2013).

Based on the existing empirical regional damage database which comprise Bolu, Kocaeli Sakarya and Yalova regions after Kocaeli (1999) Earthquake, empirical damage probability matrices of Turkey were regenerated and damage probability matrices were created for Reinforced Concrete buildings and Masonry buildings by considering No Damage, Light Damage, Moderate Damage, Heavy Damage and Collapse damage states (Bilal, 2013).

Buildings in Bolu, Kocaeli, Sakarya and Yalova were divided into three parts as A for Masonry, B for frames and C for mixed type. These main classes were also divided into subclasses. Masonry buildings were divided into six classes; A1 for Rounded Rubble Masonry, A2 for Angular Stone Masonry, A3 for Ashlars Stone Masonry, A4 for a Brick Wall, A5 for Briquette and A6 for Adobe buildings. Frame buildings were divided into three types; B1 for Half-timbered, B2 for Timberwork and B3 for Reinforced Concrete buildings. Mixed type of buildings has only one type, named C1 for Semi framed subclass.

Due to the lack of information and accuracy in the existing dataset, the number of stories and other subclasses of buildings were not considered for computation of DPMs. Moreover, since there were very low number of buildings which belong to B1, B2 and C1 subclasses compared to the Reinforced Concrete and Masonry buildings, these were neglected and only two main classes were used which are Reinforced Concrete structures in B3 section and Masonry buildings in other section, namely O.

Damage ratios and central damage ratios corresponding to each damage state are presented in Table 3.6.

Table 3.6 Damage Ratios and Central Damage Ratios Corresponding to Each Damage State (Bilal, 2013)

Damage State	Damage Ratios (%)	Central Damage Ratio (%)
No Damage	0-1	0
Light Damage	1-10	5
Moderate Damage	10-50	30
Heavy Damage	50-90	70
Collapse	90-100	100

In the second part of thesis (Bilal, 2013), a new formulation was evolved to show relationship between Modified Mercalli Intensity (MMI) and ground motion parameters PGA and PGV by utilizing the National Strong Motion Network of Turkey webpage for ground motion data, as follows (Bilal, 2003):

$$MMI_{est} = 0.287 + 3.625 \times \log(PGA) \tag{3.14}$$

$$MMI_{est} = 0.319 + 5.021 \times \log(PGV) \tag{3.15}$$

By using MMI values of each performance level (None, Light, Moderate, Heavy & Collapse) for Bolu, Kocaeli, Sakarya and Yalova, PGA(g) and PGV values are calculated by using Equations (3.14) and (3.15). These are presented in Table 3.7.

Table 3.7 Calculated Ground Motion Parameters According to Bilal (2013)

Location	MMI	log(PGA(cm/s))	log(PGV(cm/s))	PGV(cm/s)	PGA(g)
Bolu	6	1.58	1.13	13.53	0.04
Kocaeli	9	2.40	1.73	53.57	0.26
Sakarya	10	2.68	1.93	84.74	0.49
Yalova	10	2.68	1.93	84.74	0.49

After conversion of log(PGV) to normal PGV (cm/s) for Reinforced Concrete buildings and log(PGA) to normal PGA(g) m/s for Masonry buildings, the data are plotted in the same graphs as fragility curves for each type to make comparisons. Note that comparison of the points with the curves is made for only RC Frame and Masonry buildings, not for Dual structures.

3.3 Existing Fragility Curves of Turkey

Fragility curves are compared for each class of building types and presented in Figures (3.2) to (3.35). The observed data obtained from Bilal (2013) are also plotted in the corresponding curves. There are three performance levels for the curves which are Immediate Occupancy (IO), Life Safety (LS) and Collapse Prevention (CP).

From the graphs, it is concluded that as number of stories increases, probability of exceedance of performance level also increases. Infill walls make buildings stronger as compared to bare buildings and buildings which were constructed after 1980 are stronger than pre-1979 structures. Almost all curves are consistent with the data taken from Bilal (2013). What is more, curves based on Expert Opinion Method are different than the curves obtained from Analytical Methods. Since the examined parameters such as buildings with infill walls, pre 1979 buildings, calculation methods and investigated behaviors of structures for each study are different, exact classification could not be achieved. Therefore, there is large scatter between the curves, especially in Masonry type of buildings.

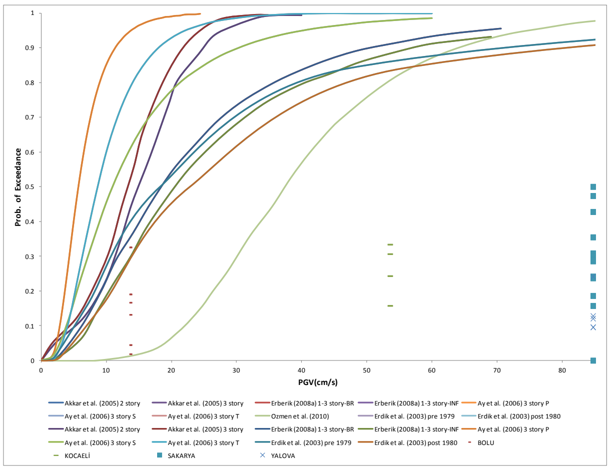

Figure 3.2 Fragility curves of **RC Frame Low-rise** type of buildings for **Immediate Occupancy** performance level

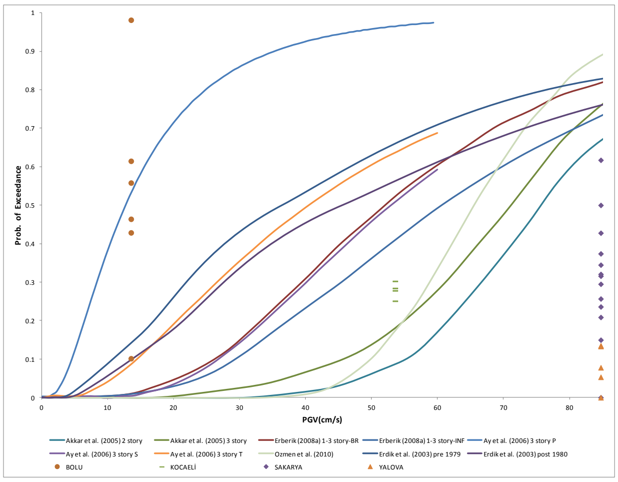

Figure 3.3 Fragility curves of **RC Frame Low-rise** type of buildings for **Life Safety** performance level

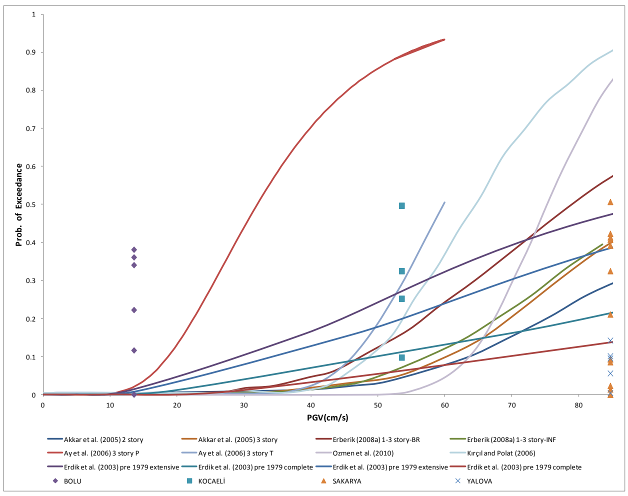

Figure 3.4 Fragility curves of **RC Frame Low-rise** type of buildings for **Collapse Prevention** performance level

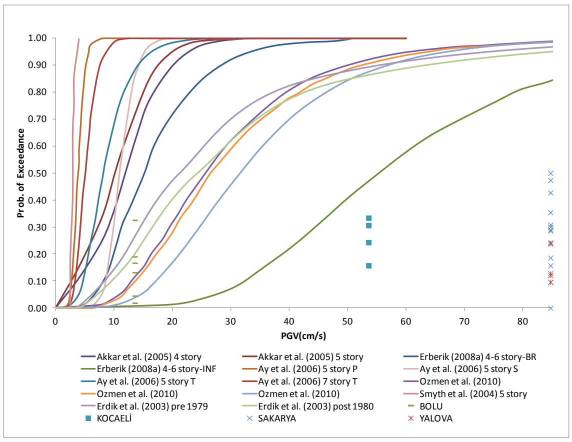

Figure 3.5 Fragility curves of **RC Frame Mid-rise** type of buildings for **Immediate Occupancy** performance level

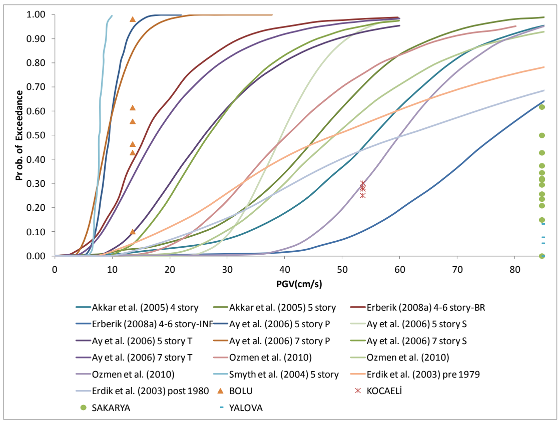

Figure 3.6 Fragility curves of **RC Frame Mid-rise** type of buildings for **Life Safety** performance level

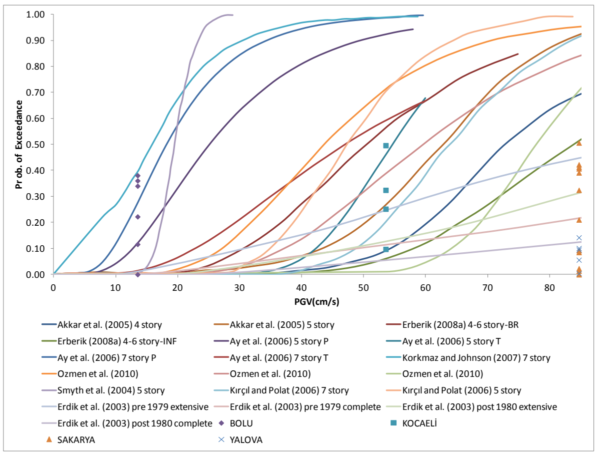

Figure 3.7 Fragility curves of **RC Frame Mid-rise** type of buildings for **Collapse Prevention** performance level

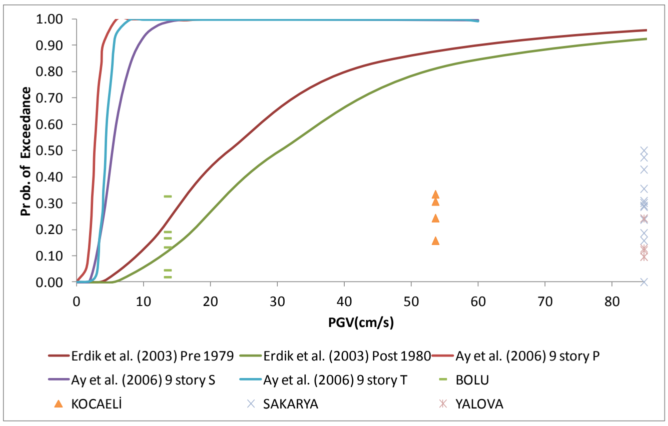

Figure 3.8 Fragility curves of **RC Frame High-rise** type of buildings for **Immediate Occupancy** performance level

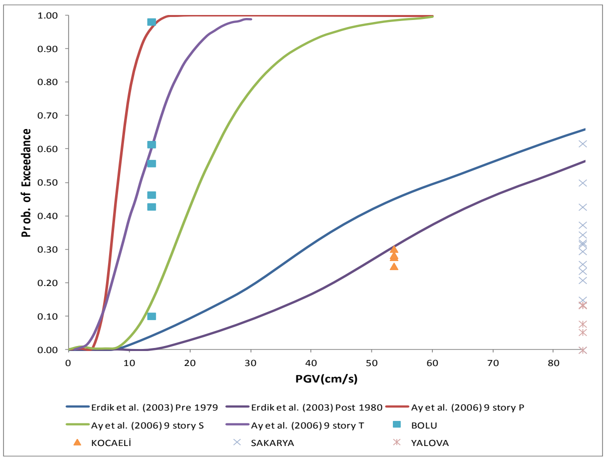

Figure 3.9 Fragility curves of **RC Frame High-rise** type of buildings for **Life Safety** performance level

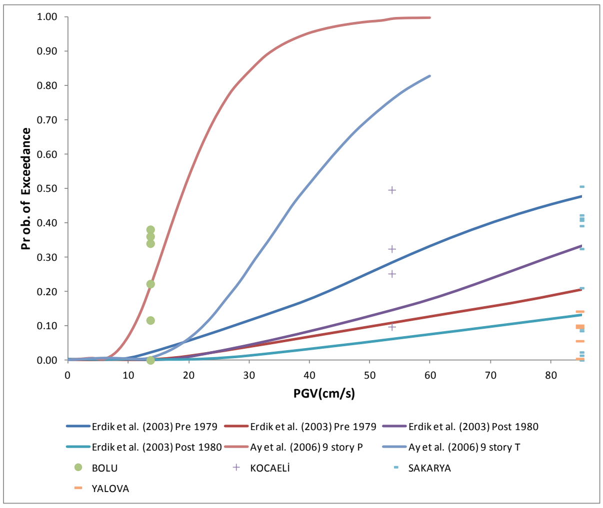

Figure 3.10 Fragility curves of **RC Frame High-rise** type of buildings for **Collapse Prevention** performance level

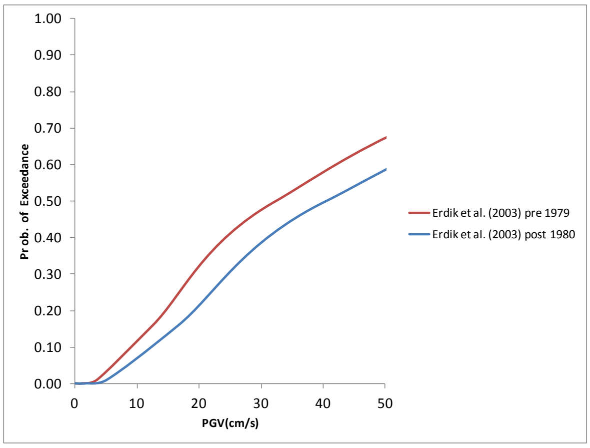

Figure 3.11 Fragility curves of **RC Dual Low-rise** type of buildings for **Immediate Occupancy** performance level

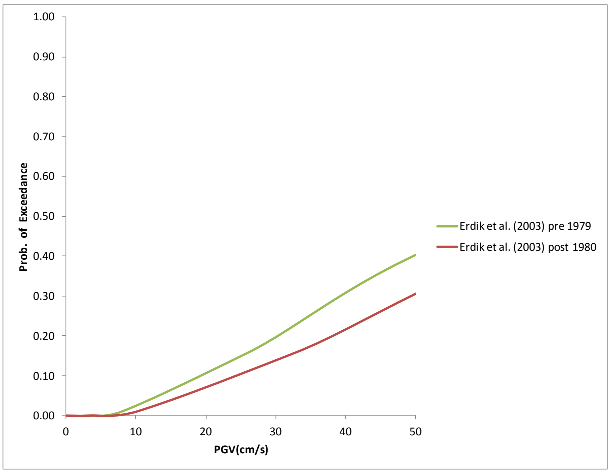

Figure 3.12 Fragility curves of **RC Dual Low-rise** type of buildings for **Life Safety** performance level

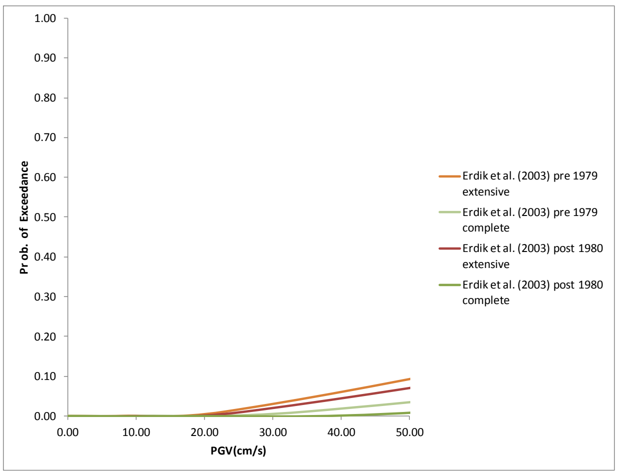

Figure 3.13 Fragility curves of **RC Dual Low-rise** type of buildings for **Collapse Prevention** performance level

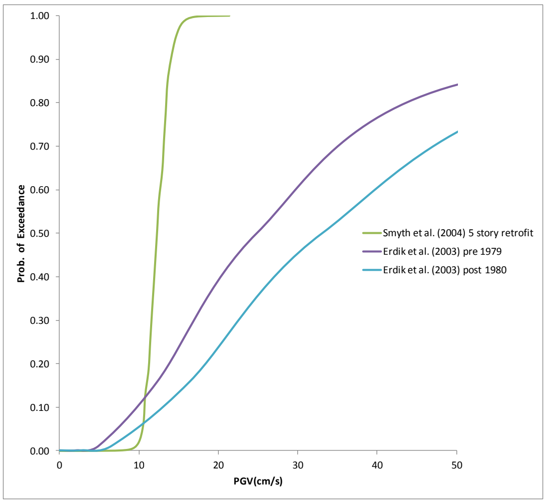

Figure 3.14 Fragility curves of **RC Dual Mid-rise** type of buildings for **Immediate Occupancy** performance level

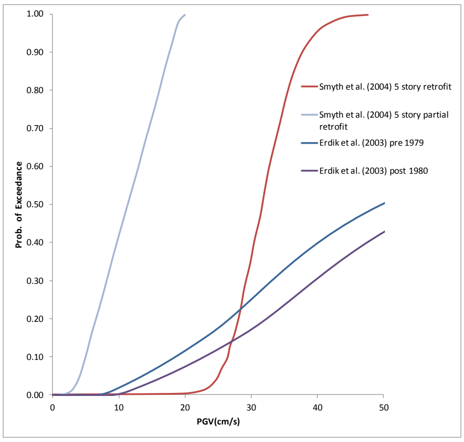

Figure 3.15 Fragility curves of **RC Dual Mid-rise** type of buildings for **Life Safety** performance level

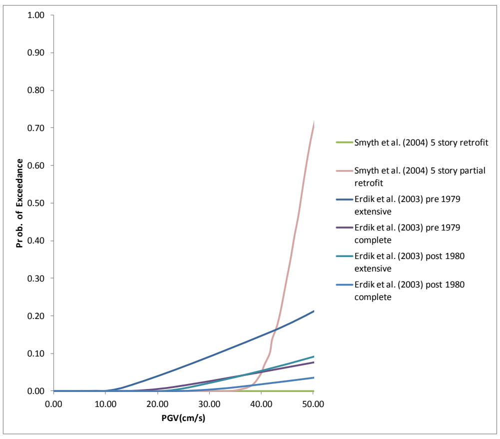

Figure 3.16 Fragility curves of **RC Dual Mid-rise** type of buildings for **Collapse Prevention** performance level

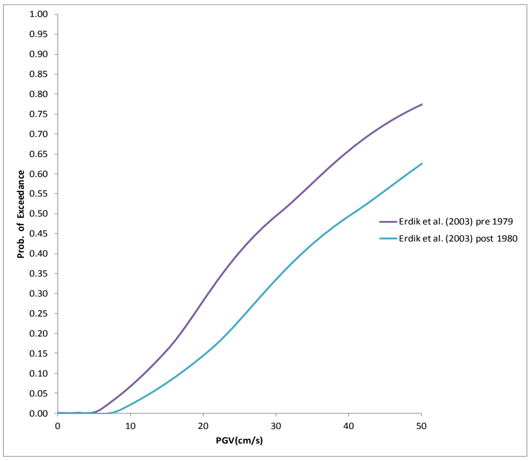

Figure 3.17 Fragility curves of **RC Dual High-rise** type of buildings for **Immediate Occupancy** performance level

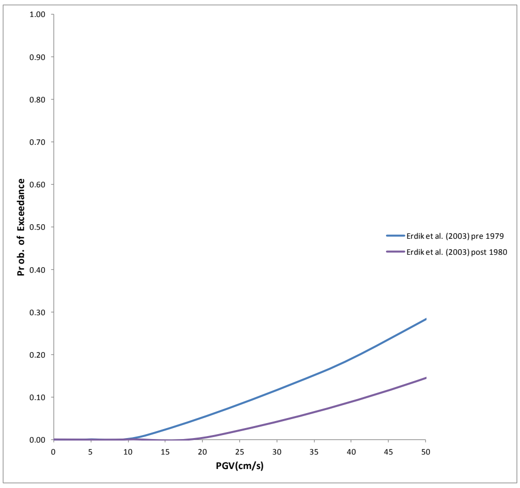

Figure 3.18 Fragility curves of **RC Dual High-rise** type of buildings for **Life Safety** performance level

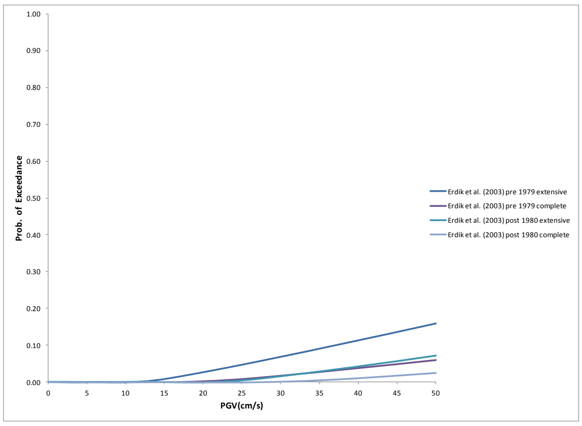

Figure 3.19 Fragility curves of **RC Dual High-rise** type of buildings for Collapse Prevention performance level

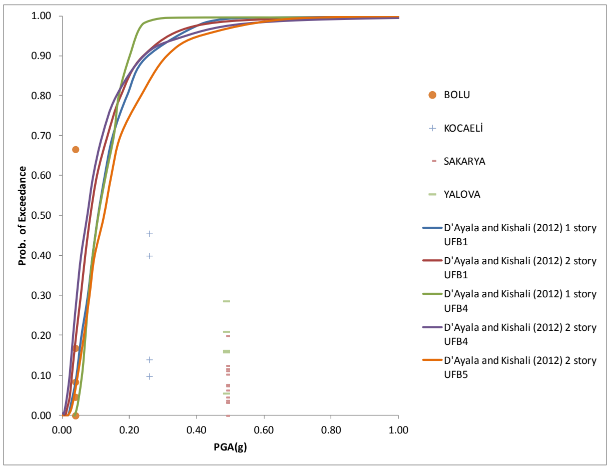

Figure 3.20 Fragility curves of Masonry **Brick Low-rise** type of buildings for **Immediate Occupancy** performance level

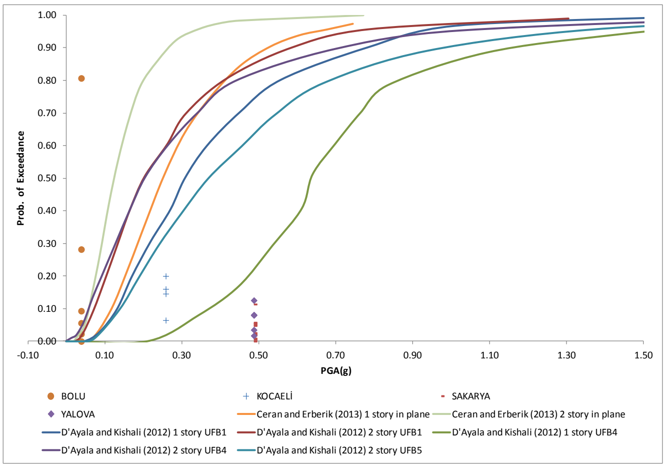

Figure 3.21 Fragility curves of Masonry **Brick Low-rise** type of buildings for **Life Safety** performance level

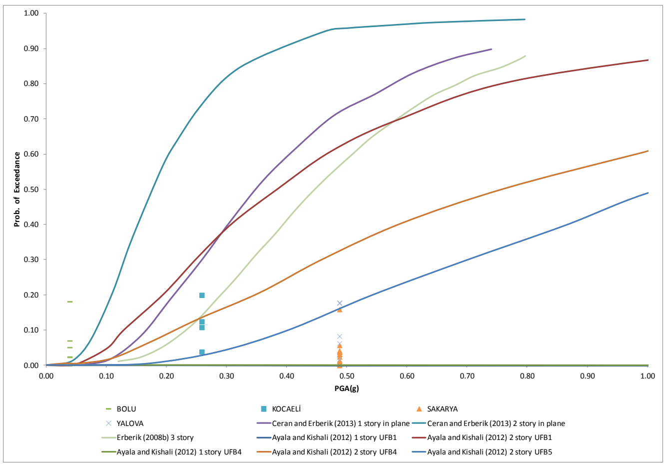

Figure 3.22 Fragility curves of Masonry **Brick Low-rise** type of buildings for **Collapse Prevention** performance level

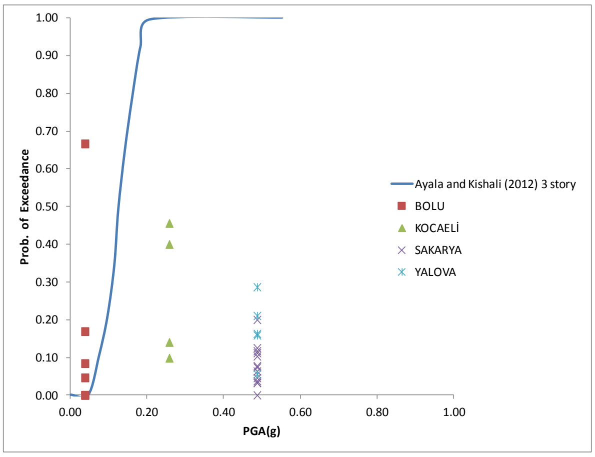

Figure 3.23 Fragility curves of Masonry **Block Low-rise** type of buildings for **Immediate Occupancy** performance level

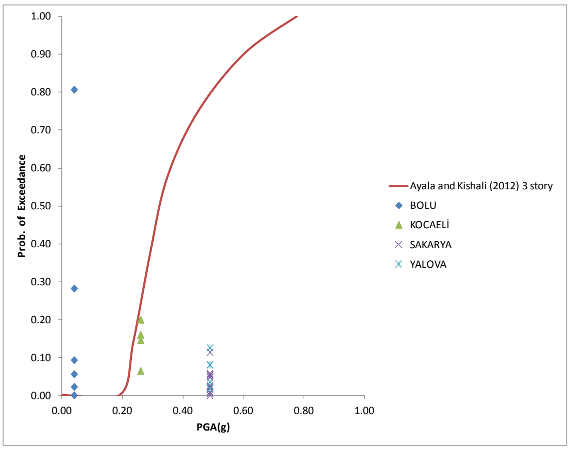

Figure 3.24 Fragility curves of Masonry **Block Low-rise** type of buildings for **Life Safety** performance level

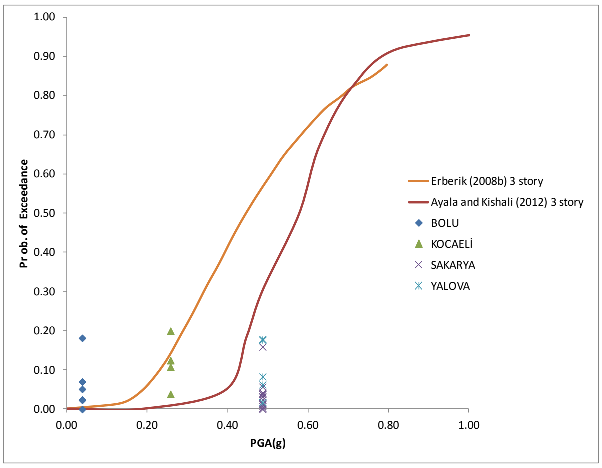

Figure 3.25 Fragility curves of Masonry **Block Low-rise** type of buildings for **Collapse Prevention** performance level

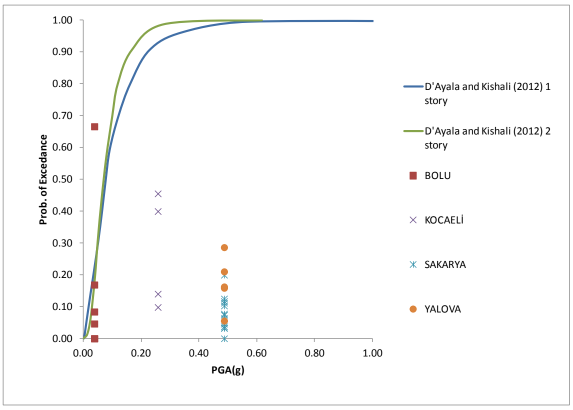

Figure 3.26 Fragility curves of Masonry **Stone Low-rise** type of buildings for **Immediate Occupancy** performance level

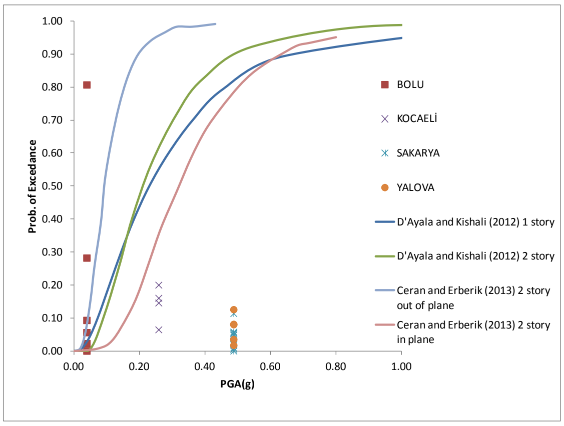

Figure 3.27 Fragility curves of Masonry **Stone Low-rise** type of buildings for **Life Safety** performance level

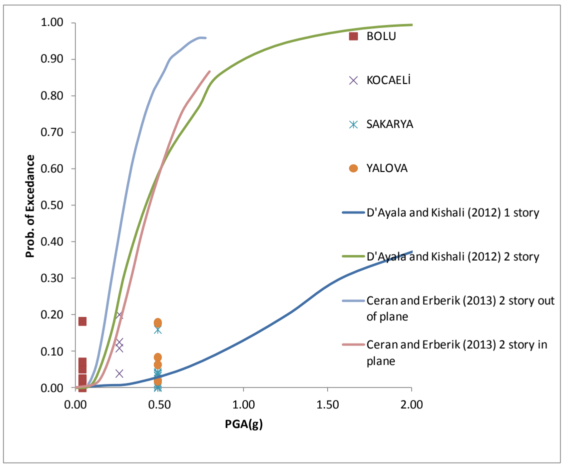

Figure 3.28 Fragility curves of Masonry **Stone Low-rise** type of buildings for **Collapse Prevention** performance level

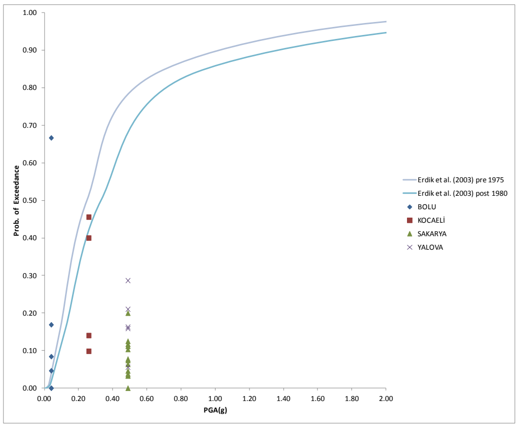

Figure 3.29 Fragility curves of Masonry **General Low-rise** type of buildings for **Immediate Occupancy** performance level

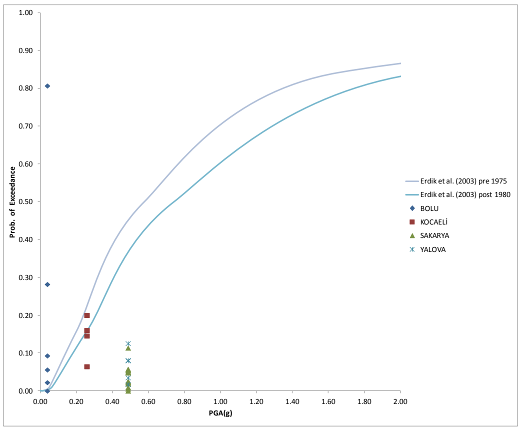

Figure 3.30 Fragility curves of Masonry **General Low-rise** type of buildings for **Life Safety** performance level

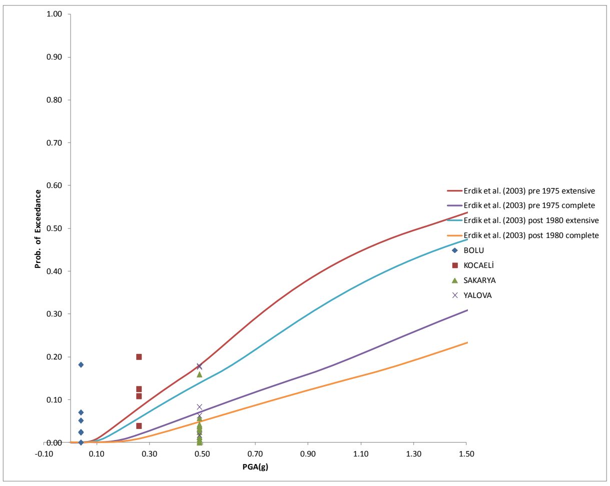

Figure 3.31 Fragility curves of Masonry **General Low-rise** type of buildings for **Collapse Prevention** performance level

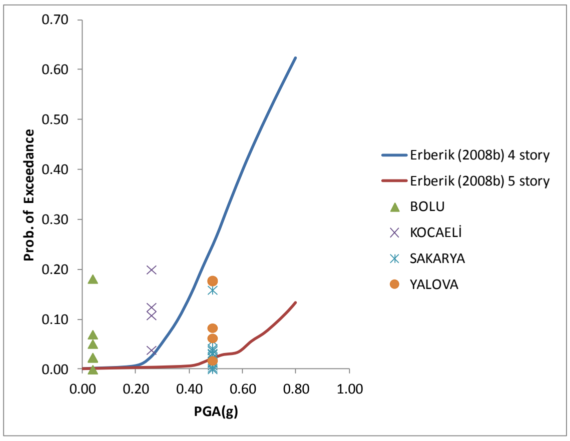

Figure 3.32 Fragility curves of Masonry **Brick Mid-rise** type of buildings for **Collapse Prevention** performance level

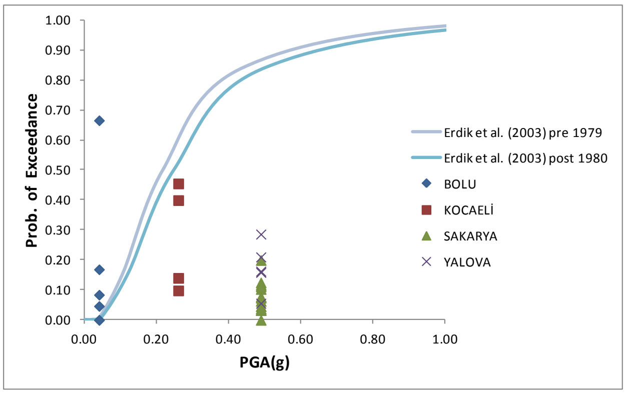

Figure 3.33 Fragility curves of Masonry **General Mid-rise** type of buildings for **Immediate Occupancy** performance level

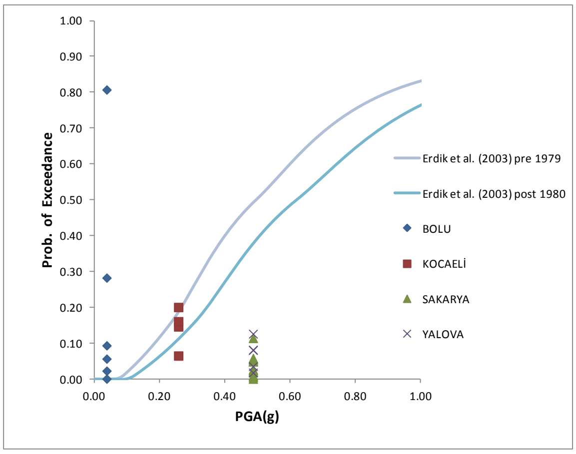

Figure 3.34 Fragility curves of Masonry **General Mid-rise** type of buildings for **Life Safety**

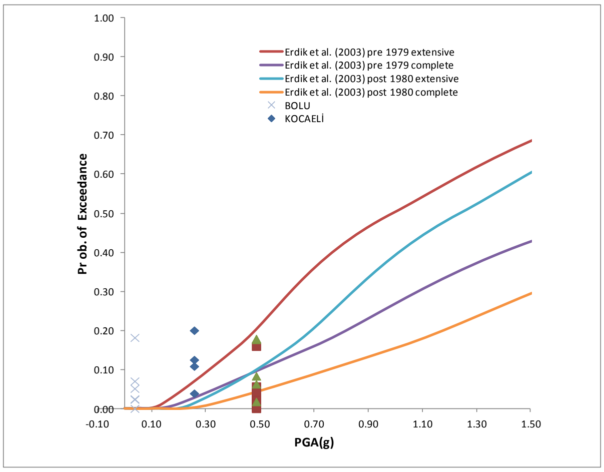

Figure 3.35 Fragility curves of Masonry **General Mid-rise** type of buildings for **Collapse Prevention**

Considering the graphs for all type of buildings, it is observed that as the number of story increases, fragility curves converge to maximum probability of exceedance value at lower ground motion intensities as it is supposed to be. For RC Frame buildings, fragility curves of buildings with poor subclass type of materials given by Ay et al. (2006) which are more vulnerable, have much lower ground motion intensities (*x* axis) than other curves for the same probability of exceedance value (*y* axis). Fragility curves of buildings with infill walls by Erberik et al. (2008a) which are more durable have much higher ground motion intensities than other curves. Moreover, fragility curves of post 1980 buildings by Erdik et al. (2003) have also higher ground motion intensities. For RC Dual buildings, there are not many study, this part depend on the studies by Smyth et al. (2004) and Erdik et al. (2003). Smyth et al. (2004) concludes that retrofit buildings converge to maximum probability of exceedance value at higher ground motion intensities than the curves of partial retrofit buildings. For Masonry buildings, there are many classifications depending on material types, but few studies for each of them and there is hard to make a general conclusion for all material classifications of masonry buildings.

From the all graphs, it is concluded that there are two main reasons for the various scattering of the curves. First one is the methodologies which are very affective for the results of the curves. The fragility curves obtained from Expert Based Methodologies such as FaMIVE methodology used by D'Ayala and Kishali (2012)

and HAZUS methodology studied by Erdik et al. (2003) have much larger ground motion intensities than other curves. Moreover, fragility curves are obtained for using very different data taken from various type of buildings and this variety causes scattered curves in spite of the collecting the curves by using classifications.
When compared with existing data taken from Bilal (2013), it is concluded that compatibility changes based on material type, height and damage performance level.

For RC buildings, as damage performance levels change from Immediate Occupancy to Collapse Prevention, compatibility of the curves with the existing data increases. For Immediate Occupancy performance level, curves are compatible with the existing data for lower ground motion intensities (PGV=13cm/s). For Life Safety, compatibility changes in between PGV=13 cm/s to PGV=50 cm/s and when compared with Immediate Occupancy performance level, much more amount of curves are compatible. For Collapse Prevention, the curves are compatible for higher ground motion intensities (in between PGV=50cm/s and PGV=80cm/s).

As the height of the buildings increases, number of compatible curves increases. Since there is no specific classification for shear wall type of buildings, existing data is not shown on the graphs of Dual type of buildings. Masonry buildings give similar results with RC Frame buildings; it is hard to conclude that there is an explicit relationship between existing data with heights and change of performance levels from IO to CP. Because, there are many classes with low number of studies. Also, fragility curves of all studies did not obtained for all performance levels. In general, the curves are consistent with existing data.

CHAPTER 4

SUGGESTED GENERALIZED FRAGILITY CURVES FOR EACH CLASSES

After compiling fragility curves from previous studies and applying intensity conversion to represent them on the same format, generalized fragility curves that aim to represent each building class are suggested. A number of fragility curves proposed for each sub-class are combined using three different methods that are Mean Method, Weighted Coefficient Method and Weighted Lognormal Cumulative Distribution Function Method. These methods are described in the following sections.

4.1 Methods for the Generalized Fragility Curves

4.1.1 Mean Method

First of all, corresponding Probability of Exceedance values of all fragility curves on the y axis are found for the chosen ground motion parameters. As mentioned in Chapter 3, PGV (cm/s) was selected as ground motion intensity for RC buildings and PGA(g) m/s^2 was selected for masonry buildings. Then, for a selected ground motion intensity value, the average of Probability of Exceedance points of all curves is calculated as shown in Equation (4.1). This way, one representative curve that reflects average of all curves on the vertical axis is obtained.

$$\bar{P} = \frac{1}{n}\sum_{i=1}^{n} p_i \tag{4.1}$$

In the Equation (4.1), $\bar{P}$ is average probability of exceeding the given damage state of the fragility curves corresponding to the same ground motion intensity, p_i is value of the probability of exceeding the given damage state for each curve corresponding to the same ground motion intensity, i represents each fragility curve within each sub class (RC Frame Low-rise, RC Frame Mid-rise, Frame High-rise, RC-Dual-Mid-rise, etc.) and n is the number of curves on the same ground motion point.

As an example for this method, Figure 4.1 is shown below.

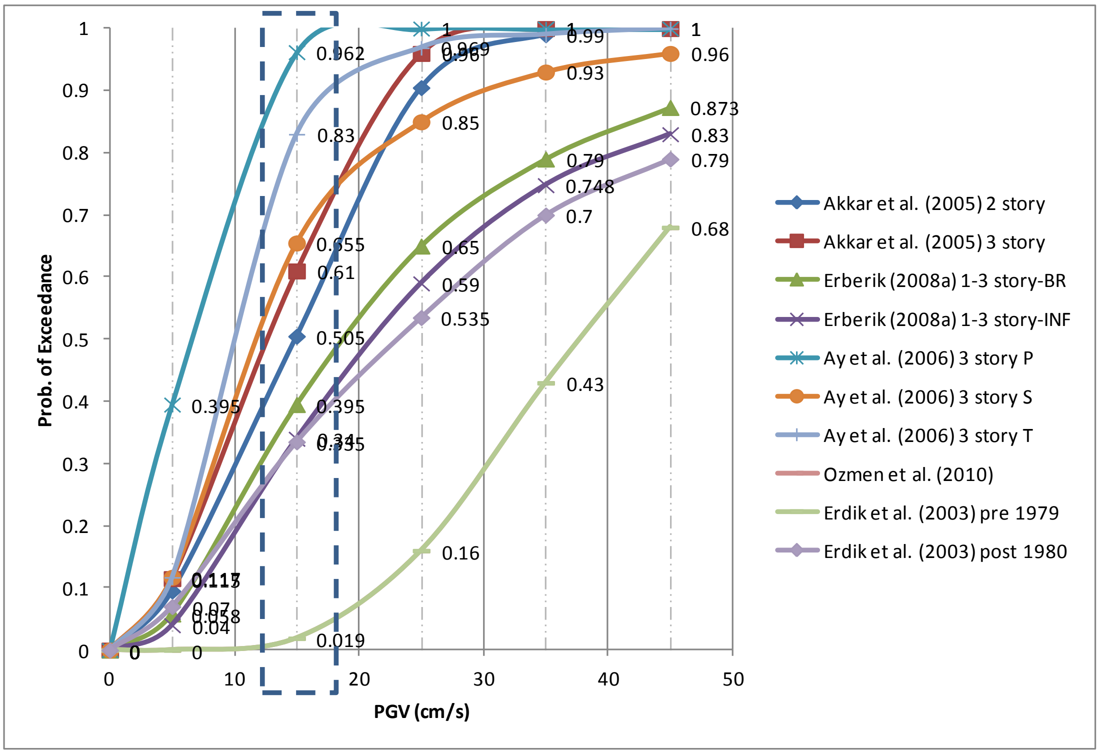

Figure 4.1 Collected data example of RC Frame Low-rise type of buildings for Immediate Occupancy performance level corresponding to the x=15 cm/s

In Figure 4.1, values are chosen from the RC Frame Low-rise Immediate Occupancy performance level for selected ground motion intensities which are x=0, 15,…45 cm/s. After that, for the calculation of the point x =15 cm/s for the represented curve, average *y* values of fragility curves are calculated which are represented in the dashed rectangular shape in Figure 4.1.

4.1.2 Weighted Coefficient Method

This method is similar to the first method. The only difference is that p_i values, are multiplied by weighted coefficients which were determined considering accuracy of the study employed. That is when taking average each curve is given a weighted coefficient. Simple formulations are given below.

$$c_i = \frac{v_i}{\sum_{i=1}^{n} v_i} \tag{4.2}$$

$$P_j = \sum_{i=1}^{n} c_i P_i \tag{4.3}$$

In Equation (4.2), c_i is weighted coefficient of i^{th} curve within each subclass, v_i is resulted value of of i^{th} curve taken from Table 4.1, $\sum_{i=1}^{n} v_i$ is sum of all resulted values of curves within each subclass and , i represents each fragility curve within each sub class (RC Frame Low-rise, RC Frame Mid-rise, Frame High-rise, RC-Dual-Mid-rise, etc.).

In Equation (4.3), P is weighted probability of exceeding damages of each subclass for a chosen ground motion value which are 0,15,25,35,45 for PGV cm/s and 0, 0.05(g), 0.10(g), 0.15(g)…0.95(g) for PGA(g) m/s^2, p_i is probability of exceeding damages of a i^{th} curve of each subclass for a chosen ground motion value.

4.1.2.1 Determination of weighted values

Existing studies used different methods to produce the curves and resulted fragility curves are depending on used methodology. To find equivalence of the studies, point scoring system is needed and since the methodologies for fragility curves of the previous studies are different, Weighted Values for Employed Curves (Table 4.1) is prepared. By using weighted values in the table, weighted coefficients are calculated for the all fragility curves. This table divided into four sections which are explained below.

1. Type of modeling

As it is mentioned before, to obtain fragility curves, mathematical modeling can be utilized or two other methods can be used which are empirical methods using existing data and expert opinion methods. When the previous studies on fragility curves here are considered, it is observed that both approaches were employed by the researchers. It has been seen that structures were modeled as two dimensional assemblies of elements (2D modeling) or three dimensional assemblies of elements (3D modeling). In addition to that equivalent single degree of freedom systems (SDOF) according to FEMA 356 or multi degree of freedom systems (MDOF) were used. Since MDOF behavior gives more realistic results, its reliability is higher than SDOF systems. So weighted values are taken into account the modeling approach used by each researcher and a corresponding weighting values are assigned. The value of weighted value is 0 for the methods where buildings were not modeled. For the SDOF and MDOF type of modeling, the weighted values are equal to 1 and 2 respectively.

2. Method of Analysis

Various methods of analyses are employed in derivation of fragility curves. The most common ones are linear static methods, linear dynamic methods, nonlinear static methods and nonlinear dynamic methods. In the previous studies employed here mostly nonlinear analysis is used for the seismic analysis of buildings. Nonlinear static analysis, in other words pushover analysis, is a popular method and generally forced controlled type is used in which the lateral load is increased incrementally until a specified ultimate displacement limit is achieved. Nonlinear dynamic analysis, in other words, time history analysis is the most precise method in which instead of target displacements, ground motion histories are used for analysis. According to FEMA 356, detailed model of the structure is exposed to the ground motion time histories to find forces and displacements. For ad hoc methods which are expert opinion method and experimental methods depend on data of past earthquakes, weighted value is equal to 1. For analytical methods which are nonlinear static and dynamic methods, weighted values are 2 and 3 respectively.

3. Classification Degree of Buildings

For the accurate suggestion of fragility curves, it is important to compare curves which belong to the same type of building. Material types; Reinforced Concrete buildings and Masonry buildings, number of stories; Low-rise, Mid-rise and High-rise and other sub-classification of Masonry buildings are important because all this parameters affect the result of fragility curves. To obtain more realistic fragility curves for each type of building, pure data which belong to same type of buildings is needed. Therefore, classification degree is an important factor. Classification degree is divided into three divisions which are Poor, Moderate and Good and weighted values are 1, 2 and 3 respectively.

4. Calibration

Calibration of estimated fragility curves and loss results with the data of past earthquakes is also an important step to determine the accuracy. Therefore, the fragility curves that are based calibration studies are considered more reliable. Thus larger weighted values are assigned such as 1 for the the studies including calibration and 0 for the studies with no calibration.

Weighting coefficients assigned to each parameter considered here are summarized in Table 4.1.

Table 4.1 Weighted Values for Employed Curves

Modelling	**Value**	**Method of Analysis**	**Value**	**Classification Degree**	**Value**	**Calibration**	**Value**	**Maximum**
Not modelling	0	Expert opinion, Data from past earthquakes, Experimental methods	1	Poor	1	Yes	1	9
SDOF	1	Nonlinear static Pushover	2	Moderate	2	No	0	
MDOF	2	Nonlinear Dynamic Time history	3	Good	3			

Based on the details and inclusion of the parameters discussed above on the fragility curve development, the weighting coefficients are assigned to these fragility curves. Table 4.2 presents the corresponding weighting coefficients assigned to each study employed here.

Table 4.2 Weighting Coefficient for Studies Employed

No	Article	Modelling	W. Point	Method of Analysis	W.Point	Classification Degree	W.Point	Calibration	W.Point	Total Point
1	Akkar et al. (2005)	SDOF	1	Nonlinear dynamic analysis	3	Good	3	Yes	1	8
2	Ceran and Erberik (2013)	Local modelling, only wall	1	Equivalent lateral load analysis	1	Good	3	Yes	1	6
3	Erberik (2008b)	3D MDOF	2	Nonlinear static and dynamic analysis	3	Good	3	Yes	1	9
4	Ay et al. (2006)	SDOF	1	Nonlinear static and dynamic analysis	3	Good	3	Yes	1	8
5	Erberik (2008a)	SDOF	1	Nonlinear static and dynamic analysis	3	Good	3	Yes	1	8
6	D'Ayala and Kishali (2012)	SDOF	1	Famive, combination of expert opinion, data coolection and nonlinear static methods	2	Moderate	2	No	0	5
7	Korkmaz and Johnson (2007)	SDOF	1	Nonlinear static and dynamic analysis	3	Good	3	No	0	7
8	Ozmen et al. (2010)	SDOF	1	Nonlinear static analysis	2	Good	3	No	0	6
9	Kırçıl and Polat (2006)	2-D	2	Nonlinear dynamic analysis	3	Poor	1	No	0	6
10	Smyth et al. (2004)	Expert opinion	0	Nonlinear dynamic analysis	3	Good	3	No	0	6
11	Erdik et al. (2003)	Expert opinion	0	Expert opinion	1	Good	3	No	0	4

4.1.3 Weighted Lognormal Cumulative Distribution Function Method

The last analysis is Weighted Log normal Cumulative Function Method, which is simply logarithmic version of standard normal cumulative function approach shown below in Equation (4.4).

$$F(x) = \Phi\left(\frac{In(x) - \mu}{\sigma}\right) \quad (4.4)$$

In Equation (4.4), x is ground motion parameter which is PGV for RC Frame and Dual type-buildings (x=0,5,15…45 cm/s) and PGA for Masonry buildings (x=0,0.05(g),0.15(g),…0.95(g) m/s2), μ is mean of the logarithmic function of the ground motion parameter, σ is standard deviation of the logarithmic function of the ground motion parameter, Φ represents normal distribution function and $F(x)$ is cumulative distribution function that gives the probability of exceedance for the given performance level.

In this method, after finding logarithmic mean and standard deviation and calculating probability of exceedance for the performance level for each curve, average of these y values are obtained to determine the final $F(x)$ for specific ground motion parameters using Equations (4.5) and (4.6).

$$z_i(x) = \left(\frac{In(x) - \mu_i}{\sigma_i}\right) \quad (4.5)$$

$$F(x) = \sum_{i=1}^{n} c_i z_i\,(x) \quad (4.6)$$

In Equation (4.5), $z_i(x)$ is standardized value for each fragility curve within each subclass, x is chosen ground motion parameter, μ_i and σ_i are mean and standard deviation of the logarithmic function of whole ground motion data belongs to i^{th} fragility curve respectively. Finally, i represents each fragility curve within each sub class (RC Frame Low-rise, RC Frame Mid-rise, Frame High-rise, RC-Dual-Mid-rise, etc.).

In Equation (4.6), $F(x)$ is cumulative distribution function of that gives the probability of exceedance damage for each x value, c_i is weighted coefficient of i^{th} curve within each building classes stated in Equation (4.2) and $z_i(x)$ is standardized value for each fragility curve within each subclass, x is chosen ground motion parameter.

4.1.4 Recommended Generalized Fragility Curves

In contrast to most of the results of RC Dual Buildings and Masonry buildings, the fragility curves obtained from Mean Method, Weighted Coefficient Method and Weighted Lognormal Cumulative Distribution Function are similar for the RC Frame buildings because in the most of the previous studies, Analytical Methods were used and therefore convergence of the lognormal curves to 1 on the % (y axis) is not take place for high ground motion intensities (x axis). However, especially for Masonry buildings, Lognormal Cumulative Distribution Function gives different results from the other two methods because most of the curves taken from the studies by Erdik et al. (2003) and D'Ayala and Kışhalı (2004) which were conducted using ad-hoc methods (Expert Opinion Method etc.). As a result of that, curves of Mean Method and Weighted Coefficient Method have low probability of exceedance damage state values until 0.95(g). However, Weighted Lognormal Cumulative Distribution Function has higher probability of exceedance values for the given damage states in between 0 and 0.95(g) to converge 1 at higher ground motion intensities. When considering affect of weighted coefficients, it is concluded that this method is useful for the studies where fragility curves conducted by different methods. At some of the graphs of RC Dual and Masonry buildings, resulted curves of Mean Method and Weighted Coefficient Method are identical as weighted coefficients are same for the curves which were produced by the same study. Graphs comprising all three methods for the classes are given in Appendix A.

After comparing all three methods, Lognormal Cumulative Distribution Function is chosen to generalize fragility curves and there are three reasons for this choice. First of all, in this method, instead of using the chosen x values, all data of a fragility curve given in a study is used and therefore behavior of curves can be found for all ground motion intensities. Secondly, since this method eliminates the reflection of ad hoc methods which give very low probability of exceedance values for a given performance level for high ground motion intensities; generalized lognormal curves of Masonry buildings are more applicable for Turkey. Thirdly, curves of the lognormal method are smoother than the ones obtained from other methods because taking average of the curves make some roughness on the curves. Generalized fragility curves are presented in Figure 4.2 to Figure 4.10. For RC Frame and Masonry buildings, existing data taken from Bilal (2013) is also added to these graphs. Since these curves are used for the calculation of premiums, some of the studies that had inadequate results are omitted for the reliable results. Moreover, the fragility curves which were not calculated for all performance damage states are not taken into account. As a result of that, for the calculation of generalized curves of RC Dual and Masonry buildings, only Erdik et. al. (2003) is used.

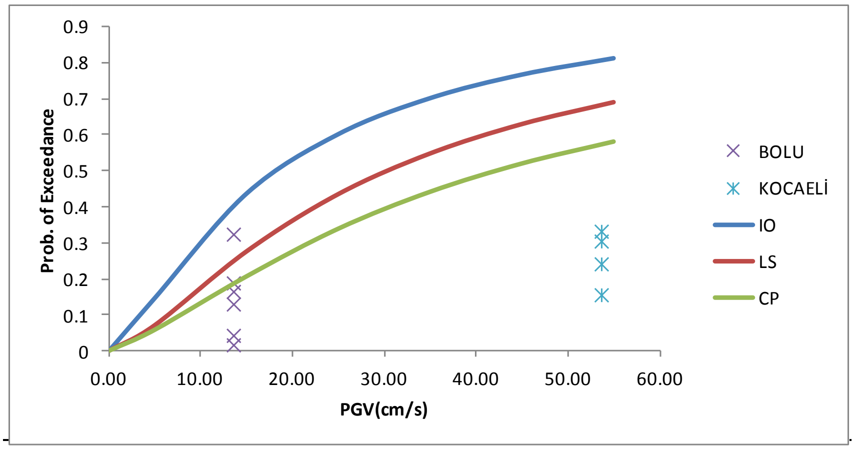

Figure 4.2 Generalized fragility curves for **RC Frame Low-rise** type of buildings

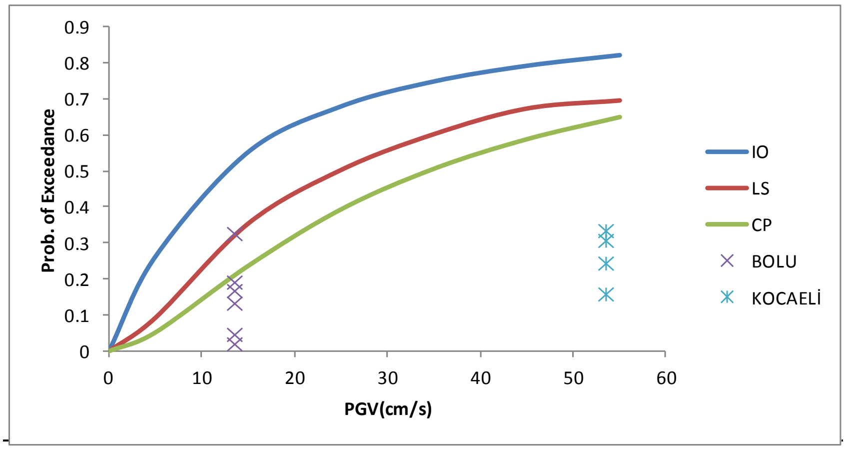

Figure 4.3 Generalized fragility curves for **RC Frame Mid-rise** type of buildings

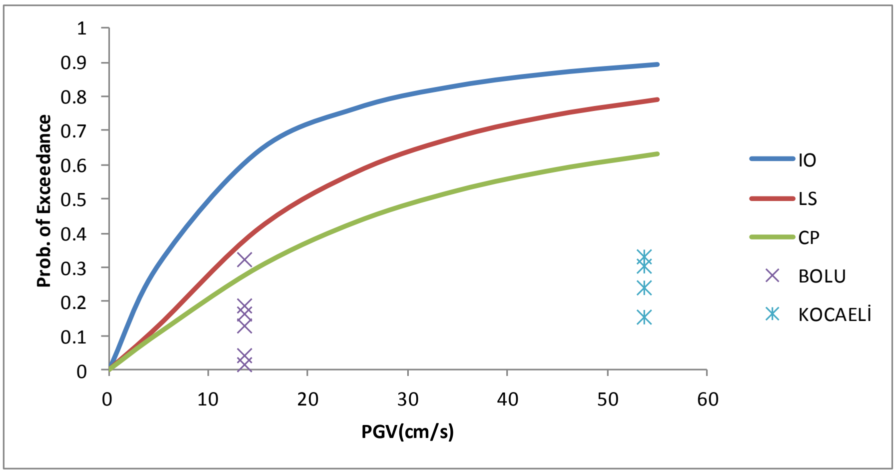

Figure 4.4 Generalized fragility curves for **RC Frame High-rise** type of buildings

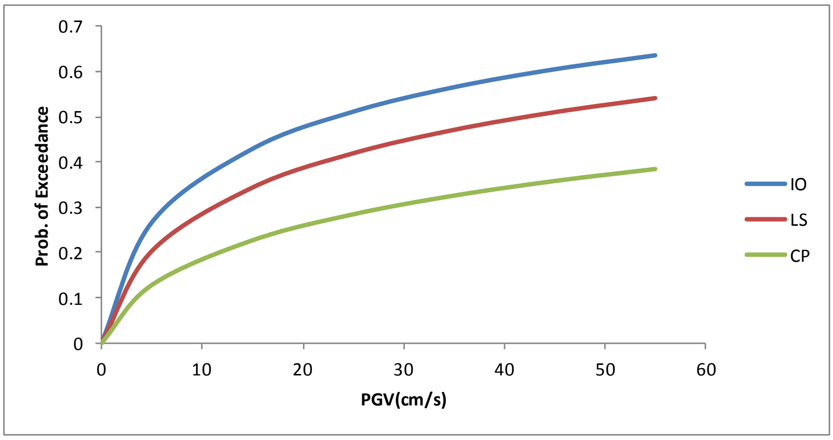

Figure 4.5 Generalized fragility curves for **RC Dual Low-rise** type of buildings

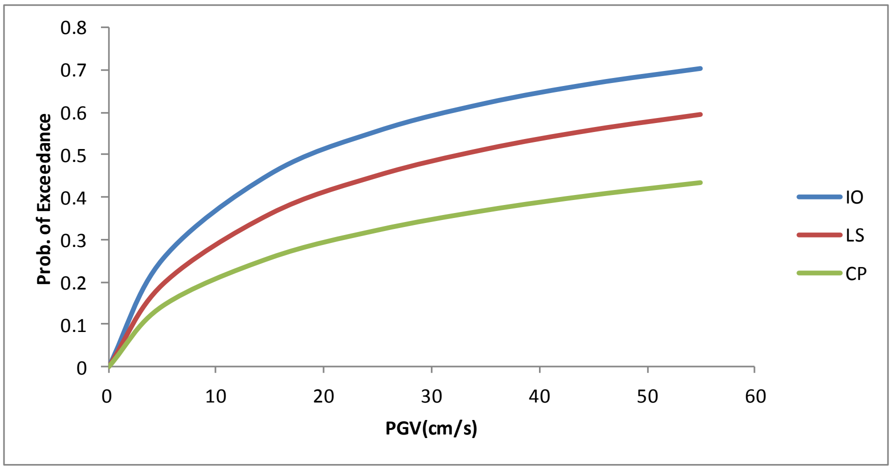

Figure 4.6 Generalized fragility curves for **RC Dual Mid-rise** type of buildings

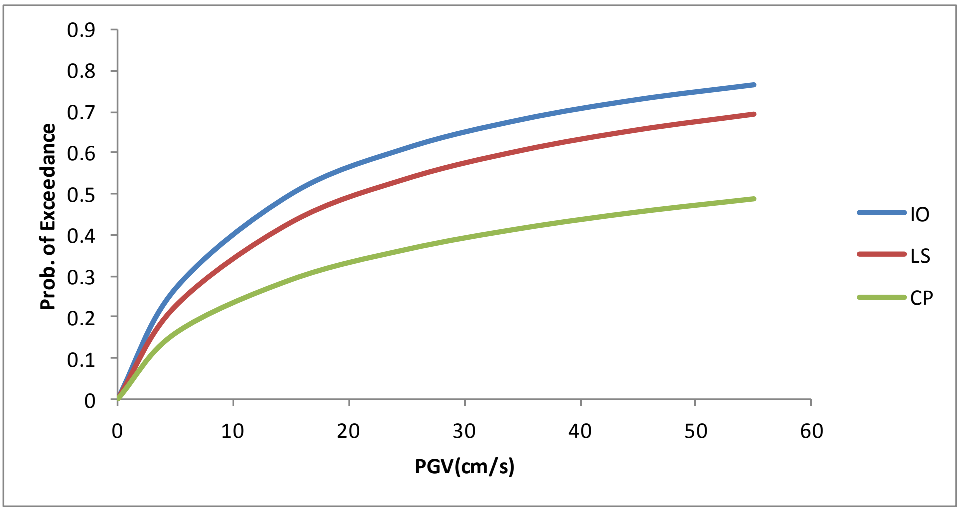

Figure 4.7 Generalized fragility curves for **RC Dual High-rise** type of buildings

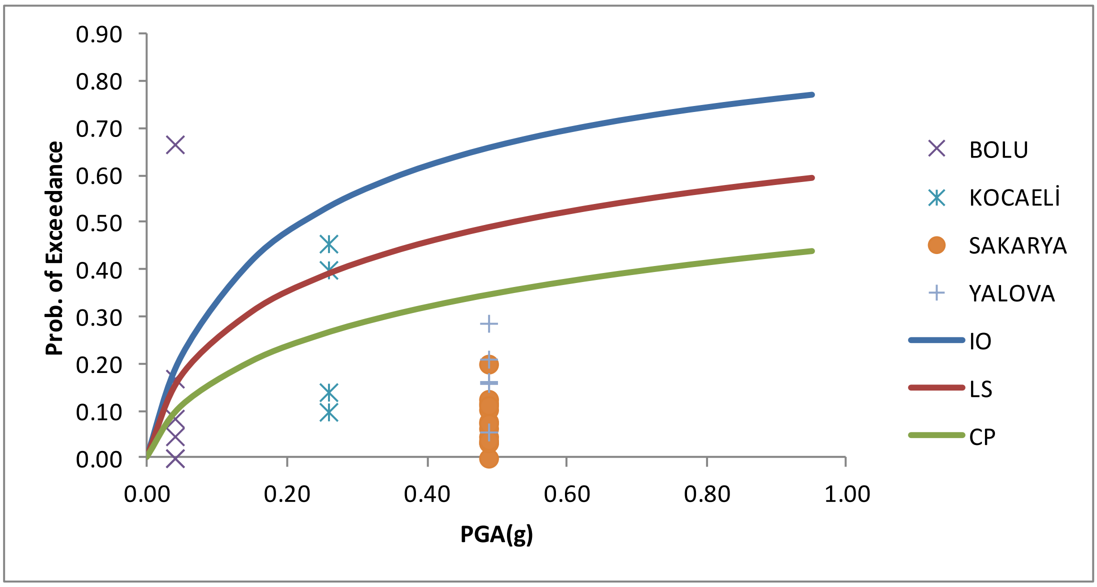

Figure 4.8 Generalized fragility curves for **General Low-rise** type of buildings

For RC buildings, the curves are consistent with the existing data taken from Bilal (2013) for the low ground motion intensities. For Masonry buildings, consistency is observed for both low and high ground motion intensities.

Generalized fragility curves represent the curves obtained as a combination of the fragility curves employed for the same building class so the scatter is considered indirectly using weighted coefficients.

CHAPTER 5

MODIFIED INSURANCE PREMIUMS FOR TCIP

5.1 Turkish Earthquake Insurance System

After Düzce and Kocaeli Earthquake (1999), to reduce the economic damages of earthquakes, Natural Disaster Insurance Institution (TCIP) is established as the legal entity which is responsible for provision, implementation and management of Compulsory Earthquake Insurance in Turkey. The aim of TCIP is to create an insurance pool for residential buildings with low premium costs providing assurance of everyone. This financial pool is not only for supporting the casualties who are suffered by earthquakes, but also contributing the economy to minimize the economic losses. According to TCIP, current penetration rate is 39.6% and from the beginning, total compensation payment is 160.643.546 TL that reveals the importance of insurance pool.

Premium calculation in Turkey is constituted depending on Compulsory Earthquake Insurance Tariff and Instructions. Premium amount is equal to multiplication of sum insured with the tariff rate. According to the this instruction, there are 15 tariff rates changing based on 3 building styles and 5 risk zones which is given in Table 5.1.

Table 5.1 Rates of Insurance Tariffs and Premiums charged by Insurance Companies based on Zones per the Building Type (‰) TCIP (2013)

Building Type	1st Zone	2nd Zone	3rd Zone	4th Zone	5th Zone
A-Steel, concrete	2.2	1.55	0.83	0.55	0.44
B-Masonry buildings	3.85	2.75	1.43	0.6	0.5
C-Other buildings	5.5	3.53	1.76	0.78	0.58

Although there are many studies about seismic risk and behaviors of Turkish buildings under earthquakes, seismic response of the buildings are not taken into account by TCIP to calculate earthquake premiums. However, to obtain more realistic premiums, it is urgent to make calculations depending on scientific methods. Using fragility curves is one of the scientific methods for the calculation of premiums. Fragility curves are main tool for loss estimation which is probability of exceeding a damage limit state for a given building under earthquake (Akkar et al. 2005). In other words, these curves are unique for every building and therefore give more realistic results. Due to considering structural capacities of buildings and since by using fragility curves loss estimation is more confidential, resulted premiums obtained from estimated losses are also more accurate.

In this chapter, insurance premiums are calculated by using suggested generalized fragility curves for Reinforced Concrete Frame, Dual and Masonry buildings for Low-rise, Mid-rise and High-rise. These premiums are compared with current TCIP premiums.

5.2 Determination of Premiums

For the calculation of insurance premiums by using fragility curves , methodology suggested by Kanda and Nishijima (2004) is utilized. In this study, by using damage cost statistics taken for eight sites in Japan after Hyogoken-Numbu Earthquake, expected seismic loss was calculated and compared with current seismic insurance premium.

First of all, fragility curves were assumed as having lognormal probability form with five damage states which were Slight, Minor, Moderate, Severe and Collapse. The parameters of loss function were postulated considering damage data of the Hyogoken-Numbu Earthquake.

Resulted formulations using Lognormal Cumulative Distribution Function (Equation (4.4)) were calculated as:

$$Damage\ ratio = \Phi\left(\frac{InV - \boldsymbol{\lambda}_{\mathbf{i}}}{\boldsymbol{\xi}}\right) \tag{5.1}$$

In Equation (5.1), V represents earthquake ground motion on surface in velocity (cm/s), i is the damage state, λ and ξ are mean and standard deviation, respectively. Secondly, the damage states were divided into three levels: level 1 for slight and minor damage; level 2 for severe and moderate damage and level 3 for collapse to estimate relationship between damage states and insured loss.

Parameters for Equation (5.1) are given in Table 5.2 for different damage states.

Table 5.2 Parameters for Lognormal Fragility Curve ((Kanda and Nishijima (2004))

Damage State *i*	λ	ξ	**Repair Cost%**
Slight	In50	0.4	-
Minor	In100	0.4	10
Moderate	In150	0.4	15
Severe	In200	0.4	30
Collapse	In250	0.4	100

According to Table 5.2, if the buildings have slight and minor damage (level 1), 5% of insured value is paid. If the buildings have moderate and severe damage (level 2), 50% of insured value is paid and finally 100% of insured value is paid for the collapsed buildings (level 3).

Finally, for the calculation of earthquake insurance, relationships are found between the earthquake insurances and the damage states using the parameters in Table 5.2. Losses for each level are obtained as:

$$L_1 = 0.05 \times \left(\Phi\left(\frac{InV - In50}{0.4}\right) - \Phi\left(\frac{Inv - In150}{0.4}\right)\right) \tag{5.2}$$

$$L_2 = 0.5 \times \left(\Phi\left(\frac{InV - In150}{0.4}\right) - \Phi\left(\frac{Inv - In250}{0.4}\right)\right) \tag{5.3}$$

$$L_3 = 1 \times \left(\Phi\left(\frac{InV - In250}{0.4}\right)\right) \tag{5.4}$$

From these loss functions and using the seismic hazard analysis, insurance premiums were calculated for 8 major cities in Japan.

5.3 Earthquake Insurance Premiums for Istanbul

By using Kanda and Nishijima (2004) methodology, earthquake insurance premiums are calculated for the center of 39 districts of Istanbul. Center of districts were taken from the webpage HaritaMap (2015). For the premium calculations, ground motion parameters were determined at the center of each district. The insurance premiums were then calculated for these districts using the generalized fragility curves.

5.3.1 Determination of Ground Motion Parameters

In order to obtain peak ground motion parameters for the center of 39 districts of Istanbul, the study conducted in the project entitled the Revision of Turkish Seismic Hazard Map (RTSHM; Akkar et al., 2015) is utilized. Probabilistic seismic hazard analysis is implemented by considering area source model and fault and gridded seismicity source models separately for the return periods of T_R= 72, T_R=475 and T_R=2475 years. The seismic hazard analyses results are obtained from the combination of area source and fault models based 50 % + 50% approach, that is the results were taken as the average of these two models. The analyses are performed by EZ-F Risk computer program which is used by engineers and seismologists to conduct site-specific and regional earthquake hazard analysis. The ground-motion attenuation logic-tree used for probabilistic seismic hazard analysis is presented in Table 5.3.

Table 5.3 Weights of Empirical Ground-Motion Prediction Equations used for Probabilistic Seismic Hazard Analysis

GMPE	Weight	Vs30
Kale et al. (2015)	0.34	760m/s
Akkar et al. (2013)	0.33	
Chiou and Youngs (2008)	0.33	

The seismic hazard analyses provided the peak ground acceleration and peak ground velocity at the center of each district. These ground motion parameters are used with the corresponding fragility curves to determine the insurance premiums.

5.3.2 Calculation of Earthquake Insurance Premiums

The probability of exceedance are determined for Immediate Occupancy, Life Safety and Collapse Prevention levels using the appropriate ground motion parameters and the fragility curves for each building class.

The loss is calculated as the multiplication of Central Damage Ratio (CDR) with difference of probability of exceedance for each damage level that is defined as:

$$L_i = CDR(DS_i) \times (Pr(DS_i) - Pr(DS_{i+1})) \quad (5.5)$$

In Equation (5.5), DS_i is damage states of i^{th} level, i represents damage states as numerically. 1 is for Immediate Occupancy (IO); 2 is for Life Safety (LS) and 3 is for Collapse Prevention (CP), $CDR(DS_i)$ is central damage ratio for each damage state, $Pr(DS_i)$ is damage state probability and L_i is seismic losses for each damage states.

The Central Damage Ratio for each damage state is given in Table 5.4.

Table 5.4 Central Damage Ratios (Bilal (2013))

Damage State	**CDR (%)**
None	0
Light	5
Moderate	30
Severe	85

By using Table 5.4, 5% is used for Immediate Occupancy, 30% is used for Life Safety and 85% is used for Collapse Prevention level based on equivalence of damage states. In other words, 5%, 30% and 85% of insured values are paid for buildings under light, moderate and severe damage states respectively which are represented in the following equations.

$$L_1 = 0.05 \times (\Pr(IO) - \Pr(LS)) \tag{5.6}$$

$$L_2 = 0.30 \times (\Pr(LS) - \Pr(CP)) \tag{5.7}$$

$$L_3 = 0.85 \times Pr(CP) \tag{5.8}$$

The losses are calculated at the district centers for three return periods that are 72 years, 475 years and 2475 years using the generalized fragility curves. The insurance premiums are obtained using losses and the CDR values (Bilal 2013). Details of calculated losses and premiums are given in Appendix B for each return period.
A safety loading is added to the TCIP premium to account for the unknown expenditures. According to the TCIP, tariff rate is equal to 0.0022 for concrete buildings in Earthquake Zone I, and the corresponding premium is $169\ TL$. The square meter unit cost of concrete buildings in Istanbul is given by TCIP as $700\ TL/m^2$. Based on this information, for consistency reasons, the safety loading, θ, is calculated as:

$$\Pi_{calc} = 0.0022 \times 100m^2 \times 700\ TL/m^2$$

$$= 154\ TL$$

$$\Pi_{TCIP} = 169\ TL$$

$$\theta = \frac{169-154}{154} = 0.097$$

Π_{calc} is calculated premium value by using given tariff rate, Π_{TCIP} is given premium value by TCIP including safety loading and θ is safety loading ratio.

To obtain consistent results, this safety loading value is also added to equations of premiums for unknown expenditures.

$$\pi_{72} = \frac{1.097 \times \sum_{i=1}^{3} L_i}{72} \tag{5.9}$$

$$\pi_{475} = \frac{1.097 \times \sum_{i=1}^{3} L_i}{475} \tag{5.10}$$

$$\pi_{2475} = \frac{1.097 \times \sum_{i=1}^{3} L_i}{2475} \tag{5.11}$$

In the equations, π_{72}, π_{475} and π_{2475} premium rates for the return periods (TR) which is equal to 72 years, 475 years and 2475 years respectively.

After calculating premiums for the return periods, several alternatives were considered to determine the final premium. The first one is the Maximum Premium value is obtained as the maximum value among the three premiums (Equations (5.9) to (5.11)). The second one is the Average Premium calculated by taking average of the three premiums. The following equations show the formulation for these alternatives:

$$\pi_{max} = \max(\pi_{\mathrm{TR}}) \tag{5.12}$$

$$\pi_{av} = \frac{\sum \pi_{TR}}{3} \tag{5.13}$$

The Maximum Premium (π_{max}) and Average Premium (π_{av}) values are compared with TCIP premium values (π_{TCIP}) for each district. Since TCIP values change for each district based on their seismic zone, earthquake zones of the districts are taken from the Earthquake Zone Map of Istanbul (Figure 5.1) and are shown in Table 5.5.

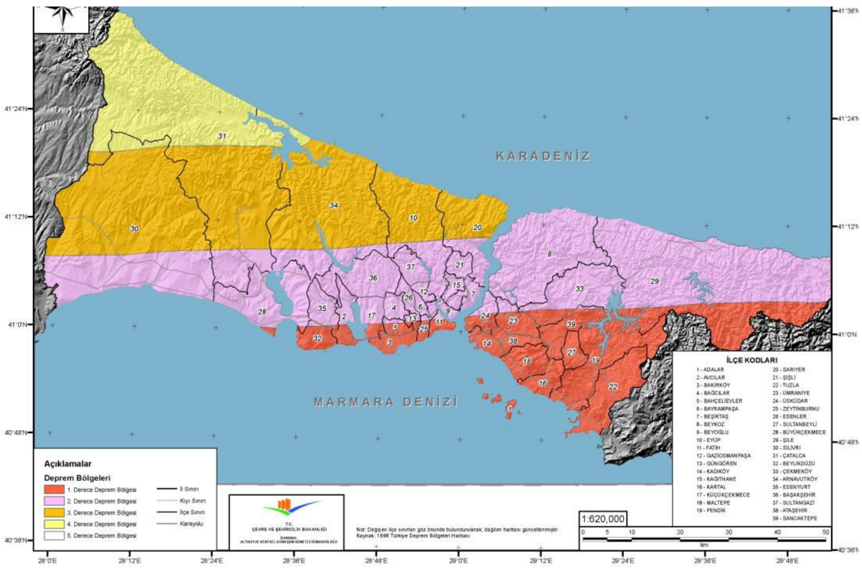

Figure 5.1 Istanbul Seismic Zone Map (Turkish Ministry of Environment and Planning)

Table 5.5 Seismic Zones of Istanbul According to the Districts

No	District	Zone	No	District	Zone
1	Adalar	1	20	Fatih	1
2	Arnavutköy	3	21	Gaziosmanpaşa	2
3	Ataşehir	1	22	Güngören	2
4	Avcılar	1	23	Kadıköy	1
5	Bağcılar	2	24	Kağıthane	2
6	Bahçelievler	2	25	Kartal	1
7	Bakırköy	1	26	Küçükçekmece	2
8	Başakşehir	2	27	Maltepe	1
9	Bayrampaşa	2	28	Pendik	1
10	Beşiktaş	2	29	Sancaktepe	1
11	Beykoz	2	30	Sarıyer	3
12	Beylikdüzü	1	31	Silivri	3
13	Beyoğlu	2	32	Sultanbeyli	1
14	Büyükçekmece	2	33	Sultangazi	2
15	Çatalca	3	34	Şile	2
16	Çekmeköy	2	35	Şişli	2
17	Esenler	2	36	Tuzla	1
18	Esenyurt	2	37	Ümraniye	1
19	Eyüp	3	38	Üsküdar	1
			39	Zeytinburnu	1

5.4 Results of Earthquake Insurance Premiums for Istanbul

The Earthquake Insurance Premiums calculated for the districts of Istanbul are presented in Tables 5.6 to 5.13. In these tables, ratios of the Maximum Premiums (π_{max}) and Average Premiums (π_{av}) to TCIP Premiums (π_{TCIP}) are also presented for better comparison.

According to these results, for RC Frame Low-rise, RC Frame Mid-rise and Masonry buildings in Zone 3, TCIP premiums are closer to Average premiums than Maximum premiums. However, for all districts in Zone 1 and Zone 2, such uniform relationship is not obtained. When RC Frame High-rise buildings and RC Dual buildings are examined, it is observed that TCIP premiums for some of the districts are closer to Maximum Premiums while others are closer to Average Premiums.

Table 5.6 Earthquake Insurance Premium Rates for **RC Frame Low-rise** Type of Buildings

Zone	District	π_{max} ‰	π_{av} ‰	π_{TCIP} ‰	π_{max} / π_{TCIP}	π_{av} / π_{TCIP}
1	Adalar	2.99	1.00	2.20	1.36	0.73
1	Ataşehir	1.33	0.44	0.83	1.60	0.28
1	Avcılar	1.95	0.65	2.20	0.88	0.73
1	Bakırköy	2.30	0.77	2.20	1.05	0.73
1	Beylikdüzü	2.04	0.68	1.55	1.31	0.52
1	Fatih	2.32	0.77	1.55	1.50	0.52
1	Kadıköy	2.58	0.86	2.20	1.17	0.73
1	Kartal	1.69	0.56	1.55	1.09	0.52
1	Maltepe	1.96	0.65	1.55	1.26	0.52
1	Pendik	1.67	0.56	1.55	1.08	0.52
1	Sancaktepe	1.30	0.43	1.55	0.84	0.52
1	Sultanbeyli	2.60	0.87	2.20	1.18	0.73
1	Tuzla	1.93	0.64	1.55	1.25	0.52
1	Ümraniye	2.34	0.78	1.55	1.51	0.52
1	Üsküdar	1.55	0.52	0.83	1.87	0.28
1	Zeytinburnu	1.31	0.44	1.55	0.84	0.52
2	Bağcılar	1.78	0.59	1.55	1.15	0.52
2	Bahçelievler	2.17	0.72	1.55	1.40	0.52
2	Başakşehir	1.93	0.64	0.83	2.32	0.28
2	Bayrampaşa	2.11	0.70	2.20	0.96	0.73
2	Beşiktaş	1.77	0.59	1.55	1.14	0.52
2	Beykoz	2.18	0.73	1.55	1.41	0.52
2	Beyoğlu	2.08	0.69	2.20	0.94	0.73
2	Büyükçekmece	1.66	0.55	1.55	1.07	0.52
2	Çekmeköy	2.35	0.78	2.20	1.07	0.73
2	Esenler	2.34	0.78	1.55	1.51	0.52
2	Esenyurt	2.07	0.69	2.20	0.94	0.73
2	Gaziosmanpaşa	1.64	0.55	2.20	0.75	0.73
2	Güngören	1.52	0.51	2.20	0.69	0.73
2	Kağıthane	1.32	0.44	0.83	1.59	0.28
2	Küçükçekmece	1.77	0.59	0.83	2.13	0.28
2	Sultangazi	1.82	0.61	2.20	0.83	0.73
2	Şile	1.63	0.54	1.55	1.05	0.52
2	Şişli	1.11	0.37	1.55	0.72	0.52
3	Arnavutköy	1.47	0.49	1.55	0.95	0.52
3	Çatalca	2.11	0.70	2.20	0.96	0.73
3	Eyüp	1.74	0.58	2.20	0.79	0.73
3	Sarıyer	1.89	0.63	2.20	0.86	0.73
3	Silivri	2.41	0.80	2.20	1.10	0.73

Table 5.7 Earthquake Insurance Premium Rates for **RC Frame Mid-rise** Type of Buildings

Zone	District	π_{max} ‰	π_{av}‰	π_{TCIP} ‰	π_{max} / π_{TCIP}	π_{av} / π_{TCIP}
1	Adalar	3.58	1.19	2.20	1.63	0.54
1	Ataşehir	1.55	0.52	0.83	1.87	0.62
1	Avcılar	2.31	0.77	2.20	1.05	0.35
1	Bakırköy	2.74	0.91	2.20	1.25	0.42
1	Beylikdüzü	2.42	0.81	1.55	1.56	0.52
1	Fatih	2.76	0.92	1.55	1.78	0.59
1	Kadıköy	3.09	1.03	2.20	1.40	0.47
1	Kartal	1.99	0.66	1.55	1.28	0.43
1	Maltepe	2.32	0.77	1.55	1.50	0.50
1	Pendik	1.97	0.66	1.55	1.27	0.42
1	Sancaktepe	1.51	0.50	1.55	0.98	0.33
1	Sultanbeyli	3.11	1.04	2.20	1.41	0.47
1	Tuzla	2.29	0.76	1.55	1.48	0.49
1	Ümraniye	2.78	0.93	1.55	1.80	0.60
1	Üsküdar	1.82	0.61	0.83	2.19	0.73
1	Zeytinburnu	1.52	0.51	1.55	0.98	0.33
2	Bağcılar	2.11	0.70	1.55	1.36	0.45
2	Bahçelievler	2.58	0.86	1.55	1.67	0.56
2	Başakşehir	2.28	0.76	0.83	2.75	0.92
2	Bayrampaşa	2.51	0.84	2.20	1.14	0.38
2	Beşiktaş	2.09	0.70	1.55	1.35	0.45
2	Beykoz	2.59	0.86	1.55	1.67	0.56
2	Beyoğlu	2.47	0.82	2.20	1.12	0.37
2	Büyükçekmece	1.96	0.65	1.55	1.26	0.42
2	Çekmeköy	2.80	0.93	2.20	1.27	0.42
2	Esenler	2.79	0.93	1.55	1.80	0.60
2	Esenyurt	2.46	0.82	2.20	1.12	0.37
2	Gaziosmanpaşa	1.93	0.64	2.20	0.88	0.29
2	Güngören	1.78	0.59	2.20	0.81	0.27
2	Kağıthane	1.53	0.51	0.83	1.85	0.62
2	Küçükçekmece	2.09	0.70	0.83	2.52	0.84
2	Sultangazi	2.15	0.72	2.20	0.98	0.33
2	Şile	1.92	0.64	1.55	1.24	0.41
2	Şişli	1.28	0.43	1.55	0.82	0.27
3	Arnavutköy	1.72	0.57	1.55	1.11	0.37
3	Çatalca	2.50	0.83	2.20	1.14	0.38
3	Eyüp	2.05	0.68	2.20	0.93	0.31
3	Sarıyer	2.24	0.75	2.20	1.02	0.34
3	Silivri	2.88	0.96	2.20	1.31	0.44

Table 5.8 Earthquake Insurance Premium Rates for **RC Frame High-rise** Type of Buildings

Zone	District	π_{max} ‰	π_{av} ‰	π_{TCIP} ‰	π_{max} / π_{TCIP}	π_{av} / π_{TCIP}
1	Adalar	4.60	1.53	2.20	2.09	0.70
1	Ataşehir	2.36	0.79	0.83	2.84	0.95
1	Avcılar	3.19	1.06	2.20	1.45	0.48
1	Bakırköy	3.68	1.23	2.20	1.67	0.56
1	Beylikdüzü	3.31	1.10	1.55	2.14	0.71
1	Fatih	3.70	1.23	1.55	2.39	0.80
1	Kadıköy	4.06	1.35	2.20	1.85	0.62
1	Kartal	2.84	0.95	1.55	1.83	0.61
1	Maltepe	3.21	1.07	1.55	2.07	0.69
1	Pendik	2.82	0.94	1.55	1.82	0.61
1	Sancaktepe	2.32	0.77	1.55	1.50	0.50
1	Sultanbeyli	4.08	1.36	2.20	1.85	0.62
1	Tuzla	3.18	1.06	1.55	2.05	0.68
1	Ümraniye	3.72	1.24	1.55	2.40	0.80
1	Üsküdar	2.65	0.88	0.83	3.20	1.07
1	Zeytinburnu	2.33	0.78	1.55	1.50	0.50
2	Bağcılar	2.97	0.99	1.55	1.92	0.64
2	Bahçelievler	3.50	1.17	1.55	2.26	0.75
2	Başakşehir	3.17	1.06	0.83	3.82	1.27
2	Bayrampaşa	3.42	1.14	2.20	1.56	0.52
2	Beşiktaş	2.96	0.99	1.55	1.91	0.64
2	Beykoz	3.51	1.17	1.55	2.26	0.75
2	Beyoğlu	3.37	1.12	2.20	1.53	0.51
2	Büyükçekmece	2.81	0.94	1.55	1.81	0.60
2	Çekmeköy	3.74	1.25	2.20	1.70	0.57
2	Esenler	3.73	1.24	1.55	2.41	0.80
2	Esenyurt	3.36	1.12	2.20	1.53	0.51
2	Gaziosmanpaşa	2.78	0.93	2.20	1.26	0.42
2	Güngören	2.61	0.87	2.20	1.19	0.40
2	Kağıthane	2.34	0.78	0.83	2.82	0.94
2	Küçükçekmece	2.95	0.98	0.83	3.56	1.19
2	Sultangazi	3.03	1.01	2.20	1.38	0.46
2	Şile	2.76	0.92	1.55	1.78	0.59
2	Şişli	2.06	0.69	1.55	1.33	0.44
3	Arnavutköy	2.54	0.85	1.55	1.64	0.55
3	Çatalca	3.41	1.14	2.20	1.55	0.52
3	Eyüp	2.91	0.97	2.20	1.32	0.44
3	Sarıyer	3.12	1.04	2.20	1.42	0.47
3	Silivri	3.82	1.27	2.20	1.74	0.58

Table 5.9 Earthquake Insurance Premium Rates for **RC Dual Low-rise** Type of Buildings

Zone	District	π_{max} ‰	π_{av} ‰	π_{TCIP} ‰	π_{max} / π_{TCIP}	π_{av} / π_{TCIP}
1	Adalar	3.45	1.15	2.20	1.57	0.52
1	Ataşehir	2.36	0.79	0.83	2.84	0.95
1	Avcılar	2.77	0.92	2.20	1.26	0.42
1	Bakırköy	3.00	1.00	2.20	1.36	0.45
1	Beylikdüzü	2.82	0.94	1.55	1.82	0.61
1	Fatih	3.01	1.00	1.55	1.94	0.65
1	Kadıköy	3.19	1.06	2.20	1.45	0.48
1	Kartal	2.59	0.86	1.55	1.67	0.56
1	Maltepe	2.77	0.92	1.55	1.79	0.60
1	Pendik	2.58	0.86	1.55	1.67	0.56
1	Sancaktepe	2.34	0.78	1.55	1.51	0.50
1	Sultanbeyli	3.20	1.07	2.20	1.45	0.48
1	Tuzla	2.76	0.92	1.55	1.78	0.59
1	Ümraniye	3.02	1.01	1.55	1.95	0.65
1	Üsküdar	2.50	0.83	0.83	3.02	1.01
1	Zeytinburnu	2.34	0.78	1.55	1.51	0.50
2	Bağcılar	2.66	0.89	1.55	1.71	0.57
2	Bahçelievler	2.91	0.97	1.55	1.88	0.63
2	Başakşehir	2.75	0.92	0.83	3.32	1.11
2	Bayrampaşa	2.88	0.96	2.20	1.31	0.44
2	Beşiktaş	2.65	0.88	1.55	1.71	0.57
2	Beykoz	2.92	0.97	1.55	1.88	0.63
2	Beyoğlu	2.85	0.95	2.20	1.30	0.43
2	Büyükçekmece	2.58	0.86	1.55	1.66	0.55
2	Çekmeköy	3.03	1.01	2.20	1.38	0.46
2	Esenler	3.03	1.01	1.55	1.95	0.65
2	Esenyurt	2.85	0.95	2.20	1.29	0.43
2	Gaziosmanpaşa	2.56	0.85	2.20	1.17	0.39
2	Güngören	2.48	0.83	2.20	1.13	0.38
2	Kağıthane	2.35	0.78	0.83	2.83	0.94
2	Küçükçekmece	2.65	0.88	0.83	3.19	1.06
2	Sultangazi	2.68	0.89	2.20	1.22	0.41
2	Şile	2.56	0.85	1.55	1.65	0.55
2	Şişli	2.21	0.74	1.55	1.43	0.48
3	Arnavutköy	2.45	0.82	1.55	1.58	0.53
3	Çatalca	2.87	0.96	2.20	1.31	0.44
3	Eyüp	2.63	0.88	2.20	1.19	0.40
3	Sarıyer	2.73	0.91	2.20	1.24	0.41
3	Silivri	3.07	1.02	2.20	1.40	0.47

Table 5.10 Earthquake Insurance Premium Rates for **RC Dual Mid-rise** Type of Buildings

Zone	District	π_{max} ‰	π_{av} ‰	π_{TCIP} ‰	π_{max} / π_{TCIP}	π_{av} / π_{TCIP}
1	Adalar	3.75	1.25	2.20	1.71	0.57
1	Ataşehir	2.48	0.83	0.83	2.99	1.00
1	Avcılar	2.95	0.98	2.20	1.34	0.45
1	Bakırköy	3.23	1.08	2.20	1.47	0.49
1	Beylikdüzü	3.02	1.01	1.55	1.95	0.65
1	Fatih	3.24	1.08	1.55	2.09	0.70
1	Kadıköy	3.44	1.15	2.20	1.57	0.52
1	Kartal	2.75	0.92	1.55	1.78	0.59
1	Maltepe	2.96	0.99	1.55	1.91	0.64
1	Pendik	2.74	0.91	1.55	1.77	0.59
1	Sancaktepe	2.46	0.82	1.55	1.59	0.53
1	Sultanbeyli	3.45	1.15	2.20	1.57	0.52
1	Tuzla	2.94	0.98	1.55	1.90	0.63
1	Ümraniye	3.25	1.08	1.55	2.10	0.70
1	Üsküdar	2.65	0.88	0.83	3.19	1.06
1	Zeytinburnu	2.46	0.82	1.55	1.59	0.53
2	Bağcılar	2.83	0.94	1.55	1.82	0.61
2	Bahçelievler	3.13	1.04	1.55	2.02	0.67
2	Başakşehir	2.94	0.98	0.83	3.54	1.18
2	Bayrampaşa	3.08	1.03	2.20	1.40	0.47
2	Beşiktaş	2.82	0.94	1.55	1.82	0.61
2	Beykoz	3.13	1.04	1.55	2.02	0.67
2	Beyoğlu	3.05	1.02	2.20	1.39	0.46
2	Büyükçekmece	2.74	0.91	1.55	1.77	0.59
2	Çekmeköy	3.26	1.09	2.20	1.48	0.49
2	Esenler	3.26	1.09	1.55	2.10	0.70
2	Esenyurt	3.05	1.02	2.20	1.38	0.46
2	Gaziosmanpaşa	2.72	0.91	2.20	1.24	0.41
2	Güngören	2.62	0.87	2.20	1.19	0.40
2	Kağıthane	2.47	0.82	0.83	2.98	0.99
2	Küçükçekmece	2.82	0.94	0.83	3.39	1.13
2	Sultangazi	2.86	0.95	2.20	1.30	0.43
2	Şile	2.71	0.90	1.55	1.75	0.58
2	Şişli	2.31	0.77	1.55	1.49	0.50
3	Arnavutköy	2.58	0.86	1.55	1.67	0.56
3	Çatalca	3.08	1.03	2.20	1.40	0.47
3	Eyüp	2.79	0.93	2.20	1.27	0.42
3	Sarıyer	2.91	0.97	2.20	1.32	0.44
3	Silivri	3.31	1.10	2.20	1.50	0.50

Table 5.11 Earthquake Insurance Premium Rates for **RC Dual High-rise** Type of Buildings

Zone	District	π_{max} ‰	π_{av} ‰	π_{TCIP} ‰	π_{max} / π_{TCIP}	π_{av} / π_{TCIP}
1	Adalar	4.33	1.44	2.20	1.97	0.66
1	Ataşehir	2.83	0.94	0.83	3.41	1.14
1	Avcılar	3.38	1.13	2.20	1.54	0.51
1	Bakırköy	3.71	1.24	2.20	1.69	0.56
1	Beylikdüzü	3.47	1.16	1.55	2.24	0.75
1	Fatih	3.72	1.24	1.55	2.40	0.80
1	Kadıköy	3.96	1.32	2.20	1.80	0.60
1	Kartal	3.15	1.05	1.55	2.03	0.68
1	Maltepe	3.40	1.13	1.55	2.19	0.73
1	Pendik	3.13	1.04	1.55	2.02	0.67
1	Sancaktepe	2.80	0.93	1.55	1.81	0.60
1	Sultanbeyli	3.98	1.33	2.20	1.81	0.60
1	Tuzla	3.37	1.12	1.55	2.18	0.73
1	Ümraniye	3.74	1.25	1.55	2.41	0.80
1	Üsküdar	3.02	1.01	0.83	3.64	1.21
1	Zeytinburnu	2.81	0.94	1.55	1.81	0.60
2	Bağcılar	3.24	1.08	1.55	2.09	0.70
2	Bahçelievler	3.59	1.20	1.55	2.32	0.77
2	Başakşehir	3.37	1.12	0.83	4.06	1.35
2	Bayrampaşa	3.54	1.18	2.20	1.61	0.54
2	Beşiktaş	3.23	1.08	1.55	2.08	0.69
2	Beykoz	3.60	1.20	1.55	2.32	0.77
2	Beyoğlu	3.50	1.17	2.20	1.59	0.53
2	Büyükçekmece	3.13	1.04	1.55	2.02	0.67
2	Çekmeköy	3.75	1.25	2.20	1.70	0.57
2	Esenler	3.75	1.25	1.55	2.42	0.81
2	Esenyurt	3.50	1.17	2.20	1.59	0.53
2	Gaziosmanpaşa	3.11	1.04	2.20	1.41	0.47
2	Güngören	3.00	1.00	2.20	1.36	0.45
2	Kağıthane	2.82	0.94	0.83	3.39	1.13
2	Küçükçekmece	3.22	1.07	0.83	3.88	1.29
2	Sultangazi	3.27	1.09	2.20	1.49	0.50
2	Şile	3.10	1.03	1.55	2.00	0.67
2	Şişli	2.63	0.88	1.55	1.70	0.57
3	Arnavutköy	2.95	0.98	1.55	1.90	0.63
3	Çatalca	3.53	1.18	2.20	1.61	0.54
3	Eyüp	3.19	1.06	2.20	1.45	0.48
3	Sarıyer	3.34	1.11	2.20	1.52	0.51
3	Silivri	3.81	1.27	2.20	1.73	0.58

Table 5.12 Earthquake Insurance Premium Rates for **Masonry Low-rise** Type of Buildings

Zone	District	π_{max} ‰	π_{av} ‰	π_{TCIP} ‰	π_{max} / π_{TCIP}	π_{av} / π_{TCIP}
1	Adalar	3.97	1.32	3.85	1.03	0.34
1	Ataşehir	2.43	0.81	3.85	0.63	0.21
1	Avcılar	3.17	1.06	3.85	0.82	0.27
1	Bakırköy	3.47	1.16	3.85	0.90	0.30
1	Beylikdüzü	3.25	1.08	3.85	0.85	0.28
1	Fatih	3.48	1.16	3.85	0.90	0.30
1	Kadıköy	3.69	1.23	3.85	0.96	0.32
1	Kartal	2.86	0.95	3.85	0.74	0.25
1	Maltepe	3.19	1.06	3.85	0.83	0.28
1	Pendik	2.83	0.94	3.85	0.74	0.25
1	Sancaktepe	2.37	0.79	3.85	0.62	0.21
1	Sultanbeyli	3.71	1.24	3.85	0.96	0.32
1	Tuzla	3.16	1.05	3.85	0.82	0.27
1	Ümraniye	3.52	1.17	3.85	0.91	0.30
1	Üsküdar	2.75	0.92	3.85	0.71	0.24
1	Zeytinburnu	2.38	0.79	3.85	0.62	0.21
2	Bağcılar	2.98	0.99	2.75	1.08	0.36
2	Bahçelievler	3.37	1.12	2.75	1.23	0.41
2	Başakşehir	3.15	1.05	2.75	1.15	0.38
2	Bayrampaşa	3.32	1.11	2.75	1.21	0.40
2	Beşiktaş	2.96	0.99	2.75	1.08	0.36
2	Beykoz	3.37	1.12	2.75	1.22	0.41
2	Beyoğlu	3.29	1.10	2.75	1.20	0.40
2	Büyükçekmece	2.83	0.94	2.75	1.03	0.34
2	Çekmeköy	3.52	1.17	2.75	1.28	0.43
2	Esenler	3.50	1.17	2.75	1.27	0.42
2	Esenyurt	3.28	1.09	2.75	1.19	0.40
2	Gaziosmanpaşa	2.79	0.93	2.75	1.02	0.34
2	Güngören	2.65	0.88	2.75	0.96	0.32
2	Kağıthane	2.40	0.80	2.75	0.87	0.29
2	Küçükçekmece	3.09	1.03	2.75	1.12	0.37
2	Sultangazi	3.03	1.01	2.75	1.10	0.37
2	Şile	2.79	0.93	2.75	1.02	0.34
2	Şişli	2.15	0.72	2.75	0.78	0.26
3	Arnavutköy	2.59	0.86	1.43	1.81	0.60
3	Çatalca	3.31	1.10	1.43	2.32	0.77
3	Eyüp	2.91	0.97	1.43	2.04	0.68
3	Sarıyer	3.11	1.04	1.43	2.17	0.72
3	Silivri	3.56	1.19	1.43	2.49	0.83

From the tables, it is concluded that the highest premiums are for Masonry buildings. However, unlike expectations RC Dual buildings appear to have larger premiums than RC Frame buildings. The reason for that is primarily due to lack enough studies for dual buildings. Contrary to RC Frame Buildings for which various past studies are used to obtain fragility curves, calculation of premiums for RC Dual is done by using only Erdik et al. (2003) and this study depends on ad hoc method while most of the studies for RC Frame buildings depend on analytical methods. Therefore, generalized curves for RC Frame and RC Dual buildings are not consistent. For low ground motion intensities, fragility curves of RC Dual buildings have higher y values than RC Frame buildings (this does not represent the general trend). As an example of this situation, Figure 5.2 is given below.

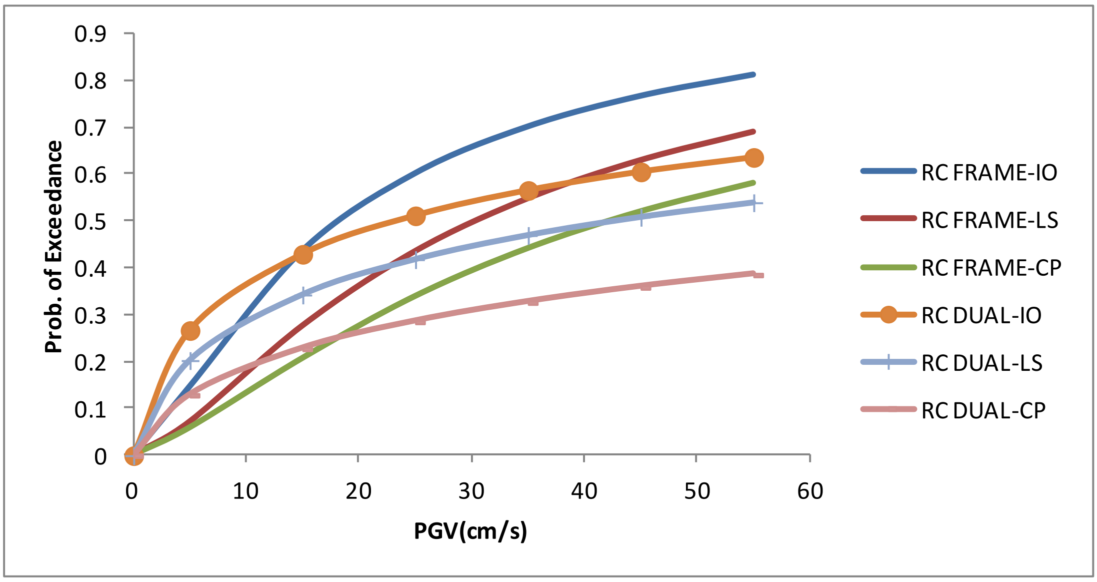

Figure 5.2 Generalized Lognormal Fragility Functions of RC Frame Lowrise and RC Dual Lowrise buildings

Ground motion intensities of the districts are generally between 0 and 15 cm/s for T_R= 72 years and since calculated premiums have the largest values for T_R= 72 years, the premiums of RC Dual buildings become larger than those for RC Frame buildings.

Since this study depends on generalized fragility curves obtained from combination of different studies, it is expected that premium results of generalized fragility curves may be different than the premiums calculated by using individual fragility curves suggested in various studies.

CHAPTER 6

SUMMARY, CONCLUSIONS AND FUTURE WORK

This chapter is devoted into two parts; in the first part summary and conclusions for existing and generalized fragility curves are discussed, in the second part the conclusions regarding calculated insurance premiums are presented.

Summary on Fragility curves

- By using 11 previous studies, fragility curves were classified according to material type and height of the buildings. So the buildings were classified as RC Frame, RC Dual and Masonry buildings. Masonry buildings were also subdivided as Brick, Block Stone and General buildings. According to height buildings were divided into three subdivision which are Low-rise buildings (from 1 to 3 story buildings), Mid-rise buildings (from 4 to 7 story buildings) and), High-rise buildings (up to 7 story).
- The fragility curves were compiled for the Immediate Occupancy, Life safety and Collapse Prevention performance levels. Ground motion parameter is taken as PGV (cm/s) for RC Frame and RC Dual type of buildings, and PGA(g) for Masonry type of buildings.
- The existing fragility curves were first converted such that all the ones for RC buildings have PGV as the ground motion parameter and PGA for Masonry buildings. This conversion has been made using the methodology given in SYNER-G (2011).
- In order to obtain Generalized Fragility Curves, three methods were used to combine different fragility curved proposed for the same building type. These methods are Normal Mean Average, Weighted Mean Average Method and Weighted Nonlinear Regression Analysis. The assumptions involved, methods of analyses used and degree of accuracy were considered when combining these fragility curves to obtain the generalized ones.

Conclusions on Fragility curves

- It is obvious that a large scatter is observed in the fragility curves suggested by different researchers for the same type of building. This inevitable scatter results due to the approach used, assumptions made, analyses procedures used and parameters considered.
- Three novel methodologies have been applied here to obtain generalized fragility curves that are believed to reflect the influence of each study by considering their reliability.

Summary and Conclusions for Calculation of Earthquake Insurance Premiums

- Earthquake insurance premiums for 39 districts of Istanbul were calculated using the methodology given in Kanda and Nishijima (2004). The ground motion intensity parameters were taken from probabilistic seismic hazard analyses obtained form a recent study. Earthquake insurance premiums were calculated using the general fragility curves for three return periods at each district center. These were then compared with the TCIP premiums.
- It is believed that the premiums calculated here reflect many parameters like seismic hazard, seismic properties of the buildings, building type and building height more accurately than the current TCIP rates.
- For Low-rise buildings, TCIP premiums are close to the Maximum premiums computed. As the height of buildings increases, differences between Maximum premium and TCIP premium also increases approaching a value between the Maximum and the Average premium. This situation is clearer for frame buildings than dual buildings.
- It is also concluded that for RC Frame Low-rise, Mid-rise and Masonry buildings, TCIP premiums are close to the Average Premiums for most of the districts in seismic zone 3. In zone 1 and zone 2, TCIP premiums for some of the districts are closer to Maximum Premiums while others are closer to Average Premiums. In other words, results are not uniform. For RC High-rise and RC Dual buildings, there is no uniform result for all zones.
- Since there are large number of fragility curves for RC Frame buildings determined based on the analytical methods, the calculated insurance premiums is more reliable for RC Frame Low-rise and Mid-rise buildings.

The following recommendations may be considered to improve the study as future work:

- Instead of using Lognormal Cumulative Distribution function, different functions may be used to generate fragility curves for each classification.
- Instead of calculation of insurance premiums using the generalized curves, each premium can be calculated for each fragility curve on the studies and average value of these resulted premiums may be calculated and compared with TCIP premiums.
- More analytical studies may be conducted to obtain fragility curves for masonry buildings to obtain reliable results.

REFERENCES

Akkar S, Azak T, Çan T, Çeken U, Demircioğlu MB, Duman T, Erdik M, Ergintav S, Kadirioğlu FT, Kalafat D, Kale Ö, Kartal RF, Kekovalı K, Kılıç T, Özalp S, Altuncu Poyraz S, Şeşetyan K, Tekin S, Yakut A, Yılmaz MT, Yücemen MS,Zülfikar Ö (2015). Türkiye sismik tehlike haritasının güncellenmesi projesi, UDAP-Ç-13-06, AFAD, Ankara.

Akkar, S., Sandikkaya, M. A., & Bommer, J. J. (2013). Empirical ground-motion models for point- and extended-source crustal earthquake scenarios in Europe and the Middle East. Bulletin of Earthquake Engineering, 1–29. doi:10.1007/s10518-013-9461-4

Akkar, S., Sucuoğlu, H., & Yakut, A. (2005). Displacement-Based Fragility Functions for Low-rise and Mid-rise Ordinary Concrete Buildings. Earthquake Spectra, 21(4), 901–927. doi:10.1193/1.2084232

Applied Technology Council (ATC). (1985). Earthquake Damage Evaluation Data for California. ATC–13, Redwood City, California.

Applied Technology Council (ATC). (1996). Seismic Evaluation and Retrofit of Concrete Buildings. ATC–40, Redwood City, California.

ASCE (American Society of Civil Engineers). (2000). Prestandard and Commentary for the Seismic Rehabilitation of Buildings. FEMA 356, Washington D.C.

ASCE (American Society of Civil Engineers). (2005). Improvement of Nonlinear Static Seismic Analysis Procedures. FEMA 440, Washington D.C.

Ay B. Ö., Erberik M. A., & S., A. (2006). Fragility Based Assessment of the Structural Deficiencies in Turkey. First European Conference on Earthquake Engineering and Seismology (a Joint Event of the 13th ECEE & 30th General Assembly of the ESC) Geneva, Switzerland, (September), 3–8

Bilal, M. (2013). Relationships Between Felt Intensity And Recorded Ground Motion, M. Sc. Thesis. Middle East Technical University.

Bogazici University, D. of E. E. (2010). Bogazici University, Department of Earthquake.Engineering.http://www.koeri.boun.edu.tr/depremmuh/eski/ELER/ELER_v3_Manual.pdf, last visited on March 2014

Ceran, H. B., & Erberik, M. A. (2013). Effect of out-of-plane behavior on seismic fragility of masonry buildings in Turkey. Bulletin of Earthquake Engineering, 11(5), 1775–1795. doi:10.1007/s10518-013-9449-0

Chiou, B. S. J., & Youngs, R. R. (2008). An NGA model for the average horizontal component of peak ground motion and response spectra. Earthquake Spectra, 24(1), 173–215. doi:10.1193/1.2894832

Chong, W. H., & Soong, T. T. (2000). Sliding Fragility of Unrestrained Equipment in Critical Facilities by. Buffalo, NY 14260. doi:00-0005

D'Ayala, D. D., & Kishali, E. (2012). Providing building vulnerability data and analytical fragility functions for PAGER. Earthquake Engineering Research Institute.

Erberik, M. A. (2008a). Fragility-based assessment of typical mid-rise and low-rise RC buildings in Turkey. Engineering Structures, 30(5), 1360–1374. doi:10.1016/j.engstruct.2007.07.016

Erberik, M. A. (2008b). Generation of fragility curves for Turkish masonry buildings considering in-plane failure modes. Earthquake Engineering and Structural Dynamics, 37(3), 387–405. doi:10.1002/eqe

Erberik, M. A. (2010). Seismic Risk Assessment of Masonry Buildings in Istanbul for Effective Risk Mitigation. Earthquake Spectra, 26(4), 967–982. doi:10.1193/1.3464344

Erdik, M., Aydinoglu, N., Fahjan, Y., Sesetyan, K., Demircioglu, M., Siyahi, B., & Durukal, E. (2003). Earthquake risk assessment for Istanbul metropolitan area, 2(1), 1–23.

Getdata Graph Digitizer. (n.d.), http://www.getdata-graph-digitizer.com/, last visited on February 2014

Güneyisi, E. M., & Altay, G. (2008). Seismic fragility assessment of effectiveness of viscous dampers in R/C buildings under scenario earthquakes. Structural Safety, 30(5), 461–480. doi:10.1016/j.strusafe.2007.06.001

Hancilar, U., Taucer, F., & Corbane, C. (2013). Empirical Fragility Functions based on Remote Sensing and Field Data after the 12 January 2010 Haiti Earthquake. Earthquake Spectra, 29(4), 1275–1310. doi:10.1193/121711EQS308M

HaritaMap. (2015). Istanbul, http://www.haritamap.com/sehir/istanbul, last visited on April 2015

Hwang, H. M., & Jaws, J. W. (1989). Seismic Fragility Analysis of Frame Structures, Technical Report, NCEER00009.

Kale, O., Akkar, S., Ansari, A., & Hamzehloo, H. (2015). A Ground-Motion Predictive Model for Iran and Turkey for Horizontal PGA, PGV, and 5% Damped Response Spectrum: Investigation of Possible Regional Effects. Bulletin of the Seismological Society of America, 105(2A), 963–980. doi:10.1785/0120140134

Kanda, J., & Nishijima, K. (2004). Scope of Insurance Premium for Residential Houses Against Seismic Risk in Japan, 1–20.

Kircil, M., Serdar, & Polat, Z., (2006). Fragility analysis of mid-rise R/C frame buildings. Engineering Structures, 28(9), 1335–1345. doi:10.1016/j.engstruct.2006.01.004

Korkmaz, A., & Johnson, P. A. (2007). Probabilistic Seismic Structural Assessment. Computing in Civil Engineering, 297.

Kuramoto, H., Teshigawara, M., Okuzono, T., Koshika, N., Takayama, M., & Hori, T. (2000). Predicting the earthquake response of buildings using equivalent single degree of freedom system, 1–8.

National Institute of Building Sciences (NIBS). (1999). HAZUS Technical Manuel (3 Volumes). prepared for Federal Emergency Management Agency, Washington, DC.

Ozmen, H. B., Inel, M., Meral, E., & Bucakli, M. (2010). Vulnerability of Low and Mid-Rise Reinforced Concrete Buildings In Turkey.

Polese, M., Verderame, G. M., Mariniello, C., Iervolino, I., & Manfredi, G. (2008). Vulnerability Analysis for Gravity Load Designed RC Buildings in Naples – Italy. Journal of Earthquake Engineering, 12(sup2), 234–245. doi:10.1080/13632460802014147

Porter, K., Kennedy, R., & Bachman, R. (2007). Creating Fragility Functions for Performance-Based Earthquake Engineering. Earthquake Spectra, 23(2), 471–489. doi:10.1193/1.2720892

Seyedi, D. M., Gehl, P., Douglas, J., Davenne, L., Mezher, N., & Ghavamian, S. (2010). Development of seismic fragility surfaces for reinforced concrete buildings by means of nonlinear time-history analysis, (August 2009), 91–108. doi:10.1002/eqe

Shinozuka, M., Feng, M. Q., Kim, H., Uzawa, T., Ueda, T., & Angeles, L. (2001). Statistical Analysis of Fragility Curves. Technical Report MCEER

Smyth, A. W., Altay, G., Deodatis, G., Erdik, M., Franco, G., Gulkan, P., …& Yuzugullu, O. (2004). Probabilistic Benefit-Cost Analysis for Earthquake Damage Mitigation: Evaluating Measures for Apartment Houses in Turkey. Earthquake Spectra, 20(1), 171–203. doi:10.1193/1.1649937

SYNER-G project (D 3.1). (2011). Systemic Seismic Vulnerability and Risk Analysis for Buildings, Lifeline Networks and Infrastructures Safety Gain Deliverable 3.1: Fragility functions for common RC building types in Europe. http://www.vce.at/SYNER-G/pdf/deliverables/D3.01_Syner-G_RC_final.pdf, last visited on March 2014

SYNER-G project (D 3.2). (2011). Systemic Seismic Vulnerability and Risk Analysis for Buildings, Lifeline Networks and Infrastructures Safety Gain Deliverable 3.2: Fragility functions for common masonry building types in Europe, http://www.vce.at/SYNER-G/pdf/deliverables/D3.02_Syner-G_MASONRY_final.pdf, last visited on March 2014

Szymanski. (n.d.). Displacement Time History Analysis. Retrieved from http://www.goodengineers.com/invitation/Invitation/seminars/TimeHistoryAnalysis-Szymanski.pdf, last visited on March 2014

TCIP.(2013). Turkish Catastrophe Insurance Pool. http://www.tcip.gov.tr/zorunlu-deprem-sigortasi-tarife-ve-primler.html, last visited on February 2015

TEC (Turkish Earthquake Code) (2007). Specifications for Structures to be Built in Disaster Areas, Ministry of Public Works and Settlement, Ankara.

Turkish Ministry of Environment and Planning. (n.d.). Istanbul Seismic Zone. http://www.csb.gov.tr/iller/istanbulakdm/index.php?Sayfa=sayfa&Tur=webmenu&Id=10462, last visited on May 2015

APPENDIX A

A.COMPARISON OF FRAGILITY CURVES WITH DIFFERENT METHODS

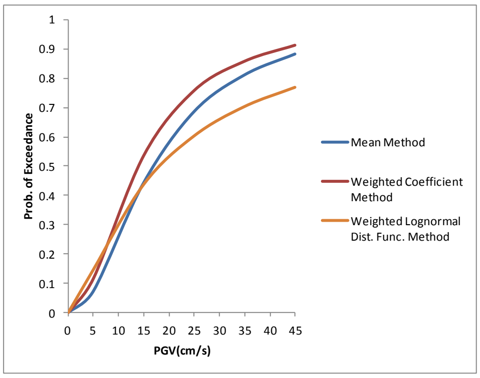

Figure A.1 Suggested fragility curves of **RC Frame Low-rise** type of buildings for **Immediate Occupancy** performance level

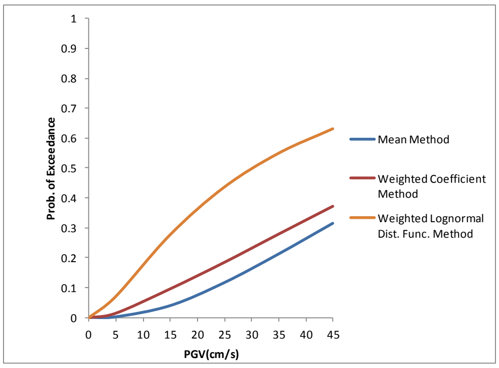

Figure A.2 Suggested fragility curves of **RC Frame Low-rise** type of buildings for **Life Safety** performance level

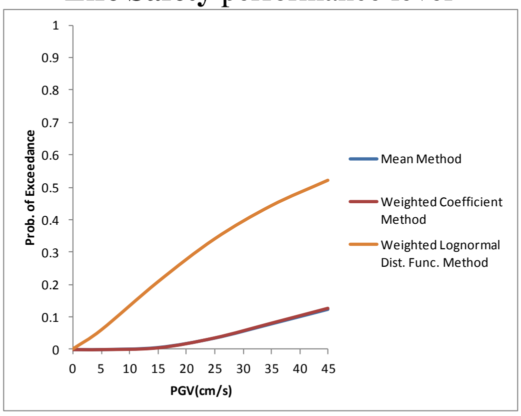

Figure A.3 Suggested fragility curves of **RC Frame Low-rise** type of buildings for **Collapse Prevention** performance level

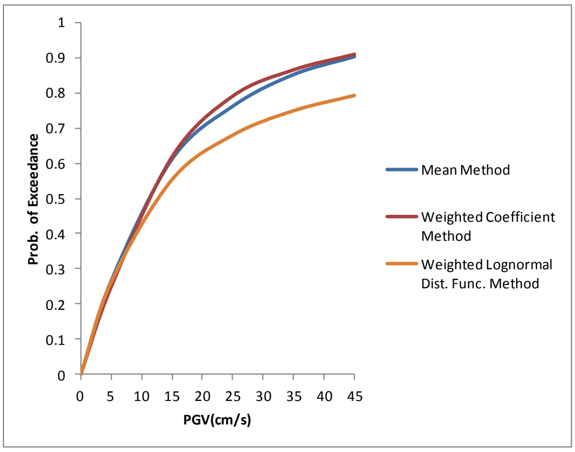

Figure A.4 Suggested fragility curves of **RC Frame Mid-rise** type of buildings for **Immediate Occupancy** performance level

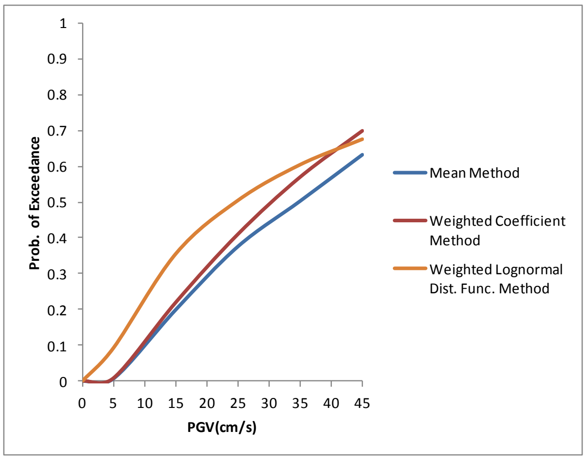

Figure A.5 Suggested fragility curves of **RC Frame Mid-rise** type of buildings for **Life Safety** performance level

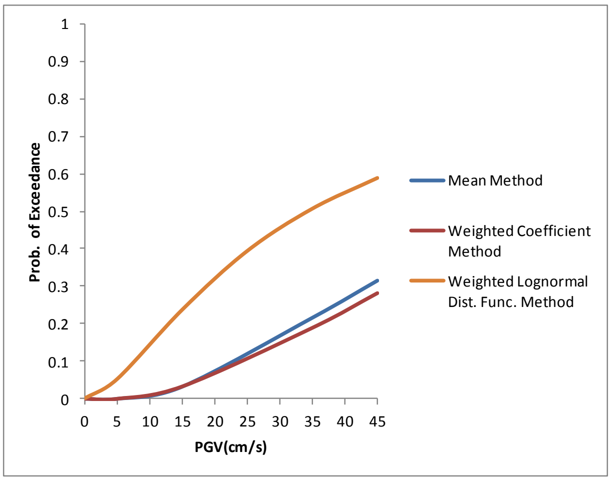

Figure A.6 Suggested fragility curves of **RC Frame Mid-rise** type of buildings for **Collapse Prevention** performance level

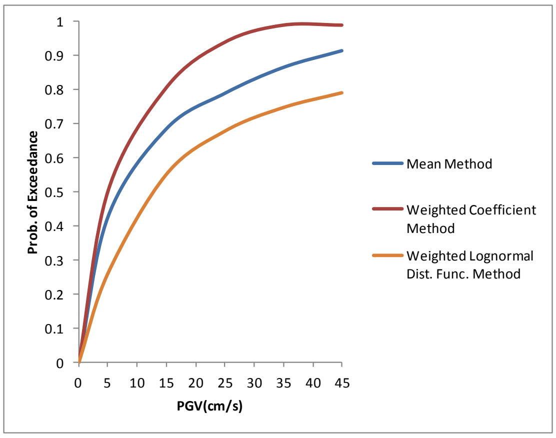

Figure A.7 Suggested fragility curves of **RC Frame High-rise** type of buildings for **Immediate Occupancy** performance level

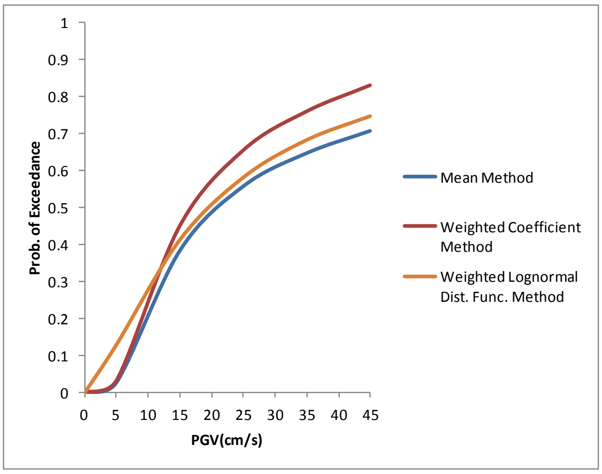

Figure A.8 Suggested fragility curves of **RC Frame High-rise** type of buildings for Life Safety performance level

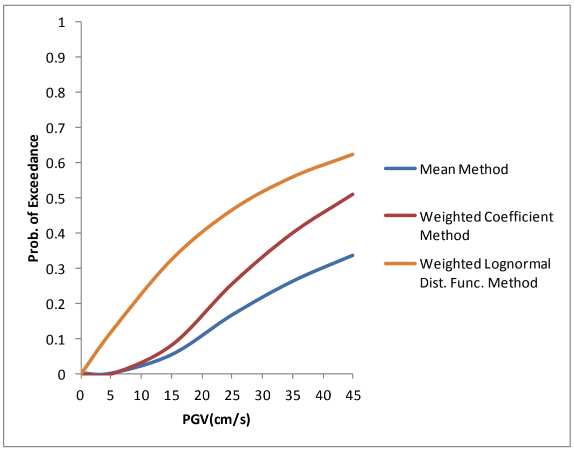

Figure A.9 Suggested fragility curves of **RC Frame High-rise** type of buildings for **Collapse Prevention** performance level

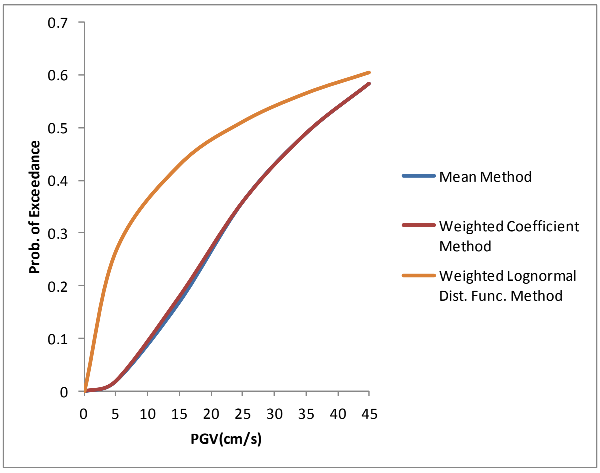

Figure A.10 Suggested fragility curves of **RC Dual Low-rise** type of buildings for **Immediate Occupancy** performance level

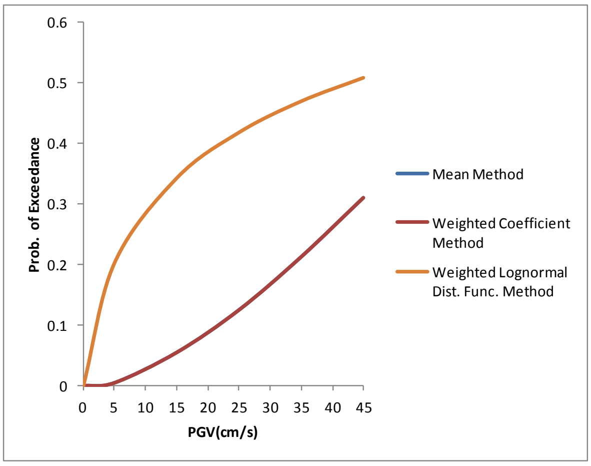

Figure A.11 Suggested fragility curves of **RC Dual Low-rise** type of buildings for **Life Safety** performance level

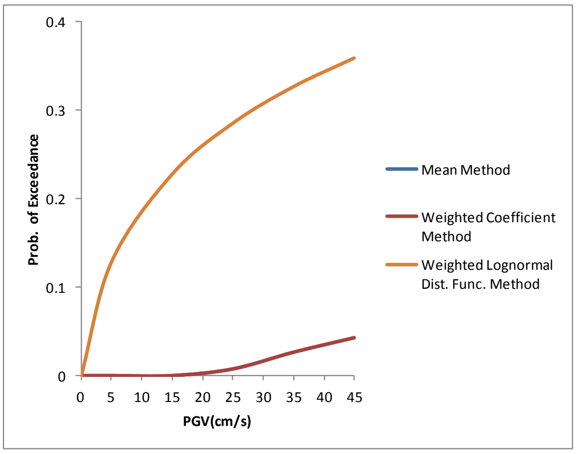

Figure A.12 Suggested fragility curves of **RC Dual Low-rise** type of buildings for **Collapse Prevention** performance level

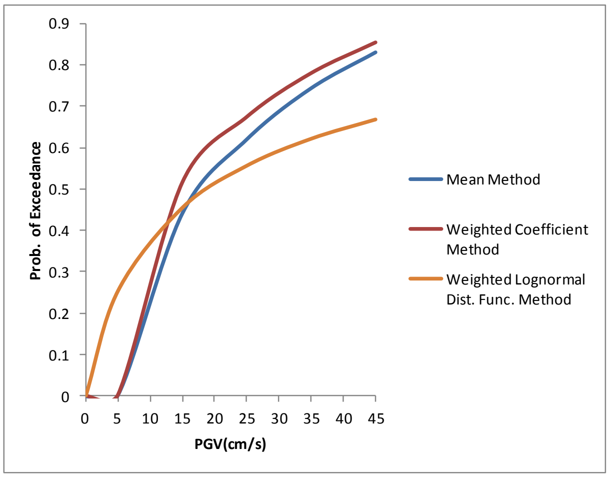

Figure A.13 Suggested fragility curves of **RC Dual Mid-rise** type of buildings for **Immediate Occupancy** performance level

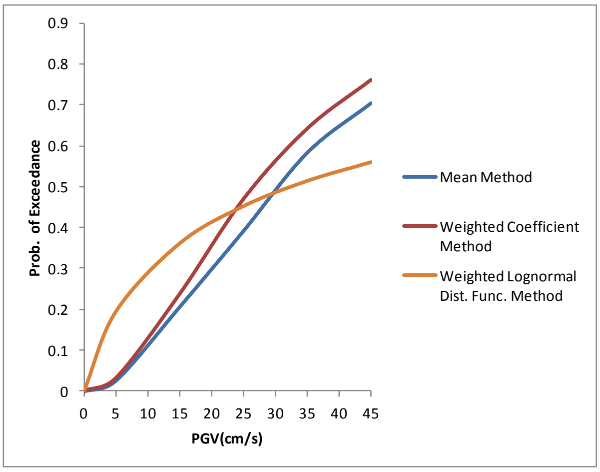

Figure A.14 Suggested fragility curves of **RC Dual Mid-rise** type of buildings for **Life Safety** performance level

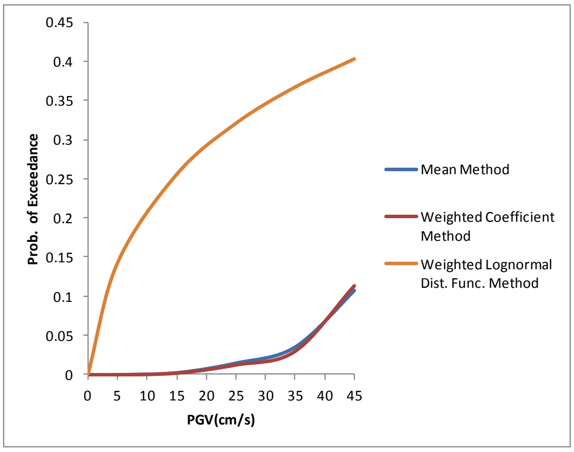

Figure A.15 Suggested fragility curves of **RC Dual Mid-rise** type of buildings for **Collapse Prevention** performance level

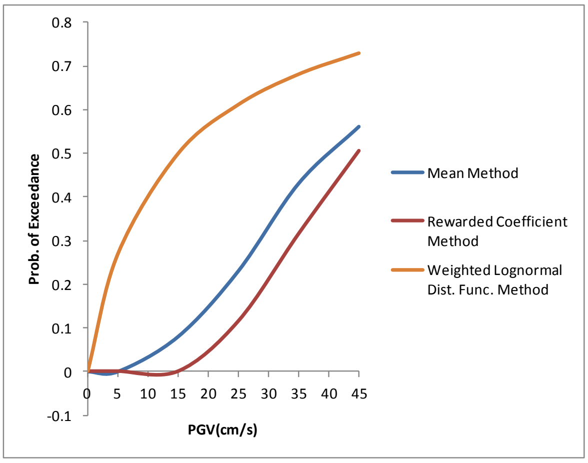

Figure A.16 Suggested fragility curves of **RC Dual High-rise** type of buildings for **Immediate Occupancy** performance level

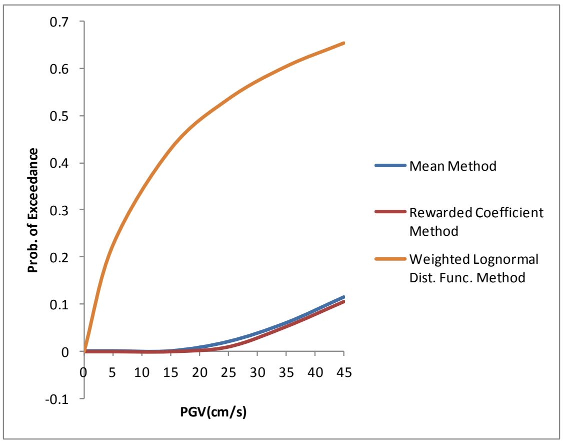

Figure A.17 Suggested fragility curves of **RC Dual High-rise** type of buildings for **Life Safety** performance level

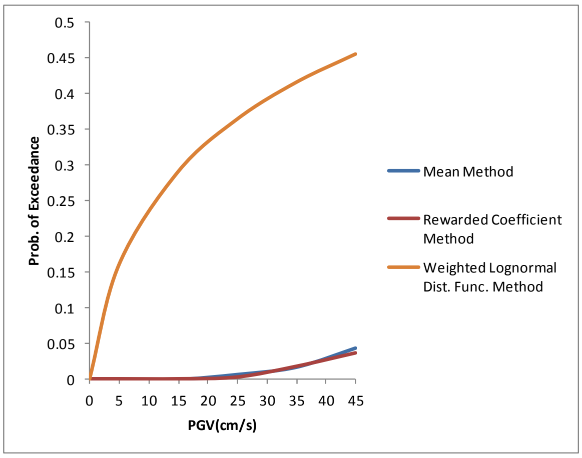

Figure A.18 Suggested fragility curves of **RC Dual High-rise** type of buildings for **Collapse Prevention** performance level

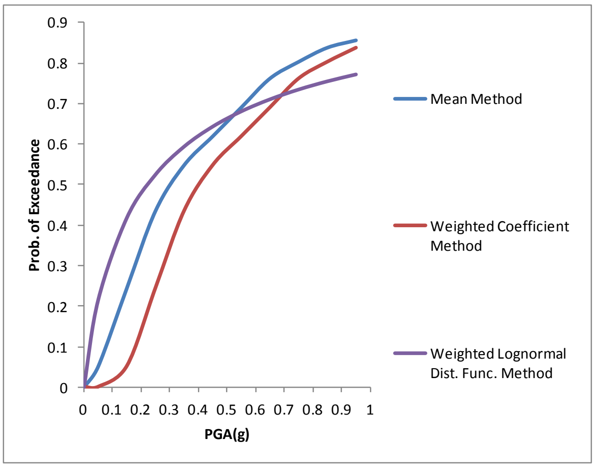

Figure A.19 Suggested fragility curves of Masonry **General Low-rise** type of buildings for **Immediate Occupancy** performance level

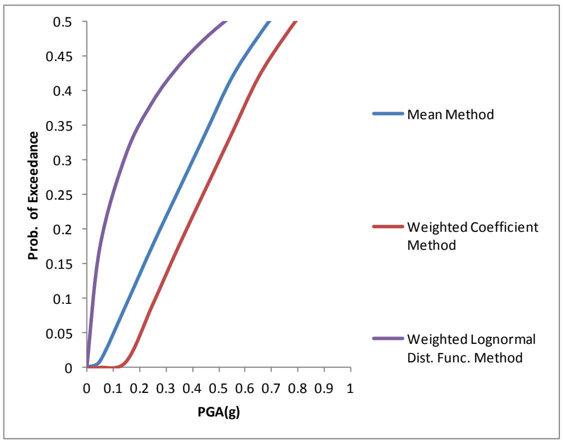

Figure A.20 Suggested fragility curves of Masonry **General Low-rise** type of buildings for **Life Safety** performance level

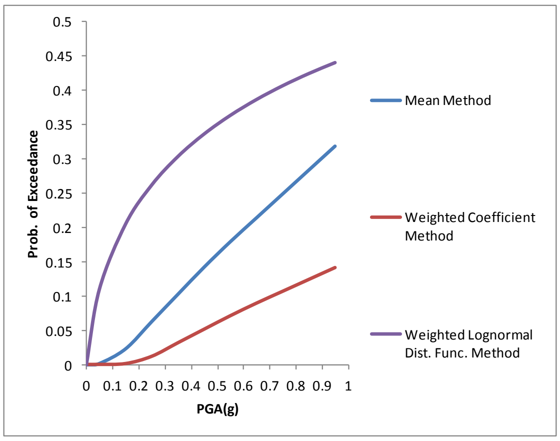

Figure A.21 Suggested fragility curves of Masonry **General Low-rise** type of buildings for **Collapse Prevention** performance level

APPENDIX B

B. DETAILED PREMIUM TABLE

Table B.1 Losses and Premium Rates for Earthquakes within the Next **72 Years** for **RC Frame Low-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=72\ yr}$ ‰
1	Adalar	14.38	0.42	0.26	0.20	7.75	19.85	168.37	2.99
2	Arnavutköy	7.03	0.21	0.11	0.09	4.63	7.29	75.43	1.33
3	Ataşehir	9.76	0.29	0.17	0.13	5.79	11.95	109.97	1.95
4	Avcılar	11.35	0.33	0.20	0.15	6.46	14.66	130.02	2.30
5	Bağcılar	10.16	0.30	0.18	0.14	5.96	12.64	115.03	2.04
6	Bahçelievler	11.42	0.33	0.20	0.15	6.49	14.78	130.90	2.32
7	Bakırköy	12.60	0.37	0.23	0.17	6.99	16.80	145.83	2.58
8	Başakşehir	8.61	0.25	0.15	0.11	5.30	9.98	95.40	1.69
9	Bayrampaşa	9.83	0.29	0.17	0.13	5.82	12.07	110.80	1.96
10	Beşiktaş	8.54	0.25	0.14	0.11	5.27	9.86	94.49	1.67
11	Beykoz	6.90	0.20	0.11	0.09	4.58	7.07	73.84	1.30
12	Beylikdüzü	12.66	0.37	0.23	0.17	7.02	16.90	146.59	2.60
13	Beyoğlu	9.70	0.28	0.17	0.13	5.77	11.86	109.27	1.93
14	Büyükçekmece	11.49	0.34	0.20	0.16	6.52	14.91	131.88	2.34
15	Çatalca	7.99	0.23	0.13	0.10	5.04	8.94	87.65	1.55
16	Çekmeköy	6.92	0.20	0.11	0.09	4.59	7.11	74.13	1.31
17	Esenler	9.04	0.26	0.15	0.12	5.49	10.72	100.87	1.78
18	Esenyurt	10.76	0.31	0.19	0.14	6.22	13.67	122.66	2.17
19	Eyüp	9.69	0.28	0.17	0.13	5.76	11.83	109.05	1.93
20	Fatih	10.51	0.31	0.18	0.14	6.11	13.24	119.46	2.11
21	Gaziosmanpaşa	8.99	0.26	0.15	0.12	5.46	10.63	100.21	1.77
22	Güngören	10.79	0.31	0.19	0.14	6.23	13.72	123.01	2.18
23	Kadıköy	10.35	0.30	0.18	0.14	6.04	12.96	117.42	2.08
24	Kağıthane	8.51	0.25	0.14	0.11	5.26	9.82	94.19	1.66
25	Kartal	11.56	0.34	0.21	0.16	6.55	15.02	132.65	2.35
26	Küçükçekmece	11.53	0.34	0.21	0.16	6.54	14.98	132.33	2.34
27	Maltepe	10.30	0.30	0.18	0.14	6.02	12.88	116.84	2.07
28	Pendik	8.41	0.25	0.14	0.11	5.22	9.65	92.92	1.64
29	Sancaktepe	7.87	0.23	0.13	0.10	4.99	8.72	86.08	1.52
30	Sarıyer	6.98	0.20	0.11	0.09	4.61	7.20	74.79	1.32
31	Silivri	8.97	0.26	0.15	0.12	5.46	10.61	100.04	1.77
32	Sultanbeyli	9.21	0.27	0.16	0.12	5.56	11.02	103.06	1.82
33	Sultangazi	8.36	0.24	0.14	0.11	5.20	9.56	92.28	1.63
34	Şile	6.05	0.18	0.09	0.07	4.22	5.62	63.10	1.11
35	Şişli	7.64	0.22	0.13	0.10	4.89	8.33	83.15	1.47
36	Tuzla	10.48	0.31	0.18	0.14	6.09	13.18	119.06	2.11
37	Ümraniye	8.83	0.26	0.15	0.12	5.40	10.37	98.23	1.74
38	Üsküdar	9.52	0.28	0.16	0.13	5.69	11.54	106.94	1.89
39	Zeytinburnu	11.82	0.34	0.21	0.16	6.66	15.48	136.04	2.41

Table B.2 Losses and Premium Rates for Earthquakes within the Next **475 Years** for **RC Frame Low-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=475\ yr}$ ‰
1	Adalar	31.62	0.67	0.51	0.41	7.84	30.99	346.70	0.89
2	Arnavutköy	13.32	0.39	0.24	0.18	7.30	18.03	154.90	0.42
3	Ataşehir	19.29	0.51	0.35	0.26	8.12	24.35	224.52	0.59
4	Avcılar	24.01	0.59	0.42	0.33	8.25	28.14	277.76	0.73
5	Bağcılar	20.75	0.53	0.37	0.28	8.16	25.52	241.03	0.63
6	Bahçelievler	24.19	0.59	0.42	0.33	8.26	28.28	279.78	0.73
7	Bakırköy	27.66	0.63	0.47	0.37	8.10	29.76	312.14	0.81
8	Başakşehir	16.93	0.47	0.31	0.23	8.06	22.45	197.89	0.53
9	Bayrampaşa	19.96	0.52	0.36	0.27	8.14	24.88	232.07	0.61
10	Beşiktaş	16.62	0.46	0.30	0.23	8.05	22.20	194.39	0.52
11	Beykoz	13.00	0.38	0.24	0.18	7.16	17.48	150.86	0.41
12	Beylikdüzü	27.99	0.63	0.47	0.37	8.08	29.86	315.00	0.82
13	Beyoğlu	19.54	0.51	0.35	0.27	8.13	24.55	227.33	0.60
14	Büyükçekmece	24.63	0.60	0.43	0.33	8.27	28.63	284.69	0.74
15	Çatalca	15.58	0.45	0.29	0.21	8.02	21.36	182.67	0.49
16	Çekmeköy	13.05	0.38	0.24	0.18	7.18	17.58	151.59	0.41
17	Esenler	17.99	0.49	0.32	0.25	8.09	23.30	209.84	0.56
18	Esenyurt	22.45	0.56	0.40	0.31	8.21	26.89	260.16	0.68
19	Eyüp	19.57	0.51	0.35	0.27	8.13	24.57	227.70	0.60
20	Fatih	21.61	0.55	0.38	0.29	8.19	26.21	250.74	0.66
21	Gaziosmanpaşa	17.85	0.48	0.32	0.25	8.08	23.19	208.29	0.55
22	Güngören	22.47	0.56	0.40	0.31	8.21	26.90	260.38	0.68
23	Kadıköy	20.84	0.53	0.37	0.28	8.17	25.59	241.96	0.64
24	Kağıthane	16.62	0.46	0.30	0.23	8.05	22.20	194.41	0.52
25	Kartal	23.77	0.58	0.42	0.32	8.25	27.95	275.04	0.72
26	Küçükçekmece	24.52	0.59	0.43	0.33	8.27	28.55	283.47	0.74
27	Maltepe	20.61	0.53	0.37	0.28	8.16	25.41	239.41	0.63
28	Pendik	16.39	0.46	0.30	0.23	8.05	22.02	191.90	0.51
29	Sancaktepe	15.04	0.44	0.28	0.21	8.01	20.93	176.65	0.47
30	Sarıyer	13.17	0.38	0.24	0.18	7.23	17.78	153.11	0.41
31	Silivri	17.88	0.48	0.32	0.25	8.09	23.22	208.67	0.55
32	Sultanbeyli	18.07	0.49	0.33	0.25	8.09	23.36	210.75	0.56
33	Sultangazi	16.34	0.46	0.30	0.22	8.04	21.97	191.24	0.51
34	Şile	11.68	0.34	0.21	0.16	6.60	15.24	134.26	0.36
35	Şişli	14.60	0.43	0.27	0.20	7.84	20.21	171.09	0.46
36	Tuzla	21.60	0.55	0.38	0.29	8.19	26.20	250.57	0.66
37	Ümraniye	17.18	0.47	0.31	0.24	8.07	22.65	200.73	0.53
38	Üsküdar	18.87	0.50	0.34	0.26	8.11	24.01	219.82	0.58
39	Zeytinburnu	25.35	0.61	0.44	0.34	8.26	29.04	291.98	0.76

Table B.3 Losses and Premium Rates for Earthquakes within the Next **2475 Years** for **RC Frame Low-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=2475\ yr}$ ‰
1	Adalar	50.74	0.79	0.67	0.56	6.36	32.96	472.94	0.227
2	Arnavutköy	21.60	0.55	0.38	0.29	8.19	26.20	250.52	0.126
3	Ataşehir	30.93	0.66	0.50	0.40	7.89	30.77	340.64	0.168
4	Avcılar	39.23	0.73	0.58	0.48	7.28	32.43	404.51	0.197
5	Bağcılar	33.45	0.69	0.53	0.43	7.72	31.55	362.67	0.178
6	Bahçelievler	39.55	0.73	0.59	0.48	7.25	32.46	406.64	0.198
7	Bakırköy	45.15	0.77	0.63	0.52	6.79	32.98	443.89	0.214
8	Başakşehir	27.46	0.63	0.46	0.37	8.12	29.70	310.38	0.154
9	Bayrampaşa	32.06	0.67	0.52	0.41	7.82	31.12	350.54	0.173
10	Beşiktaş	26.88	0.62	0.46	0.36	8.16	29.52	305.30	0.152
11	Beykoz	21.02	0.54	0.37	0.29	8.17	25.74	244.02	0.123
12	Beylikdüzü	45.56	0.77	0.63	0.52	6.76	32.98	445.99	0.215
13	Beyoğlu	31.44	0.67	0.51	0.41	7.86	30.93	345.14	0.170
14	Büyükçekmece	40.30	0.74	0.59	0.48	7.19	32.53	411.67	0.200
15	Çatalca	25.48	0.61	0.44	0.34	8.25	29.08	293.13	0.146
16	Çekmeköy	21.15	0.54	0.37	0.29	8.17	25.84	245.46	0.124
17	Esenler	29.17	0.64	0.48	0.38	8.01	30.23	325.35	0.161
18	Esenyurt	36.49	0.71	0.56	0.45	7.50	32.17	386.19	0.189
19	Eyüp	31.51	0.67	0.51	0.41	7.85	30.95	345.75	0.170
20	Fatih	34.97	0.70	0.55	0.44	7.62	32.02	375.92	0.184
21	Gaziosmanpaşa	28.95	0.64	0.48	0.38	8.02	30.16	323.39	0.160
22	Güngören	36.51	0.71	0.56	0.45	7.50	32.18	386.31	0.189
23	Kadıköy	33.37	0.69	0.53	0.43	7.73	31.53	361.99	0.178
24	Kağıthane	26.91	0.62	0.46	0.36	8.15	29.53	305.59	0.152
25	Kartal	38.29	0.72	0.58	0.47	7.35	32.34	398.23	0.194
26	Küçükçekmece	40.12	0.74	0.59	0.48	7.20	32.52	410.44	0.200
27	Maltepe	32.94	0.68	0.53	0.42	7.76	31.40	358.27	0.176
28	Pendik	26.69	0.62	0.46	0.36	8.17	29.46	303.62	0.151
29	Sancaktepe	24.35	0.59	0.43	0.33	8.26	28.41	281.61	0.141
30	Sarıyer	21.33	0.54	0.38	0.29	8.18	25.99	247.55	0.125
31	Silivri	29.49	0.65	0.49	0.39	7.98	30.33	328.11	0.162
32	Sultanbeyli	29.27	0.64	0.48	0.38	8.00	30.26	326.15	0.162
33	Sultangazi	26.49	0.62	0.45	0.36	8.18	29.40	301.93	0.150
34	Şile	19.07	0.50	0.34	0.26	8.12	24.17	222.04	0.113
35	Şişli	23.61	0.58	0.41	0.32	8.24	27.82	273.25	0.137
36	Tuzla	35.27	0.70	0.55	0.44	7.60	32.06	378.03	0.185
37	Ümraniye	27.72	0.63	0.47	0.37	8.10	29.78	312.66	0.155
38	Üsküdar	30.41	0.66	0.50	0.40	7.92	30.61	336.15	0.166
39	Zeytinburnu	41.48	0.74	0.60	0.49	7.09	32.65	419.56	0.204

Table B.4 Losses and Premium Rates for Earthquakes within the Next **72 Years** for **RC Frame Mid-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=72\ yr}$ ‰
1	Adalar	14.38	0.53	0.34	0.23	9.78	33.96	191.51	3.58
2	Arnavutköy	7.03	0.32	0.15	0.09	8.75	16.94	75.94	1.55
3	Ataşehir	9.76	0.40	0.22	0.14	9.13	23.26	118.89	2.31
4	Avcılar	11.35	0.45	0.26	0.17	9.36	26.94	143.82	2.74
5	Bağcılar	10.16	0.41	0.23	0.15	9.19	24.19	125.19	2.42
6	Bahçelievler	11.42	0.45	0.26	0.17	9.37	27.10	144.91	2.76
7	Bakırköy	12.60	0.48	0.29	0.19	9.53	29.83	163.49	3.09
8	Başakşehir	8.61	0.37	0.19	0.12	8.97	20.59	100.77	1.99
9	Bayrampaşa	9.83	0.40	0.22	0.14	9.14	23.41	119.92	2.32
10	Beşiktaş	8.54	0.36	0.19	0.12	8.96	20.43	99.64	1.97
11	Beykoz	6.90	0.32	0.14	0.09	8.73	16.65	73.97	1.51
12	Beylikdüzü	12.66	0.48	0.29	0.19	9.54	29.97	164.42	3.11
13	Beyoğlu	9.70	0.40	0.22	0.14	9.13	23.13	118.02	2.29
14	Büyükçekmece	11.49	0.45	0.26	0.17	9.38	27.27	146.13	2.78
15	Çatalca	7.99	0.35	0.17	0.11	8.89	19.18	91.14	1.82
16	Çekmeköy	6.92	0.32	0.14	0.09	8.74	16.70	74.33	1.52
17	Esenler	9.04	0.38	0.20	0.13	9.03	21.60	107.58	2.11
18	Esenyurt	10.76	0.43	0.24	0.16	9.27	25.59	134.67	2.58
19	Eyüp	9.69	0.40	0.22	0.14	9.12	23.09	117.74	2.28
20	Fatih	10.51	0.42	0.24	0.15	9.24	25.00	130.69	2.51
21	Gaziosmanpaşa	8.99	0.38	0.20	0.13	9.03	21.47	106.75	2.09
22	Güngören	10.79	0.43	0.24	0.16	9.28	25.65	135.11	2.59
23	Kadıköy	10.35	0.42	0.23	0.15	9.22	24.63	128.15	2.47
24	Kağıthane	8.51	0.36	0.18	0.12	8.96	20.37	99.26	1.96
25	Kartal	11.56	0.45	0.26	0.17	9.39	27.42	147.10	2.80
26	Küçükçekmece	11.53	0.45	0.26	0.17	9.38	27.36	146.70	2.79
27	Maltepe	10.30	0.42	0.23	0.15	9.21	24.52	127.43	2.46
28	Pendik	8.41	0.36	0.18	0.11	8.94	20.14	97.69	1.93
29	Sancaktepe	7.87	0.35	0.17	0.10	8.87	18.89	89.18	1.78
30	Sarıyer	6.98	0.32	0.14	0.09	8.74	16.82	75.14	1.53
31	Silivri	8.97	0.38	0.20	0.13	9.02	21.44	106.54	2.09
32	Sultanbeyli	9.21	0.38	0.20	0.13	9.06	22.00	110.30	2.15
33	Sultangazi	8.36	0.36	0.18	0.11	8.94	20.02	96.89	1.92
34	Şile	6.05	0.29	0.12	0.07	8.61	14.68	60.61	1.28
35	Şişli	7.64	0.34	0.16	0.10	8.84	18.35	85.54	1.72
36	Tuzla	10.48	0.42	0.24	0.15	9.23	24.93	130.19	2.50
37	Ümraniye	8.83	0.37	0.19	0.12	9.00	21.11	104.29	2.05
38	Üsküdar	9.52	0.39	0.21	0.14	9.10	22.71	115.13	2.24
39	Zeytinburnu	11.82	0.46	0.27	0.18	9.42	28.04	151.31	2.88

Table B.5 Losses and Premium Rates for Earthquakes within the Next **475 Years** for **RC Frame Mid-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=475\ yr}$ ‰
1	Adalar	31.62	0.72	0.57	0.47	7.74	30.40	397.83	1.01
2	Arnavutköy	13.32	0.50	0.31	0.21	9.63	31.49	174.76	0.50
3	Ataşehir	19.29	0.61	0.42	0.30	9.39	34.37	258.37	0.70
4	Avcılar	24.01	0.67	0.49	0.38	8.86	33.24	321.31	0.84
5	Bağcılar	20.75	0.62	0.44	0.33	9.22	34.02	277.88	0.74
6	Bahçelievler	24.19	0.67	0.49	0.38	8.84	33.20	323.70	0.84
7	Bakırköy	27.66	0.70	0.53	0.42	8.34	31.96	359.95	0.92
8	Başakşehir	16.93	0.58	0.38	0.27	9.65	34.93	226.89	0.63
9	Bayrampaşa	19.96	0.61	0.43	0.31	9.31	34.21	267.29	0.72
10	Beşiktaş	16.62	0.57	0.38	0.26	9.69	35.00	222.75	0.62
11	Beykoz	13.00	0.49	0.30	0.20	9.59	30.75	169.74	0.49
12	Beylikdüzü	27.99	0.70	0.53	0.43	8.29	31.83	363.09	0.93
13	Beyoğlu	19.54	0.61	0.42	0.31	9.36	34.31	261.69	0.71
14	Büyükçekmece	24.63	0.67	0.50	0.39	8.79	33.10	329.51	0.86
15	Çatalca	15.58	0.56	0.36	0.25	9.80	35.25	208.90	0.59
16	Çekmeköy	13.05	0.50	0.30	0.20	9.60	30.88	170.64	0.49
17	Esenler	17.99	0.59	0.40	0.28	9.53	34.68	241.02	0.66
18	Esenyurt	22.45	0.65	0.47	0.35	9.03	33.62	300.50	0.79
19	Eyüp	19.57	0.61	0.42	0.31	9.35	34.30	262.12	0.71
20	Fatih	21.61	0.64	0.45	0.34	9.12	33.81	289.37	0.77
21	Gaziosmanpaşa	17.85	0.59	0.40	0.28	9.55	34.71	239.18	0.65
22	Güngören	22.47	0.65	0.47	0.35	9.03	33.61	300.76	0.79
23	Kadıköy	20.84	0.63	0.44	0.33	9.21	34.00	278.99	0.74
24	Kağıthane	16.62	0.57	0.38	0.26	9.69	35.00	222.77	0.62
25	Kartal	23.77	0.66	0.49	0.37	8.88	33.30	318.10	0.83
26	Küçükçekmece	24.52	0.67	0.50	0.39	8.80	33.12	328.07	0.85
27	Maltepe	20.61	0.62	0.44	0.32	9.24	34.05	275.97	0.74
28	Pendik	16.39	0.57	0.38	0.26	9.71	35.06	219.80	0.61
29	Sancaktepe	15.04	0.55	0.36	0.24	9.86	35.38	201.78	0.57
30	Sarıyer	13.17	0.50	0.31	0.20	9.61	31.16	172.53	0.49
31	Silivri	17.88	0.59	0.40	0.28	9.54	34.70	239.63	0.66
32	Sultanbeyli	18.07	0.59	0.40	0.28	9.52	34.66	242.09	0.66
33	Sultangazi	16.34	0.57	0.37	0.26	9.72	35.07	219.03	0.61
34	Şile	11.68	0.46	0.27	0.18	9.40	27.71	149.09	0.43
35	Şişli	14.60	0.54	0.34	0.23	9.81	34.46	194.89	0.55
36	Tuzla	21.60	0.64	0.45	0.34	9.13	33.82	289.16	0.77
37	Ümraniye	17.18	0.58	0.39	0.27	9.62	34.87	230.24	0.63
38	Üsküdar	18.87	0.60	0.41	0.30	9.43	34.47	252.82	0.69
39	Zeytinburnu	25.35	0.68	0.51	0.40	8.69	32.87	337.85	0.88

Table B.6 Losses and Premiums for Earthquakes within the Next **2475 Years** for **RC Frame Mid-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=2475\ yr}$ %
1	Adalar	50.74	0.79	0.68	0.62	5.49	19.69	525.71	0.244
2	Arnavutköy	21.60	0.62	0.45	0.34	8.63	32.99	286.40	0.145
3	Ataşehir	30.93	0.70	0.56	0.46	7.26	30.84	387.46	0.189
4	Avcılar	39.23	0.75	0.63	0.54	6.00	28.52	455.56	0.217
5	Bağcılar	33.45	0.72	0.58	0.48	6.86	30.08	411.44	0.199
6	Bahçelievler	39.55	0.75	0.63	0.54	5.96	28.44	457.78	0.218
7	Bakırköy	45.15	0.78	0.67	0.58	5.18	26.83	496.45	0.234
8	Başakşehir	27.46	0.68	0.52	0.42	7.82	31.87	354.53	0.175
9	Bayrampaşa	32.06	0.71	0.57	0.47	7.08	30.50	398.24	0.193
10	Beşiktaş	26.88	0.68	0.52	0.41	7.91	32.05	349.01	0.172
11	Beykoz	21.02	0.61	0.44	0.33	8.70	33.06	278.81	0.142
12	Beylikdüzü	45.56	0.78	0.67	0.59	5.20	26.32	498.56	0.235
13	Beyoğlu	31.44	0.71	0.56	0.46	7.18	30.68	392.36	0.191
14	Büyükçekmece	40.30	0.76	0.64	0.54	5.85	28.25	463.00	0.220
15	Çatalca	25.48	0.67	0.50	0.40	8.13	32.46	335.77	0.167
16	Çekmeköy	21.15	0.61	0.44	0.33	8.68	33.04	280.49	0.143
17	Esenler	29.17	0.69	0.54	0.44	7.54	31.36	370.83	0.182
18	Esenyurt	36.49	0.74	0.61	0.51	6.40	29.23	436.53	0.209
19	Eyüp	31.51	0.71	0.56	0.46	7.17	30.66	393.02	0.191
20	Fatih	34.97	0.73	0.60	0.50	6.62	29.63	425.85	0.205
21	Gaziosmanpaşa	28.95	0.69	0.54	0.43	7.58	31.43	368.70	0.181
22	Güngören	36.51	0.74	0.61	0.51	6.40	29.23	436.66	0.209
23	Kadıköy	33.37	0.72	0.58	0.48	6.87	30.11	410.70	0.198
24	Kağıthane	26.91	0.68	0.52	0.41	7.90	32.04	349.33	0.173
25	Kartal	38.29	0.75	0.62	0.53	6.14	28.77	449.04	0.215
26	Küçükçekmece	40.12	0.75	0.64	0.54	5.87	28.29	461.72	0.220
27	Maltepe	32.94	0.72	0.58	0.48	6.94	30.23	406.65	0.197
28	Pendik	26.69	0.67	0.52	0.41	7.94	32.10	347.19	0.172
29	Sancaktepe	24.35	0.65	0.49	0.38	8.29	32.68	322.66	0.161
30	Sarıyer	21.33	0.62	0.44	0.33	8.66	33.02	282.92	0.144
31	Silivri	29.49	0.69	0.54	0.44	7.49	31.27	373.83	0.183
32	Sultanbeyli	29.27	0.69	0.54	0.44	7.53	31.33	371.70	0.182
33	Sultangazi	26.49	0.67	0.51	0.41	7.97	32.16	345.35	0.171
34	Şile	19.07	0.59	0.41	0.30	8.94	33.27	253.18	0.131
35	Şişli	23.61	0.64	0.48	0.37	8.38	32.76	312.91	0.157
36	Tuzla	35.27	0.73	0.60	0.50	6.57	29.55	428.06	0.206
37	Ümraniye	27.72	0.68	0.53	0.42	7.77	31.79	357.02	0.176
38	Üsküdar	30.41	0.70	0.55	0.45	7.34	30.99	382.58	0.187
39	Zeytinburnu	41.48	0.76	0.65	0.55	5.68	27.94	471.20	0.224

Table B.7 Losses and Premium Rates for Earthquakes within the Next **72 Years** for **RC Frame High-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=72\ yr}$ ‰
1	Adalar	14.38	0.62	0.40	0.29	11.16	32.18	245.19	4.40
2	Arnavutköy	7.03	0.38	0.19	0.15	9.42	12.25	124.57	2.23
3	Ataşehir	9.76	0.47	0.26	0.20	10.07	19.66	169.41	3.03
4	Avcılar	11.35	0.52	0.31	0.23	10.44	23.96	195.42	3.50
5	Bağcılar	10.16	0.48	0.28	0.21	10.16	20.74	175.97	3.15
6	Bahçelievler	11.42	0.52	0.31	0.23	10.46	24.15	196.56	3.52
7	Bakırköy	12.60	0.56	0.35	0.25	10.74	27.35	215.95	3.87
8	Başakşehir	8.61	0.43	0.23	0.18	9.80	16.53	150.49	2.69
9	Bayrampaşa	9.83	0.47	0.27	0.20	10.08	19.84	170.47	3.05
10	Beşiktaş	8.54	0.43	0.23	0.18	9.78	16.34	149.31	2.67
11	Beykoz	6.90	0.37	0.18	0.14	9.39	11.91	122.52	2.19
12	Beylikdüzü	12.66	0.56	0.35	0.26	10.75	27.51	216.92	3.89
13	Beyoğlu	9.70	0.46	0.26	0.20	10.05	19.51	168.49	3.02
14	Büyükçekmece	11.49	0.52	0.31	0.23	10.48	24.36	197.83	3.54
15	Çatalca	7.99	0.41	0.21	0.17	9.65	14.87	140.44	2.51
16	Çekmeköy	6.92	0.37	0.18	0.14	9.40	11.98	122.89	2.20
17	Esenler	9.04	0.44	0.24	0.19	9.90	17.71	157.60	2.82
18	Esenyurt	10.76	0.50	0.29	0.22	10.30	22.38	185.87	3.33
19	Eyüp	9.69	0.46	0.26	0.20	10.05	19.46	168.21	3.01
20	Fatih	10.51	0.49	0.29	0.21	10.25	21.69	181.71	3.26
21	Gaziosmanpaşa	8.99	0.44	0.24	0.18	9.89	17.57	156.73	2.81
22	Güngören	10.79	0.50	0.29	0.22	10.31	22.46	186.33	3.34
23	Kadıköy	10.35	0.49	0.28	0.21	10.21	21.25	179.06	3.21
24	Kağıthane	8.51	0.42	0.23	0.18	9.77	16.27	148.92	2.67
25	Kartal	11.56	0.53	0.32	0.23	10.49	24.52	198.84	3.56
26	Küçükçekmece	11.53	0.52	0.31	0.23	10.49	24.45	198.42	3.56
27	Maltepe	10.30	0.48	0.28	0.21	10.20	21.13	178.32	3.19
28	Pendik	8.41	0.42	0.23	0.17	9.75	16.00	147.28	2.64
29	Sancaktepe	7.87	0.40	0.21	0.16	9.62	14.54	138.39	2.48
30	Sarıyer	6.98	0.37	0.19	0.15	9.41	12.12	123.74	2.21
31	Silivri	8.97	0.44	0.24	0.18	9.88	17.53	156.52	2.80
32	Sultanbeyli	9.21	0.45	0.25	0.19	9.94	18.18	160.44	2.87
33	Sultangazi	8.36	0.42	0.23	0.17	9.74	15.86	146.44	2.62
34	Şile	6.05	0.34	0.16	0.13	9.19	9.61	108.57	1.94
35	Şişli	7.64	0.40	0.20	0.16	9.57	13.91	134.59	2.41
36	Tuzla	10.48	0.49	0.29	0.21	10.24	21.61	181.20	3.25
37	Ümraniye	8.83	0.44	0.24	0.18	9.85	17.14	154.16	2.76
38	Üsküdar	9.52	0.46	0.26	0.19	10.01	19.01	165.48	2.96
39	Zeytinburnu	11.82	0.53	0.32	0.24	10.55	25.25	203.23	3.64

Table B.8 Losses and Premium Rates for Earthquakes within the Next **475 Years** for **RC Frame High-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=475\ yr}$ ‰
1	Adalar	31.62	0.81	0.65	0.49	8.01	46.30	420.20	1.10
2	Arnavutköy	13.32	0.58	0.37	0.27	10.91	29.29	227.72	0.62
3	Ataşehir	19.29	0.69	0.49	0.36	10.42	38.23	304.37	0.82
4	Avcılar	24.01	0.75	0.57	0.42	9.44	43.05	358.38	0.95
5	Bağcılar	20.75	0.71	0.51	0.38	10.11	39.72	321.11	0.86
6	Bahçelievler	24.19	0.76	0.57	0.42	9.40	43.23	360.43	0.95
7	Bakırköy	27.66	0.78	0.61	0.46	8.74	44.96	389.99	1.02
8	Başakşehir	16.93	0.66	0.45	0.33	10.91	35.82	277.35	0.75
9	Bayrampaşa	19.96	0.70	0.50	0.37	10.28	38.91	312.02	0.83
10	Beşiktaş	16.62	0.66	0.44	0.32	10.97	35.50	273.80	0.74
11	Beykoz	13.00	0.57	0.36	0.26	10.83	28.43	222.47	0.60
12	Beylikdüzü	27.99	0.79	0.61	0.46	8.68	45.07	392.49	1.03
13	Beyoğlu	19.54	0.70	0.49	0.36	10.37	38.48	307.22	0.82
14	Büyükçekmece	24.63	0.76	0.58	0.43	9.31	43.67	365.41	0.97
15	Çatalca	15.58	0.65	0.42	0.31	11.18	34.44	261.91	0.71
16	Çekmeköy	13.05	0.58	0.36	0.26	10.84	28.58	223.41	0.61
17	Esenler	17.99	0.68	0.46	0.34	10.69	36.90	289.48	0.78
18	Esenyurt	22.45	0.73	0.54	0.40	9.76	41.45	340.52	0.90
19	Eyüp	19.57	0.70	0.49	0.36	10.36	38.52	307.59	0.82
20	Fatih	21.61	0.72	0.52	0.39	9.94	40.60	330.97	0.88
21	Gaziosmanpaşa	17.85	0.68	0.46	0.34	10.71	36.76	287.91	0.77
22	Güngören	22.47	0.73	0.54	0.40	9.76	41.47	340.75	0.91
23	Kadıköy	20.84	0.71	0.51	0.38	10.10	39.81	322.06	0.86
24	Kağıthane	16.62	0.66	0.44	0.32	10.97	35.50	273.82	0.74
25	Kartal	23.77	0.75	0.56	0.42	9.49	42.80	355.62	0.94
26	Küçükçekmece	24.52	0.76	0.57	0.43	9.34	43.56	364.18	0.96
27	Maltepe	20.61	0.71	0.51	0.38	10.14	39.58	319.47	0.85
28	Pendik	16.39	0.66	0.44	0.32	11.02	35.28	271.27	0.73
29	Sancaktepe	15.04	0.64	0.41	0.30	11.30	33.90	255.81	0.70
30	Sarıyer	13.17	0.58	0.36	0.27	10.87	28.91	225.38	0.61
31	Silivri	17.88	0.68	0.46	0.34	10.71	36.79	288.29	0.78
32	Sultanbeyli	18.07	0.68	0.46	0.34	10.67	36.98	290.40	0.78
33	Sultangazi	16.34	0.66	0.44	0.32	11.03	35.22	270.61	0.73
34	Şile	11.68	0.53	0.32	0.24	10.52	24.87	200.92	0.55
35	Şişli	14.60	0.63	0.40	0.29	11.21	32.76	248.72	0.68
36	Tuzla	21.60	0.72	0.52	0.39	9.94	40.59	330.79	0.88
37	Ümraniye	17.18	0.67	0.45	0.33	10.85	36.08	280.23	0.76
38	Üsküdar	18.87	0.69	0.48	0.35	10.50	37.80	299.60	0.80
39	Zeytinburnu	25.35	0.77	0.59	0.44	9.17	44.17	372.37	0.98

Table B.9 Losses and Premium Rates for Earthquakes within the Next **2475 Years** for **RC Frame High-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=2475\ yr}$ ‰
1	Adalar	50.74	0.88	0.77	0.61	5.47	48.07	520.65	0.254
2	Arnavutköy	21.60	0.72	0.52	0.39	9.94	40.58	330.75	0.169
3	Ataşehir	30.93	0.80	0.64	0.49	8.14	46.07	414.91	0.208
4	Avcılar	39.23	0.85	0.71	0.55	6.81	47.78	468.34	0.232
5	Bağcılar	33.45	0.82	0.67	0.51	7.67	46.92	434.17	0.217
6	Bahçelievler	39.55	0.85	0.71	0.55	6.77	47.81	470.02	0.233
7	Bakırköy	45.15	0.87	0.75	0.59	6.01	48.23	499.38	0.245
8	Başakşehir	27.46	0.78	0.61	0.46	8.78	44.89	388.45	0.196
9	Bayrampaşa	32.06	0.81	0.65	0.50	7.93	46.45	423.56	0.212
10	Beşiktaş	26.88	0.78	0.60	0.45	8.89	44.69	384.01	0.194
11	Beykoz	21.02	0.72	0.51	0.38	10.06	39.99	324.15	0.166
12	Beylikdüzü	45.56	0.87	0.75	0.59	5.97	48.21	500.91	0.246
13	Beyoğlu	31.44	0.81	0.65	0.49	8.04	46.24	418.84	0.210
14	Büyükçekmece	40.30	0.85	0.72	0.56	6.66	47.86	473.99	0.234
15	Çatalca	25.48	0.77	0.59	0.44	9.15	44.22	373.38	0.189
16	Çekmeköy	21.15	0.72	0.52	0.38	10.03	40.12	325.61	0.167
17	Esenler	29.17	0.79	0.62	0.47	8.46	45.47	401.54	0.202
18	Esenyurt	36.49	0.84	0.69	0.53	7.18	47.57	453.88	0.225
19	Eyüp	31.51	0.81	0.65	0.49	8.03	46.27	419.38	0.210
20	Fatih	34.97	0.83	0.68	0.52	7.39	47.44	445.74	0.222
21	Gaziosmanpaşa	28.95	0.79	0.62	0.47	8.50	45.40	399.83	0.201
22	Güngören	36.51	0.84	0.69	0.53	7.18	47.57	453.97	0.225
23	Kadıköy	33.37	0.82	0.67	0.51	7.68	46.90	433.57	0.216
24	Kağıthane	26.91	0.78	0.60	0.45	8.88	44.70	384.27	0.194
25	Kartal	38.29	0.84	0.70	0.55	6.94	47.71	463.38	0.230
26	Küçükçekmece	40.12	0.85	0.72	0.56	6.69	47.85	473.02	0.234
27	Maltepe	32.94	0.82	0.66	0.51	7.76	46.75	430.32	0.215
28	Pendik	26.69	0.78	0.60	0.45	8.92	44.63	382.55	0.193
29	Sancaktepe	24.35	0.76	0.57	0.43	9.37	43.40	362.29	0.184
30	Sarıyer	21.33	0.72	0.52	0.39	9.99	40.31	327.73	0.168
31	Silivri	29.49	0.80	0.63	0.48	8.40	45.58	403.96	0.203
32	Sultanbeyli	29.27	0.79	0.62	0.47	8.44	45.50	402.25	0.202
33	Sultangazi	26.49	0.78	0.60	0.45	8.96	44.56	381.07	0.193
34	Şile	19.07	0.69	0.48	0.36	10.46	38.00	301.86	0.155
35	Şişli	23.61	0.75	0.56	0.42	9.52	42.64	353.80	0.180
36	Tuzla	35.27	0.83	0.68	0.53	7.34	47.47	447.44	0.223
37	Ümraniye	27.72	0.78	0.61	0.46	8.73	44.98	390.45	0.197
38	Üsküdar	30.41	0.80	0.64	0.48	8.23	45.89	410.98	0.206
39	Zeytinburnu	41.48	0.85	0.72	0.56	6.50	47.96	480.22	0.237

Table B.10 Losses and Premium Rates for Earthquakes within the Next **72 Years** for **RC Dual Low-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=72\ yr}$ ‰
1	Adalar	14.38	0.42	0.33	0.22	4.27	33.81	188.52	3.45
2	Arnavutköy	7.03	0.30	0.23	0.15	3.44	24.74	126.62	2.36
3	Ataşehir	9.76	0.34	0.27	0.18	3.75	28.11	149.63	2.77
4	Avcılar	11.35	0.37	0.29	0.19	3.93	30.07	162.98	3.00
5	Bağcılar	10.16	0.35	0.28	0.18	3.79	28.61	153.00	2.82
6	Bahçelievler	11.42	0.37	0.29	0.19	3.94	30.16	163.56	3.01
7	Bakırköy	12.60	0.39	0.31	0.20	4.07	31.61	173.51	3.19
8	Başakşehir	8.61	0.33	0.25	0.16	3.62	26.69	139.92	2.59
9	Bayrampaşa	9.83	0.35	0.27	0.18	3.76	28.19	150.18	2.77
10	Beşiktaş	8.54	0.32	0.25	0.16	3.61	26.60	139.32	2.58
11	Beykoz	6.90	0.30	0.23	0.15	3.42	24.59	125.57	2.34
12	Beylikdüzü	12.66	0.39	0.31	0.20	4.08	31.69	174.01	3.20
13	Beyoğlu	9.70	0.34	0.27	0.18	3.74	28.05	149.16	2.76
14	Büyükçekmece	11.49	0.37	0.29	0.19	3.95	30.25	164.22	3.02
15	Çatalca	7.99	0.32	0.25	0.16	3.55	25.94	134.77	2.50
16	Çekmeköy	6.92	0.30	0.23	0.15	3.43	24.62	125.76	2.34
17	Esenler	9.04	0.33	0.26	0.17	3.67	27.23	143.57	2.66
18	Esenyurt	10.76	0.36	0.28	0.19	3.86	29.35	158.08	2.91
19	Eyüp	9.69	0.34	0.27	0.18	3.74	28.02	149.01	2.75
20	Fatih	10.51	0.36	0.28	0.18	3.83	29.04	155.95	2.88
21	Gaziosmanpaşa	8.99	0.33	0.26	0.17	3.66	27.16	143.13	2.65
22	Güngören	10.79	0.36	0.28	0.19	3.87	29.39	158.31	2.92
23	Kadıköy	10.35	0.35	0.28	0.18	3.82	28.84	154.59	2.85
24	Kağıthane	8.51	0.32	0.25	0.16	3.61	26.57	139.12	2.58
25	Kartal	11.56	0.37	0.29	0.19	3.95	30.33	164.73	3.03
26	Küçükçekmece	11.53	0.37	0.29	0.19	3.95	30.30	164.52	3.03
27	Maltepe	10.30	0.35	0.28	0.18	3.81	28.78	154.20	2.85
28	Pendik	8.41	0.32	0.25	0.16	3.60	26.45	138.28	2.56
29	Sancaktepe	7.87	0.31	0.24	0.16	3.53	25.78	133.72	2.48
30	Sarıyer	6.98	0.30	0.23	0.15	3.43	24.68	126.20	2.35
31	Silivri	8.97	0.33	0.26	0.17	3.66	27.15	143.02	2.65
32	Sultanbeyli	9.21	0.34	0.26	0.17	3.69	27.44	145.03	2.68
33	Sultangazi	8.36	0.32	0.25	0.16	3.59	26.39	137.84	2.56
34	Şile	6.05	0.28	0.22	0.14	3.33	23.54	118.41	2.21
35	Şişli	7.64	0.31	0.24	0.16	3.51	25.50	131.77	2.45
36	Tuzla	10.48	0.36	0.28	0.18	3.83	29.00	155.68	2.87
37	Ümraniye	8.83	0.33	0.26	0.17	3.64	26.97	141.81	2.63
38	Üsküdar	9.52	0.34	0.27	0.17	3.72	27.82	147.61	2.73
39	Zeytinburnu	11.82	0.38	0.30	0.20	3.98	30.66	166.99	3.07

Table B.11 Losses and Premium Rates for Earthquakes within the Next **475 Years** for **RC Dual Low-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=475\ yr}$ ‰
1	Adalar	31.62	0.55	0.45	0.31	4.76	41.98	265.93	0.72
2	Arnavutköy	13.32	0.40	0.32	0.21	4.15	32.50	179.55	0.50
3	Ataşehir	19.29	0.47	0.38	0.25	4.49	36.87	214.72	0.59
4	Avcılar	24.01	0.50	0.41	0.28	4.65	39.41	237.84	0.65
5	Bağcılar	20.75	0.48	0.39	0.26	4.54	37.66	221.88	0.61
6	Bahçelievler	24.19	0.51	0.41	0.28	4.65	39.50	238.72	0.65
7	Bakırköy	27.66	0.53	0.43	0.30	4.71	40.76	252.03	0.69
8	Başakşehir	16.93	0.45	0.36	0.24	4.41	35.61	203.15	0.56
9	Bayrampaşa	19.96	0.47	0.38	0.26	4.51	37.23	217.99	0.60
10	Beşiktaş	16.62	0.44	0.36	0.24	4.40	35.44	201.63	0.56
11	Beykoz	13.00	0.40	0.32	0.21	4.12	32.10	176.86	0.49
12	Beylikdüzü	27.99	0.53	0.43	0.30	4.72	40.86	253.18	0.69
13	Beyoğlu	19.54	0.47	0.38	0.25	4.50	37.01	215.93	0.59
14	Büyükçekmece	24.63	0.51	0.42	0.28	4.67	39.74	240.85	0.66
15	Çatalca	15.58	0.43	0.35	0.23	4.36	34.88	196.54	0.54
16	Çekmeköy	13.05	0.40	0.32	0.21	4.12	32.17	177.34	0.49
17	Esenler	17.99	0.45	0.37	0.25	4.44	36.18	208.34	0.57
18	Esenyurt	22.45	0.49	0.40	0.27	4.59	38.57	230.19	0.63
19	Eyüp	19.57	0.47	0.38	0.25	4.50	37.03	216.10	0.59
20	Fatih	21.61	0.48	0.39	0.27	4.57	38.12	226.10	0.62
21	Gaziosmanpaşa	17.85	0.45	0.36	0.24	4.44	36.10	207.67	0.57
22	Güngören	22.47	0.49	0.40	0.27	4.60	38.58	230.29	0.63
23	Kadıköy	20.84	0.48	0.39	0.26	4.54	37.70	222.29	0.61
24	Kağıthane	16.62	0.44	0.36	0.24	4.40	35.44	201.64	0.56
25	Kartal	23.77	0.50	0.41	0.28	4.64	39.28	236.66	0.65
26	Küçükçekmece	24.52	0.51	0.41	0.28	4.66	39.68	240.32	0.66
27	Maltepe	20.61	0.48	0.39	0.26	4.53	37.58	221.18	0.61
28	Pendik	16.39	0.44	0.35	0.24	4.39	35.32	200.55	0.55
29	Sancaktepe	15.04	0.43	0.34	0.23	4.35	34.60	193.93	0.54
30	Sarıyer	13.17	0.40	0.32	0.21	4.14	32.32	178.36	0.50
31	Silivri	17.88	0.45	0.36	0.24	4.44	36.12	207.83	0.57
32	Sultanbeyli	18.07	0.46	0.37	0.25	4.45	36.22	208.73	0.58
33	Sultangazi	16.34	0.44	0.35	0.24	4.39	35.29	200.26	0.55
34	Şile	11.68	0.38	0.30	0.20	3.97	30.48	165.80	0.46
35	Şişli	14.60	0.42	0.34	0.22	4.30	34.08	190.33	0.53
36	Tuzla	21.60	0.48	0.39	0.27	4.57	38.11	226.03	0.62
37	Ümraniye	17.18	0.45	0.36	0.24	4.42	35.74	204.38	0.56
38	Üsküdar	18.87	0.46	0.37	0.25	4.47	36.65	212.68	0.59
39	Zeytinburnu	25.35	0.51	0.42	0.29	4.68	40.05	243.91	0.67

Table B.12 Losses and Premium Rates for Earthquakes within the Next **2475 Years** for **RC Dual Low-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=2475\ yr}$ ‰
1	Adalar	50.74	0.62	0.53	0.37	4.84	45.76	318.27	0.163
2	Arnavutköy	21.60	0.48	0.39	0.27	4.57	38.11	226.01	0.119
3	Ataşehir	30.93	0.54	0.45	0.31	4.75	41.76	263.50	0.137
4	Avcılar	39.23	0.58	0.49	0.34	4.82	43.85	289.44	0.150
5	Bağcılar	33.45	0.56	0.46	0.32	4.79	42.54	272.36	0.142
6	Bahçelievler	39.55	0.58	0.49	0.34	4.82	43.92	290.32	0.150
7	Bakırköy	45.15	0.61	0.51	0.36	4.84	45.01	305.65	0.158
8	Başakşehir	27.46	0.53	0.43	0.30	4.71	40.70	251.32	0.132
9	Bayrampaşa	32.06	0.55	0.46	0.31	4.77	42.11	267.48	0.139
10	Beşiktaş	26.88	0.52	0.43	0.29	4.70	40.52	249.27	0.131
11	Beykoz	21.02	0.48	0.39	0.26	4.55	37.80	223.18	0.118
12	Beylikdüzü	45.56	0.61	0.51	0.36	4.84	45.07	306.56	0.158
13	Beyoğlu	31.44	0.55	0.45	0.31	4.76	41.92	265.31	0.138
14	Büyükçekmece	40.30	0.59	0.49	0.34	4.83	44.06	292.39	0.151
15	Çatalca	25.48	0.51	0.42	0.29	4.69	40.09	244.38	0.128
16	Çekmeköy	21.15	0.48	0.39	0.26	4.55	37.87	223.81	0.118
17	Esenler	29.17	0.53	0.44	0.30	4.73	41.22	257.34	0.134
18	Esenyurt	36.49	0.57	0.48	0.33	4.81	43.31	281.91	0.146
19	Eyüp	31.51	0.55	0.45	0.31	4.76	41.94	265.55	0.138
20	Fatih	34.97	0.57	0.47	0.33	4.80	43.01	277.69	0.144
21	Gaziosmanpaşa	28.95	0.53	0.44	0.30	4.73	41.15	256.56	0.134
22	Güngören	36.51	0.57	0.48	0.33	4.81	43.32	281.96	0.146
23	Kadıköy	33.37	0.56	0.46	0.32	4.78	42.52	272.09	0.142
24	Kağıthane	26.91	0.52	0.43	0.29	4.70	40.53	249.39	0.131
25	Kartal	38.29	0.58	0.48	0.34	4.82	43.67	286.86	0.149
26	Küçükçekmece	40.12	0.59	0.49	0.34	4.82	44.03	291.88	0.151
27	Maltepe	32.94	0.56	0.46	0.32	4.78	42.38	270.59	0.141
28	Pendik	26.69	0.52	0.43	0.29	4.70	40.46	248.60	0.130
29	Sancaktepe	24.35	0.51	0.41	0.28	4.66	39.59	239.51	0.126
30	Sarıyer	21.33	0.48	0.39	0.26	4.56	37.97	224.72	0.118
31	Silivri	29.49	0.54	0.44	0.30	4.74	41.32	258.46	0.135
32	Sultanbeyli	29.27	0.54	0.44	0.30	4.73	41.25	257.67	0.135
33	Sultangazi	26.49	0.52	0.43	0.29	4.70	40.40	247.92	0.130
34	Şile	19.07	0.46	0.37	0.25	4.48	36.76	213.64	0.113
35	Şişli	23.61	0.50	0.41	0.28	4.63	39.19	235.88	0.124
36	Tuzla	35.27	0.57	0.47	0.33	4.81	43.07	278.56	0.145
37	Ümraniye	27.72	0.53	0.43	0.30	4.71	40.78	252.24	0.132
38	Üsküdar	30.41	0.54	0.45	0.31	4.75	41.60	261.69	0.137
39	Zeytinburnu	41.48	0.59	0.50	0.35	4.83	44.30	295.63	0.153

Table B.13 Losses and Premium Rates for Earthquakes within the Next **72 Years** for **RC Dual Mid-rise** Type of Buildings

No	District	PGV (cm/s)	y-IO	y-LS	y-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=72\ yr}$ ‰
1	Adalar	14.38	0.44	0.35	0.25	4.61	30.33	211.43	3.75
2	Arnavutköy	7.03	0.29	0.23	0.17	3.34	18.64	140.70	2.48
3	Ataşehir	9.76	0.35	0.27	0.20	3.81	22.99	166.99	2.95
4	Avcılar	11.35	0.38	0.30	0.21	4.09	25.51	182.25	3.23
5	Bağcılar	10.16	0.36	0.28	0.20	3.88	23.62	170.84	3.02
6	Bahçelievler	11.42	0.38	0.30	0.22	4.10	25.62	182.91	3.24
7	Bakırköy	12.60	0.41	0.32	0.23	4.30	27.50	194.28	3.44
8	Başakşehir	8.61	0.33	0.25	0.18	3.61	21.15	155.90	2.75
9	Bayrampaşa	9.83	0.35	0.27	0.20	3.82	23.09	167.62	2.96
10	Beşiktaş	8.54	0.32	0.25	0.18	3.60	21.04	155.20	2.74
11	Beykoz	6.90	0.29	0.23	0.16	3.31	18.44	139.49	2.46
12	Beylikdüzü	12.66	0.41	0.32	0.23	4.32	27.59	194.85	3.45
13	Beyoğlu	9.70	0.35	0.27	0.20	3.80	22.90	166.45	2.94
14	Büyükçekmece	11.49	0.38	0.30	0.22	4.11	25.74	183.66	3.25
15	Çatalca	7.99	0.31	0.24	0.18	3.50	20.18	150.00	2.65
16	Çekmeköy	6.92	0.29	0.23	0.16	3.32	18.48	139.72	2.46
17	Esenler	9.04	0.33	0.26	0.19	3.69	21.84	160.06	2.83
18	Esenyurt	10.76	0.37	0.29	0.21	3.99	24.58	176.64	3.13
19	Eyüp	9.69	0.35	0.27	0.20	3.80	22.87	166.29	2.94
20	Fatih	10.51	0.36	0.29	0.20	3.94	24.18	174.21	3.08
21	Gaziosmanpaşa	8.99	0.33	0.26	0.19	3.68	21.76	159.56	2.82
22	Güngören	10.79	0.37	0.29	0.21	3.99	24.63	176.91	3.13
23	Kadıköy	10.35	0.36	0.28	0.20	3.91	23.92	172.65	3.05
24	Kağıthane	8.51	0.32	0.25	0.18	3.59	21.00	154.97	2.74
25	Kartal	11.56	0.39	0.30	0.22	4.12	25.84	184.25	3.26
26	Küçükçekmece	11.53	0.38	0.30	0.22	4.12	25.80	184.00	3.26
27	Maltepe	10.30	0.36	0.28	0.20	3.91	23.85	172.22	3.05
28	Pendik	8.41	0.32	0.25	0.18	3.58	20.84	154.02	2.72
29	Sancaktepe	7.87	0.31	0.24	0.18	3.48	19.98	148.80	2.62
30	Sarıyer	6.98	0.29	0.23	0.16	3.33	18.56	140.21	2.47
31	Silivri	8.97	0.33	0.26	0.19	3.67	21.74	159.43	2.82
32	Sultanbeyli	9.21	0.34	0.26	0.19	3.72	22.12	161.73	2.86
33	Sultangazi	8.36	0.32	0.25	0.18	3.57	20.76	153.52	2.71
34	Şile	6.05	0.27	0.21	0.15	3.17	17.09	131.32	2.31
35	Şişli	7.64	0.31	0.24	0.17	3.44	19.61	146.58	2.58
36	Tuzla	10.48	0.36	0.29	0.20	3.94	24.13	173.90	3.08
37	Ümraniye	8.83	0.33	0.26	0.19	3.65	21.51	158.05	2.79
38	Üsküdar	9.52	0.34	0.27	0.19	3.77	22.61	164.68	2.91
39	Zeytinburnu	11.82	0.39	0.31	0.22	4.17	26.27	186.83	3.31

Table B.14 Losses and Premium Rates for Earthquakes within the Next **475 Years** for **RC Dual Mid-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=475\ yr}$ ‰
1	Adalar	31.62	0.60	0.49	0.35	5.37	42.02	298.94	0.80
2	Arnavutköy	13.32	0.42	0.33	0.24	4.43	28.64	201.18	0.54
3	Ataşehir	19.29	0.50	0.40	0.28	4.95	34.61	241.17	0.65
4	Avcılar	24.01	0.55	0.44	0.31	5.20	38.24	267.36	0.72
5	Bağcılar	20.75	0.51	0.41	0.29	5.03	35.73	249.29	0.67
6	Bahçelievler	24.19	0.55	0.44	0.32	5.21	38.37	268.36	0.72
7	Bakırköy	27.66	0.57	0.47	0.33	5.30	40.21	283.34	0.76
8	Başakşehir	16.93	0.47	0.38	0.27	4.82	32.80	228.06	0.61
9	Bayrampaşa	19.96	0.50	0.41	0.29	4.99	35.12	244.88	0.66
10	Beşiktaş	16.62	0.47	0.37	0.27	4.81	32.56	226.34	0.61
11	Beykoz	13.00	0.41	0.33	0.23	4.37	28.13	198.11	0.53
12	Beylikdüzü	27.99	0.58	0.47	0.33	5.31	40.36	284.63	0.76
13	Beyoğlu	19.54	0.50	0.40	0.29	4.96	34.80	242.55	0.65
14	Büyükçekmece	24.63	0.55	0.45	0.32	5.23	38.71	270.77	0.73
15	Çatalca	15.58	0.46	0.37	0.26	4.75	31.76	220.57	0.59
16	Çekmeköy	13.05	0.42	0.33	0.23	4.38	28.22	198.66	0.53
17	Esenler	17.99	0.48	0.39	0.28	4.88	33.61	233.94	0.63
18	Esenyurt	22.45	0.53	0.43	0.30	5.12	37.04	258.70	0.69
19	Eyüp	19.57	0.50	0.40	0.29	4.96	34.83	242.73	0.65
20	Fatih	21.61	0.52	0.42	0.30	5.07	36.40	254.07	0.68
21	Gaziosmanpaşa	17.85	0.48	0.39	0.27	4.87	33.50	233.18	0.63
22	Güngören	22.47	0.53	0.43	0.30	5.12	37.05	258.81	0.70
23	Kadıköy	20.84	0.51	0.41	0.29	5.03	35.80	249.75	0.67
24	Kağıthane	16.62	0.47	0.37	0.27	4.81	32.56	226.35	0.61
25	Kartal	23.77	0.54	0.44	0.31	5.19	38.05	266.03	0.71
26	Küçükçekmece	24.52	0.55	0.45	0.32	5.23	38.63	270.18	0.73
27	Maltepe	20.61	0.51	0.41	0.29	5.02	35.62	248.49	0.67
28	Pendik	16.39	0.47	0.37	0.26	4.80	32.39	225.11	0.61
29	Sancaktepe	15.04	0.45	0.36	0.26	4.72	31.35	217.61	0.59
30	Sarıyer	13.17	0.42	0.33	0.24	4.40	28.41	199.82	0.54
31	Silivri	17.88	0.48	0.39	0.27	4.88	33.53	233.36	0.63
32	Sultanbeyli	18.07	0.49	0.39	0.28	4.89	33.67	234.39	0.63
33	Sultangazi	16.34	0.47	0.37	0.26	4.79	32.34	224.79	0.60
34	Şile	11.68	0.39	0.31	0.22	4.15	26.04	185.47	0.50
35	Şişli	14.60	0.45	0.35	0.25	4.65	30.68	213.50	0.57
36	Tuzla	21.60	0.52	0.42	0.30	5.07	36.38	253.98	0.68
37	Ümraniye	17.18	0.48	0.38	0.27	4.84	32.99	229.46	0.62
38	Üsküdar	18.87	0.49	0.40	0.28	4.93	34.29	238.85	0.64
39	Zeytinburnu	25.35	0.56	0.45	0.32	5.26	39.16	274.23	0.74

Table B.15 Losses and Premium Rates for Earthquakes within the next **2475 Years** for **RC Dual Mid-rise** Type of Buildings

No	District	PGV (cm/s)	y-IO	y-LS	y-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=2475\ yr}$ ‰
1	Adalar	50.74	0.69	0.58	0.42	5.45	47.73	357.14	0.182
2	Arnavutköy	21.60	0.52	0.42	0.30	5.07	36.38	253.96	0.131
3	Ataşehir	30.93	0.59	0.49	0.35	5.36	41.70	296.20	0.152
4	Avcılar	39.23	0.64	0.53	0.38	5.45	44.83	325.20	0.166
5	Bağcılar	33.45	0.61	0.50	0.36	5.41	42.86	306.15	0.157
6	Bahçelievler	39.55	0.64	0.53	0.38	5.45	44.92	326.17	0.167
7	Bakırköy	45.15	0.67	0.56	0.40	5.47	46.58	343.21	0.175
8	Başakşehir	27.46	0.57	0.47	0.33	5.30	40.12	282.54	0.145
9	Bayrampaşa	32.06	0.60	0.49	0.35	5.38	42.22	300.68	0.154
10	Beşiktaş	26.88	0.57	0.46	0.33	5.29	39.85	280.25	0.144
11	Beykoz	21.02	0.52	0.41	0.30	5.04	35.94	250.76	0.129
12	Beylikdüzü	45.56	0.67	0.56	0.40	5.47	46.67	344.22	0.176
13	Beyoğlu	31.44	0.60	0.49	0.35	5.37	41.94	298.24	0.153
14	Büyükçekmece	40.30	0.65	0.54	0.39	5.45	45.15	328.47	0.168
15	Çatalca	25.48	0.56	0.45	0.32	5.26	39.22	274.76	0.141
16	Çekmeköy	21.15	0.52	0.42	0.30	5.05	36.04	251.47	0.130
17	Esenler	29.17	0.58	0.48	0.34	5.33	40.90	289.30	0.149
18	Esenyurt	36.49	0.63	0.52	0.37	5.44	44.01	316.82	0.162
19	Eyüp	31.51	0.60	0.49	0.35	5.37	41.97	298.51	0.153
20	Fatih	34.97	0.62	0.51	0.37	5.43	43.55	312.13	0.160
21	Gaziosmanpaşa	28.95	0.58	0.48	0.34	5.32	40.80	288.42	0.148
22	Güngören	36.51	0.63	0.52	0.37	5.44	44.02	316.88	0.162
23	Kadıköy	33.37	0.61	0.50	0.36	5.41	42.82	305.84	0.157
24	Kağıthane	26.91	0.57	0.46	0.33	5.29	39.87	280.38	0.144
25	Kartal	38.29	0.64	0.53	0.38	5.45	44.55	322.33	0.165
26	Küçükçekmece	40.12	0.65	0.54	0.39	5.45	45.09	327.91	0.168
27	Maltepe	32.94	0.61	0.50	0.36	5.40	42.63	304.16	0.156
28	Pendik	26.69	0.57	0.46	0.33	5.28	39.77	279.49	0.144
29	Sancaktepe	24.35	0.55	0.45	0.32	5.22	38.50	269.26	0.139
30	Sarıyer	21.33	0.52	0.42	0.30	5.06	36.18	252.49	0.130
31	Silivri	29.49	0.59	0.48	0.34	5.33	41.05	290.55	0.149
32	Sultanbeyli	29.27	0.58	0.48	0.34	5.33	40.95	289.66	0.149
33	Sultangazi	26.49	0.57	0.46	0.33	5.28	39.68	278.73	0.143
34	Şile	19.07	0.50	0.40	0.28	4.94	34.44	239.95	0.124
35	Şişli	23.61	0.54	0.44	0.31	5.18	37.93	265.14	0.137
36	Tuzla	35.27	0.62	0.51	0.37	5.44	43.65	313.10	0.161
37	Ümraniye	27.72	0.57	0.47	0.33	5.30	40.24	283.57	0.146
38	Üsküdar	30.41	0.59	0.48	0.35	5.35	41.47	294.18	0.151
39	Zeytinburnu	41.48	0.65	0.54	0.39	5.46	45.50	332.07	0.170

Table B.16 Losses and Premium Rates for Earthquakes within the Next **72 Years** for **RC Dual High-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=72\ yr}$ ‰
1	Adalar	14.38	0.49	0.42	0.28	3.42	40.27	240.37	4.33
2	Arnavutköy	7.03	0.32	0.27	0.19	2.43	24.07	159.01	2.83
3	Ataşehir	9.76	0.38	0.32	0.22	2.80	30.09	189.25	3.38
4	Avcılar	11.35	0.42	0.36	0.24	3.01	33.59	206.80	3.71
5	Bağcılar	10.16	0.39	0.33	0.23	2.85	30.97	193.68	3.47
6	Bahçelievler	11.42	0.42	0.36	0.24	3.02	33.74	207.57	3.72
7	Bakırköy	12.60	0.44	0.38	0.26	3.18	36.34	220.65	3.96
8	Başakşehir	8.61	0.35	0.30	0.21	2.64	27.55	176.50	3.15
9	Bayrampaşa	9.83	0.38	0.32	0.22	2.80	30.24	189.97	3.40
10	Beşiktaş	8.54	0.35	0.30	0.21	2.63	27.39	175.70	3.13
11	Beykoz	6.90	0.31	0.26	0.19	2.41	23.80	157.63	2.80
12	Beylikdüzü	12.66	0.45	0.38	0.26	3.18	36.47	221.31	3.98
13	Beyoğlu	9.70	0.38	0.32	0.22	2.79	29.97	188.64	3.37
14	Büyükçekmece	11.49	0.42	0.36	0.25	3.03	33.91	208.43	3.74
15	Çatalca	7.99	0.34	0.29	0.20	2.56	26.20	169.72	3.02
16	Çekmeköy	6.92	0.31	0.27	0.19	2.42	23.85	157.88	2.81
17	Esenler	9.04	0.36	0.31	0.21	2.70	28.51	181.29	3.24
18	Esenyurt	10.76	0.40	0.34	0.24	2.93	32.30	200.36	3.59
19	Eyüp	9.69	0.38	0.32	0.22	2.79	29.93	188.44	3.37
20	Fatih	10.51	0.40	0.34	0.23	2.90	31.74	197.56	3.54
21	Gaziosmanpaşa	8.99	0.36	0.31	0.21	2.69	28.39	180.71	3.23
22	Güngören	10.79	0.40	0.34	0.24	2.93	32.36	200.67	3.60
23	Kadıköy	10.35	0.39	0.33	0.23	2.87	31.39	195.77	3.50
24	Kağıthane	8.51	0.35	0.30	0.21	2.63	27.34	175.43	3.13
25	Kartal	11.56	0.42	0.36	0.25	3.04	34.04	209.11	3.75
26	Küçükçekmece	11.53	0.42	0.36	0.25	3.03	33.99	208.83	3.75
27	Maltepe	10.30	0.39	0.33	0.23	2.87	31.29	195.27	3.50
28	Pendik	8.41	0.35	0.30	0.21	2.62	27.12	174.33	3.11
29	Sancaktepe	7.87	0.34	0.28	0.20	2.54	25.93	168.34	3.00
30	Sarıyer	6.98	0.31	0.27	0.19	2.42	23.96	158.45	2.82
31	Silivri	8.97	0.36	0.31	0.21	2.69	28.36	180.56	3.22
32	Sultanbeyli	9.21	0.37	0.31	0.22	2.72	28.89	183.21	3.27
33	Sultangazi	8.36	0.35	0.29	0.20	2.61	27.01	173.76	3.10
34	Şile	6.05	0.29	0.25	0.17	2.30	21.93	148.22	2.63
35	Şişli	7.64	0.33	0.28	0.20	2.51	25.42	165.77	2.95
36	Tuzla	10.48	0.40	0.34	0.23	2.89	31.68	197.21	3.53
37	Ümraniye	8.83	0.36	0.30	0.21	2.67	28.05	178.97	3.19
38	Üsküdar	9.52	0.37	0.32	0.22	2.76	29.56	186.60	3.34
39	Zeytinburnu	11.82	0.43	0.36	0.25	3.07	34.63	212.07	3.81

Table B.17 Losses and Premiums for Earthquakes within the Next **475 Years** for **RC Dual High-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=475\ yr}$ ‰
1	Adalar	31.62	0.66	0.58	0.40	3.83	54.83	338.89	0.92
2	Arnavutköy	13.32	0.46	0.40	0.27	3.27	37.92	228.59	0.62
3	Ataşehir	19.29	0.55	0.48	0.32	3.63	45.81	274.08	0.75
4	Avcılar	24.01	0.60	0.53	0.36	3.78	50.41	303.67	0.83
5	Bağcılar	20.75	0.56	0.49	0.33	3.68	47.23	283.25	0.77
6	Bahçelievler	24.19	0.60	0.53	0.36	3.78	50.58	304.79	0.83
7	Bakırköy	27.66	0.63	0.55	0.38	3.82	52.76	321.53	0.87
8	Başakşehir	16.93	0.52	0.45	0.31	3.56	43.50	259.28	0.71
9	Bayrampaşa	19.96	0.56	0.48	0.33	3.65	46.46	278.27	0.76
10	Beşiktaş	16.62	0.52	0.45	0.30	3.55	43.20	257.33	0.70
11	Beykoz	13.00	0.45	0.39	0.26	3.23	37.22	225.05	0.61
12	Beylikdüzü	27.99	0.63	0.56	0.38	3.82	52.93	322.97	0.88
13	Beyoğlu	19.54	0.55	0.48	0.32	3.64	46.05	275.64	0.75
14	Büyükçekmece	24.63	0.61	0.53	0.36	3.79	51.01	307.52	0.84
15	Çatalca	15.58	0.51	0.44	0.30	3.52	42.19	250.82	0.68
16	Çekmeköy	13.05	0.45	0.39	0.27	3.24	37.34	225.68	0.61
17	Esenler	17.99	0.53	0.46	0.31	3.59	44.54	265.92	0.73
18	Esenyurt	22.45	0.58	0.51	0.35	3.73	48.89	293.88	0.80
19	Eyüp	19.57	0.55	0.48	0.32	3.64	46.08	275.84	0.75
20	Fatih	21.61	0.57	0.50	0.34	3.70	48.07	288.65	0.79
21	Gaziosmanpaşa	17.85	0.53	0.46	0.31	3.59	44.40	265.06	0.72
22	Güngören	22.47	0.58	0.51	0.35	3.73	48.90	294.01	0.80
23	Kadıköy	20.84	0.57	0.49	0.33	3.68	47.31	283.77	0.77
24	Kağıthane	16.62	0.52	0.45	0.30	3.55	43.20	257.34	0.70
25	Kartal	23.77	0.60	0.52	0.36	3.77	50.17	302.16	0.82
26	Küçükçekmece	24.52	0.61	0.53	0.36	3.79	50.90	306.84	0.83
27	Maltepe	20.61	0.56	0.49	0.33	3.67	47.09	282.35	0.77
28	Pendik	16.39	0.52	0.44	0.30	3.54	42.98	255.95	0.70
29	Sancaktepe	15.04	0.50	0.43	0.29	3.50	41.67	247.47	0.68
30	Sarıyer	13.17	0.46	0.39	0.27	3.25	37.61	227.01	0.62
31	Silivri	17.88	0.53	0.46	0.31	3.59	44.43	265.27	0.72
32	Sultanbeyli	18.07	0.53	0.46	0.31	3.59	44.61	266.42	0.73
33	Sultangazi	16.34	0.51	0.44	0.30	3.54	42.93	255.58	0.70
34	Şile	11.68	0.42	0.36	0.25	3.05	34.32	210.51	0.57
35	Şişli	14.60	0.49	0.42	0.29	3.44	40.74	242.76	0.66
36	Tuzla	21.60	0.57	0.50	0.34	3.70	48.06	288.56	0.79
37	Ümraniye	17.18	0.52	0.45	0.31	3.57	43.75	260.86	0.71
38	Üsküdar	18.87	0.54	0.47	0.32	3.62	45.40	271.47	0.74
39	Zeytinburnu	25.35	0.61	0.54	0.37	3.81	51.55	311.41	0.85

Table B.18 Losses and Premiums for Earthquakes within the Next **2475 Years** for **RC Dual High-rise** Type of Buildings

No	District	PGV (cm/s)	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=2475\ yr}$ ‰
1	Adalar	50.74	0.75	0.68	0.47	3.71	60.67	402.86	0.207
2	Arnavutköy	21.60	0.57	0.50	0.34	3.70	48.05	288.53	0.151
3	Ataşehir	30.93	0.65	0.58	0.40	3.83	54.47	335.85	0.175
4	Avcılar	39.23	0.70	0.63	0.43	3.81	57.88	367.93	0.190
5	Bağcılar	33.45	0.67	0.59	0.41	3.83	55.79	346.92	0.180
6	Bahçelievler	39.55	0.70	0.63	0.43	3.81	57.98	369.00	0.191
7	Bakırköy	45.15	0.73	0.66	0.46	3.77	59.66	387.72	0.200
8	Başakşehir	27.46	0.63	0.55	0.38	3.81	52.66	320.65	0.167
9	Bayrampaşa	32.06	0.66	0.58	0.40	3.83	55.06	340.82	0.177
10	Beşiktaş	26.88	0.62	0.55	0.37	3.81	52.35	318.10	0.166
11	Beykoz	21.02	0.57	0.49	0.34	3.68	47.49	284.91	0.149
12	Beylikdüzü	45.56	0.73	0.66	0.46	3.77	59.73	388.82	0.200
13	Beyoğlu	31.44	0.66	0.58	0.40	3.83	54.74	338.11	0.176
14	Büyükçekmece	40.30	0.71	0.63	0.44	3.80	58.21	371.52	0.192
15	Çatalca	25.48	0.62	0.54	0.37	3.81	51.62	311.99	0.163
16	Çekmeköy	21.15	0.57	0.49	0.34	3.69	47.61	285.71	0.149
17	Esenler	29.17	0.64	0.56	0.39	3.82	53.55	328.17	0.171
18	Esenyurt	36.49	0.69	0.61	0.42	3.83	57.05	358.73	0.186
19	Eyüp	31.51	0.66	0.58	0.40	3.83	54.78	338.42	0.176
20	Fatih	34.97	0.68	0.60	0.42	3.84	56.58	353.57	0.183
21	Gaziosmanpaşa	28.95	0.64	0.56	0.38	3.82	53.44	327.19	0.170
22	Güngören	36.51	0.69	0.61	0.42	3.83	57.06	358.79	0.186
23	Kadıköy	33.37	0.67	0.59	0.41	3.83	55.75	346.57	0.180
24	Kağıthane	26.91	0.63	0.55	0.37	3.81	52.37	318.24	0.166
25	Kartal	38.29	0.70	0.62	0.43	3.82	57.60	364.78	0.189
26	Küçükçekmece	40.12	0.71	0.63	0.44	3.81	58.15	370.91	0.192
27	Maltepe	32.94	0.67	0.59	0.41	3.83	55.53	344.70	0.179
28	Pendik	26.69	0.62	0.55	0.37	3.81	52.25	317.26	0.165
29	Sancaktepe	24.35	0.60	0.53	0.36	3.79	50.74	305.81	0.160
30	Sarıyer	21.33	0.57	0.50	0.34	3.69	47.80	286.88	0.150
31	Silivri	29.49	0.64	0.57	0.39	3.82	53.72	329.56	0.172
32	Sultanbeyli	29.27	0.64	0.57	0.39	3.82	53.60	328.57	0.171
33	Sultangazi	26.49	0.62	0.55	0.37	3.81	52.15	316.41	0.165
34	Şile	19.07	0.55	0.47	0.32	3.62	45.59	272.70	0.143
35	Şişli	23.61	0.60	0.52	0.35	3.76	50.02	301.16	0.157
36	Tuzla	35.27	0.68	0.61	0.42	3.84	56.68	354.63	0.184
37	Ümraniye	27.72	0.63	0.55	0.38	3.82	52.79	321.79	0.168
38	Üsküdar	30.41	0.65	0.57	0.39	3.82	54.20	333.59	0.174
39	Zeytinburnu	41.48	0.71	0.64	0.44	3.80	58.57	375.49	0.194

Table B.19 Losses and Premium Rates for Earthquakes within the Next **72 Years** for Masonry **General Low-rise** Type of Buildings

No	District	PGA (g) m/s^2	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=72\ yr}$ ‰
1	Adalar	0.24	0.25	0.19	0.13	3.01	17.90	112.74	2.04
2	Arnavutköy	0.10	0.14	0.11	0.08	1.72	10.29	64.15	1.16
3	Ataşehir	0.15	0.19	0.15	0.10	2.34	13.87	86.05	1.56
4	Avcılar	0.18	0.22	0.16	0.11	2.59	15.37	95.95	1.74
5	Bağcılar	0.15	0.20	0.15	0.10	2.41	14.27	88.62	1.60
6	Bahçelievler	0.18	0.22	0.16	0.11	2.60	15.41	96.21	1.74
7	Bakırköy	0.21	0.23	0.18	0.12	2.78	16.48	103.29	1.87
8	Başakşehir	0.13	0.17	0.13	0.09	2.08	12.37	76.89	1.39
9	Bayrampaşa	0.15	0.20	0.15	0.10	2.35	13.95	86.53	1.57
10	Beşiktaş	0.12	0.17	0.13	0.09	2.05	12.22	75.96	1.37
11	Beykoz	0.09	0.14	0.11	0.07	1.67	10.01	62.43	1.13
12	Beylikdüzü	0.21	0.23	0.18	0.12	2.79	16.57	103.94	1.88
13	Beyoğlu	0.15	0.19	0.15	0.10	2.33	13.79	85.59	1.55
14	Büyükçekmece	0.19	0.22	0.17	0.11	2.63	15.62	97.57	1.76
15	Çatalca	0.12	0.17	0.13	0.09	1.98	11.81	73.47	1.33
16	Çekmeköy	0.09	0.14	0.11	0.07	1.67	10.02	62.47	1.13
17	Esenler	0.13	0.18	0.14	0.09	2.17	12.92	80.28	1.45
18	Esenyurt	0.17	0.21	0.16	0.11	2.51	14.86	92.56	1.67
19	Eyüp	0.15	0.19	0.15	0.10	2.32	13.78	85.53	1.55
20	Fatih	0.16	0.20	0.16	0.11	2.46	14.58	90.68	1.64
21	Gaziosmanpaşa	0.13	0.18	0.14	0.09	2.16	12.85	79.82	1.44
22	Güngören	0.17	0.21	0.16	0.11	2.50	14.84	92.37	1.67
23	Kadıköy	0.16	0.20	0.15	0.11	2.44	14.44	89.73	1.62
24	Kağıthane	0.12	0.17	0.13	0.09	2.05	12.19	75.79	1.37
25	Kartal	0.19	0.22	0.17	0.11	2.63	15.60	97.47	1.76
26	Küçükçekmece	0.18	0.22	0.17	0.11	2.62	15.53	96.97	1.75
27	Maltepe	0.16	0.20	0.15	0.11	2.43	14.41	89.54	1.62
28	Pendik	0.12	0.17	0.13	0.09	2.02	12.03	74.81	1.35
29	Sancaktepe	0.11	0.16	0.12	0.08	1.90	11.33	70.49	1.28
30	Sarıyer	0.09	0.14	0.11	0.07	1.69	10.12	63.13	1.14
31	Silivri	0.14	0.19	0.14	0.10	2.27	13.45	83.49	1.51
32	Sultanbeyli	0.14	0.18	0.14	0.10	2.22	13.17	81.76	1.48
33	Sultangazi	0.12	0.17	0.13	0.09	2.02	12.03	74.78	1.35
34	Şile	0.08	0.12	0.10	0.07	1.48	8.92	55.74	1.01
35	Şişli	0.11	0.15	0.12	0.08	1.85	11.05	68.80	1.24
36	Tuzla	0.16	0.20	0.16	0.11	2.46	14.57	90.63	1.64
37	Ümraniye	0.13	0.18	0.13	0.09	2.12	12.62	78.40	1.42
38	Üsküdar	0.14	0.19	0.14	0.10	2.29	13.56	84.16	1.52
39	Zeytinburnu	0.19	0.22	0.17	0.12	2.66	15.79	98.72	1.79

Table B.20 Losses and Premium Rates for Earthquakes within the Next **475 Years** for Masonry **General Low-rise** Type of Buildings

No	District	PGA (g) m/s^2	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=475\ yr}$ ‰
1	Adalar	0.50	0.36	0.28	0.19	4.09	24.83	163.94	0.45
2	Arnavutköy	0.19	0.22	0.17	0.12	2.65	15.73	98.34	0.27
3	Ataşehir	0.29	0.28	0.21	0.15	3.29	19.64	124.97	0.34
4	Avcılar	0.37	0.31	0.24	0.17	3.66	21.95	141.67	0.39
5	Bağcılar	0.31	0.29	0.22	0.15	3.39	20.26	129.39	0.35
6	Bahçelievler	0.37	0.31	0.24	0.17	3.67	22.00	142.07	0.39
7	Bakırköy	0.43	0.33	0.26	0.18	3.87	23.34	152.19	0.41
8	Başakşehir	0.25	0.26	0.20	0.14	3.09	18.35	115.72	0.32
9	Bayrampaşa	0.30	0.28	0.21	0.15	3.32	19.84	126.34	0.35
10	Beşiktaş	0.24	0.26	0.19	0.13	3.05	18.12	114.21	0.31
11	Beykoz	0.18	0.22	0.16	0.11	2.59	15.36	95.83	0.26
12	Beylikdüzü	0.44	0.34	0.26	0.18	3.89	23.48	153.24	0.42
13	Beyoğlu	0.29	0.28	0.21	0.15	3.30	19.67	125.17	0.34
14	Büyükçekmece	0.39	0.32	0.24	0.17	3.71	22.28	144.17	0.39
15	Çatalca	0.24	0.25	0.19	0.13	2.98	17.73	111.62	0.31
16	Çekmeköy	0.18	0.22	0.16	0.11	2.59	15.35	95.77	0.26
17	Esenler	0.27	0.27	0.20	0.14	3.17	18.88	119.52	0.33
18	Esenyurt	0.35	0.30	0.23	0.16	3.55	21.27	136.59	0.37
19	Eyüp	0.29	0.28	0.21	0.15	3.30	19.67	125.17	0.34
20	Fatih	0.33	0.30	0.23	0.16	3.48	20.80	133.19	0.36
21	Gaziosmanpaşa	0.26	0.27	0.20	0.14	3.16	18.81	119.03	0.33
22	Güngören	0.34	0.30	0.23	0.16	3.55	21.23	136.25	0.37
23	Kadıköy	0.32	0.29	0.22	0.15	3.42	20.44	130.65	0.36
24	Kağıthane	0.24	0.26	0.19	0.13	3.05	18.11	114.12	0.31
25	Kartal	0.38	0.31	0.24	0.17	3.67	22.03	142.29	0.39
26	Küçükçekmece	0.38	0.32	0.24	0.17	3.69	22.15	143.17	0.39
27	Maltepe	0.31	0.29	0.22	0.15	3.41	20.35	130.00	0.36
28	Pendik	0.24	0.25	0.19	0.13	3.00	17.85	112.39	0.31
29	Sancaktepe	0.22	0.24	0.18	0.12	2.85	16.91	106.13	0.29
30	Sarıyer	0.18	0.22	0.17	0.11	2.62	15.53	96.96	0.27
31	Silivri	0.29	0.28	0.21	0.15	3.27	19.47	123.74	0.34
32	Sultanbeyli	0.27	0.27	0.20	0.14	3.19	18.99	120.31	0.33
33	Sultangazi	0.24	0.25	0.19	0.13	3.01	17.90	112.76	0.31
34	Şile	0.15	0.20	0.15	0.10	2.41	14.27	88.57	0.24
35	Şişli	0.21	0.23	0.18	0.12	2.80	16.63	104.31	0.29
36	Tuzla	0.33	0.29	0.23	0.16	3.47	20.76	132.91	0.36
37	Ümraniye	0.25	0.26	0.20	0.14	3.11	18.52	116.93	0.32
38	Üsküdar	0.28	0.28	0.21	0.15	3.26	19.42	123.36	0.34
39	Zeytinburnu	0.40	0.32	0.25	0.17	3.75	22.52	146.01	0.40

Table B.21 Losses and Premiums for Earthquakes within the Next **2475 Years** for Masonry **General Low-rise** Type of Buildings

No	District	PGA (g) m/s^2	γ-IO	γ-LS	γ-CP	L_1‰	L_2‰	L_3‰	PREMIUM $_{TR=2475\ yr}$ %
1	Adalar	0.82	0.45	0.35	0.25	4.97	30.77	211.41	0.100
2	Arnavutköy	0.31	0.28	0.22	0.15	3.36	20.06	127.94	0.061
3	Ataşehir	0.47	0.35	0.27	0.19	4.00	24.18	158.70	0.076
4	Avcılar	0.60	0.39	0.30	0.21	4.37	26.72	179.05	0.085
5	Bağcılar	0.51	0.36	0.28	0.19	4.09	24.84	163.99	0.078
6	Bahçelievler	0.61	0.39	0.30	0.21	4.38	26.79	179.63	0.085
7	Bakırköy	0.70	0.42	0.32	0.23	4.65	28.59	194.00	0.092
8	Başakşehir	0.40	0.32	0.25	0.17	3.77	22.68	147.18	0.070
9	Bayrampaşa	0.48	0.35	0.27	0.19	4.03	24.38	160.35	0.076
10	Beşiktaş	0.40	0.32	0.25	0.17	3.74	22.49	145.77	0.069
11	Beykoz	0.29	0.28	0.21	0.15	3.30	19.66	125.08	0.060
12	Beylikdüzü	0.71	0.42	0.33	0.23	4.67	28.73	195.11	0.092
13	Beyoğlu	0.47	0.35	0.27	0.19	4.00	24.21	159.00	0.076
14	Büyükçekmece	0.62	0.39	0.30	0.21	4.43	27.09	182.04	0.086
15	Çatalca	0.39	0.32	0.24	0.17	3.70	22.25	143.92	0.069
16	Çekmeköy	0.29	0.28	0.21	0.15	3.29	19.65	125.01	0.060
17	Esenler	0.43	0.33	0.26	0.18	3.87	23.31	151.96	0.072
18	Esenyurt	0.56	0.37	0.29	0.20	4.25	25.93	172.68	0.082
19	Eyüp	0.47	0.35	0.27	0.19	4.00	24.21	158.96	0.076
20	Fatih	0.54	0.37	0.28	0.20	4.18	25.45	168.87	0.088
21	Gaziosmanpaşa	0.43	0.33	0.26	0.18	3.86	23.23	151.40	0.079
22	Güngören	0.56	0.37	0.29	0.20	4.25	25.89	172.41	0.090
23	Kadıköy	0.52	0.36	0.28	0.19	4.12	25.03	165.56	0.086
24	Kağıthane	0.39	0.32	0.25	0.17	3.74	22.48	145.65	0.076
25	Kartal	0.60	0.39	0.30	0.21	4.38	26.75	179.25	0.093
26	Küçükçekmece	0.62	0.39	0.30	0.21	4.41	26.96	181.00	0.094
27	Maltepe	0.51	0.36	0.28	0.19	4.11	24.93	164.71	0.086
28	Pendik	0.39	0.32	0.24	0.17	3.70	22.25	143.96	0.075
29	Sancaktepe	0.35	0.30	0.23	0.16	3.57	21.34	137.10	0.072
30	Sarıyer	0.30	0.28	0.21	0.15	3.33	19.84	126.39	0.066
31	Silivri	0.47	0.35	0.27	0.19	4.00	24.22	159.04	0.083
32	Sultanbeyli	0.44	0.34	0.26	0.18	3.89	23.48	153.24	0.080
33	Sultangazi	0.39	0.32	0.24	0.17	3.71	22.27	144.11	0.075
34	Şile	0.26	0.26	0.20	0.14	3.13	18.61	117.61	0.062
35	Şişli	0.34	0.30	0.23	0.16	3.51	21.01	134.68	0.071
36	Tuzla	0.54	0.37	0.28	0.20	4.18	25.45	168.91	0.088
37	Ümraniye	0.41	0.33	0.25	0.18	3.80	22.89	148.77	0.078
38	Üsküdar	0.46	0.34	0.26	0.18	3.96	23.94	156.80	0.082
39	Zeytinburnu	0.64	0.40	0.31	0.22	4.48	27.44	184.81	0.096