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PML STUDY FOR A SEISMICALLY ISOLATED HOSPITAL COMPLEX IN TURKEY

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ABSTRACT

In the framework of Performance Based Earthquake Engineering that has been introduced to earthquake engineering society in last two decades the seismic design is handled not only considering the structural member behavior but also the economic loss, casualty and down time parameters. In FEMA P-58 "Seismic Performance Assessment of Buildings, Methodology and Implementation "document can be considered as a milestone study, for practical implementation of the proposed methodology, work included the development of an electronic tool, referred to as the Performance Assessment Calculation Tool, or PACT, to help capture building inventory data, input a given earthquake shaking probability or intensity, apply specific fragilities and consequences to each building component, and present the results of a large number of runs, or realizations, in a logical format.

In this study a case study for FEMA P-58 methodology is applied on a seismically isolated hospital complex. Considering the high level of economic investment, the seismic risk plays an important aspect on determination of insurance premiums. In the content of this study an application of the time-based performance assessment methodology using nonlinear response history analysis in the Performance Assessment Calculation Tool (PACT) with provided fragility and consequence function dataThe analysis results have been displayed in a time-based fashion which shows annual probability of exceedance for repair cost of different amounts as well as average annual loss values.

Keywords: seismic isolation, nonlinear response history analysis, PML (probable maximum loss), PACT Tool

1. INTRODUCTION

This study involves the methodology to be performed in earthquake loss estimation study for a Hospital Complex designed using seismic isolation. The so-called Performance Based Earthquake Engineering introduced in earthquake engineering society in the beginning of 2000 has defined the earthquake performance of a building based on the structural response quantities in terms of deformation for different levels of seismic input. The advances in earthquake engineering has proposed an alternative performance criteria based on a new set of parameters that are other than engineering demand parameters such as "repair cost" and "downtime". The proposed parameters provided a better and easy understanding of seismic performance of a building not only to the engineers but also to the non-engineers like investors, renters, decision makers and insurance market. One of the recent studies performed by FEMA, a new methodology as an updated version of performance based earthquake engineering has been proposed. The FEMA P-58 document involves the theoretical back ground and application procedure for the so-called new version of PBEE approach. In this study, the loss estimation methodology has been basically be based on "*FEMA P-58: Seismic Performance Assessment of Buildings*" document.
FEMA P-58 methodology can be applied for a unique site, for loss estimation of structural and non-

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structural components, considering the occupancy characteristics of the individual building to obtain time-based earthquake performance assessments. Implementation requires basic data on the vulnerability of structural and non-structural components to damage (fragility), as well as estimates of potential casualties, repair costs, and repair times (consequences) associated with this damage.

2. FEMA P-58 METHODOLOGY

The maximum probable loss of the hospital complex has been determined based on the procedure defined in FEMA P-58 document. In the relevant document, a time-based performance assessment using nonlinear response history analysis has been defined. The work necessary to obtain a "probable maximum loss" (PML) that reflects the repair cost, expressed as percentage of building replacement cost, having a 2% probability of exceedance over 50 year period. The flow chart of FEMA P-58 tool is given in Figure 1 below.

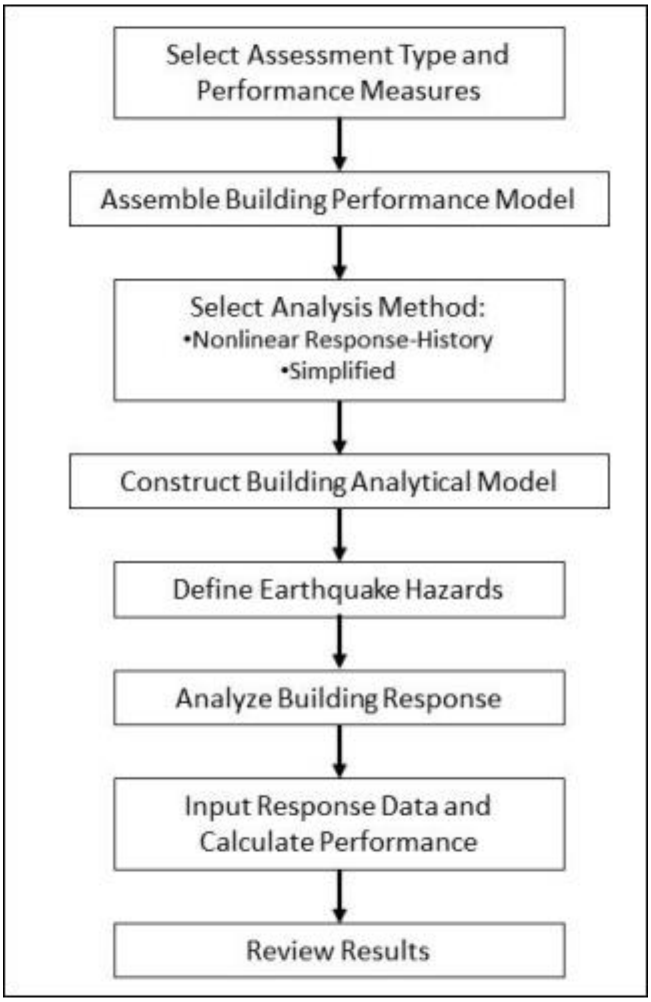

Figure 1. Flow chart of FEMA P-58 tool

1.1 Assessment Types

The structural assessment types defined in FEMA P-58 are basically given as three approaches. Intensity-based assessments evaluate a building's probable performance assuming that it is subjected to a specified earthquake shaking intensity. Shaking intensity is defined by 5% damped, elastic acceleration response spectra. Scenario-based assessments evaluate a building's probable performance assuming that it is subjected to a specified earthquake scenario consisting of a specific magnitude earthquake occurring at a specific location relative to the building site. In this study "***Time-based assessments***" that evaluate a building's probable performance over a specified period of time (e.g., 1-year, 30-years, or 50-years) considering all earthquakes that could occur in that time period, and the probability of occurrence associated with each earthquake.

1.2 Performance Measures

The performance measures used as the result of assessment studies are defined as;

- Casualties. Loss of life or serious injury requiring hospitalization, occurring within the building envelope.
- Repair cost. The cost, in present dollars, necessary to restore a building to its pre-earthquake condition, or in the case of total loss, to replace the building with a new structure of similar construction.
- Repair time. The time necessary to repair a damaged building to its pre-earthquake condition.
- Unsafe placarding. A post-earthquake inspection rating that deems a building or portion of a building damaged to the point that entry, use, or occupancy poses immediate risk to safety

1.2 Analysis Methods

The analysis method options include use of a simplified analytical estimation of building response or suites of detailed nonlinear response history analyses. The simplest application of the methodology includes use of the simplified analysis method to estimate building response and the selection of provided, occupancy-dependent fragility and consequence functions for the building assets at risk. In this study, a detailed nonlinear response history analysis have been used.

2. APPLICATION OF FEMA P-58 METHODOLOGY

The details of the methodology defined in previous section has been given through an application on the seismically isolated hospital complex below.

2.1 Building Information

The hospital complex includes a main hospital building to include three specialty towers, six clinic buildings, a Facilities Management Logistics Building, an Administration, Teaching & Conference Building, a Physical Therapy & Rehabilitation Building, a Psychiatric Hospital, a central plant building and car parking as shown in Figure 2.

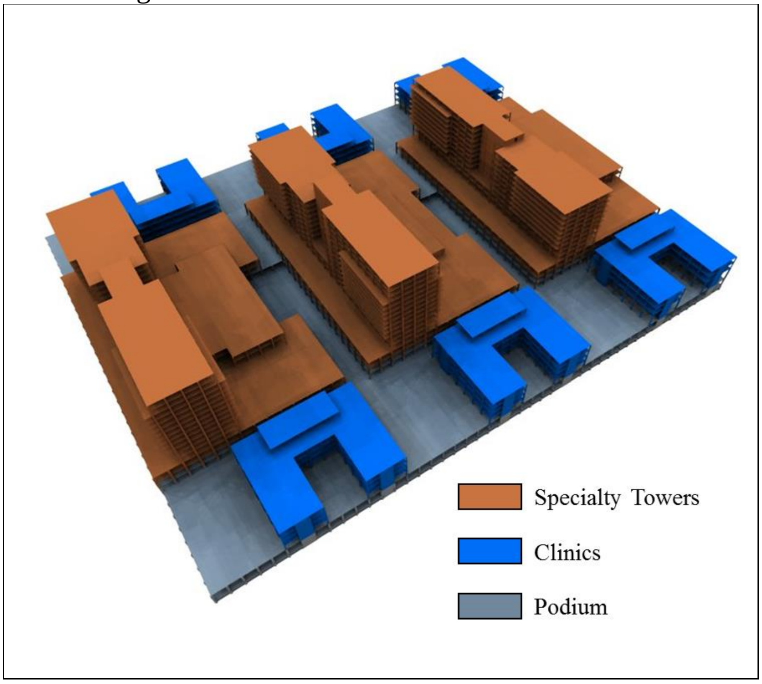

Figure 2. Hospital complex model

The specialty towers and the clinics share a common podium that includes three layers of basement. The basement levels house the car parking. The whole podium and the towers and the clinics above shall be seismically isolated.

2.2 Seismic Hazard

Seismic hazard information is based on the site specific seismic hazard study and the seismic hazard parameters for BSE-2N (2%in 50 years) and BSE-1N (10% in 50 years) with NEHRP site class of "C" is given in Table 1 below.

Table 1. Seismic hazard parameters for 50/10 and 50/2 seismic level.

NEHRP SITE CLASS	**C**
S_{MS}	1.150 g
S_{M1}	0.820 g
S_{DS}	0.750 g
S_{D1}	0.510 g
DISTANCE FROM FAULT	< 24 km

Site Specific Acceleration Response Spectra for the site is shown at Figure 3 below.

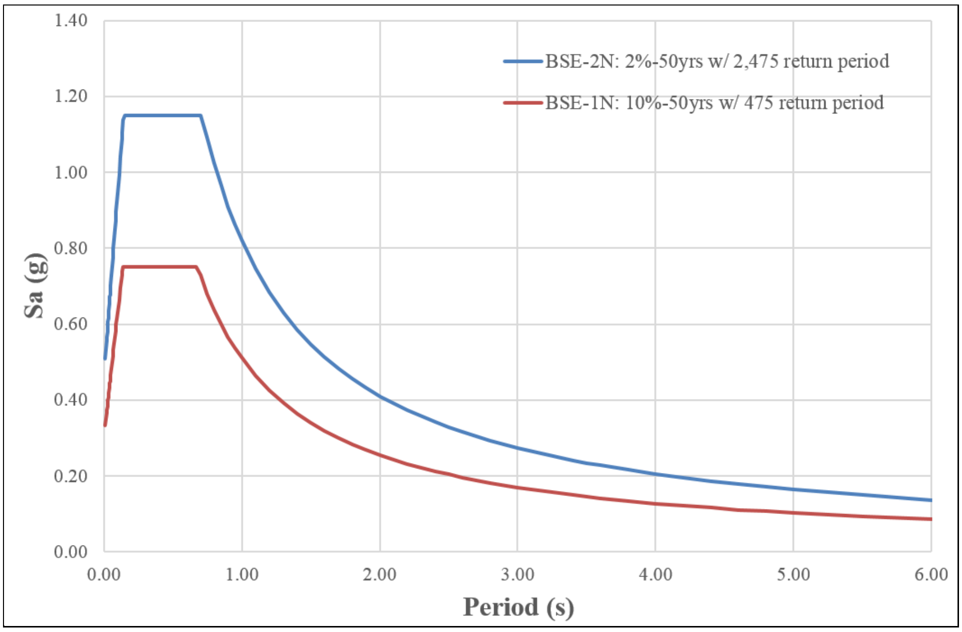

Figure 3. Acceleration response spectra for 50/10 and 50/2 level earthquakes

A set of ground motion has been developed that are spectrally matched to the 50/2 spectrum histories. Figure 4 represents the spectra developed using the scaled ground motions and their comparison to the target design spectrum.

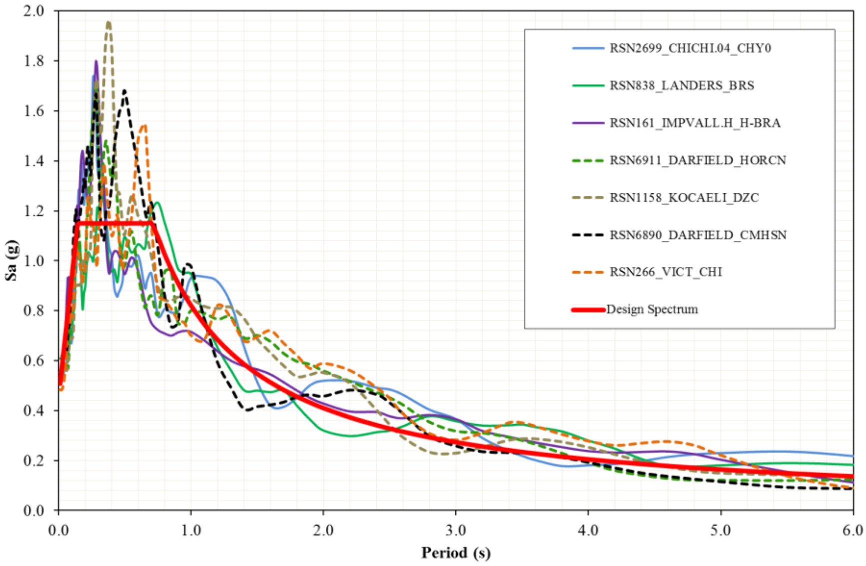

Figure 4. Comparison of 50/2 response spectrum with spectrum of the ground motion set

2.3 Building Information Compilation for "Performance Evaluation Calculation Tool"-PACT Analysis

As the assessment type "time-based assessment" shall be performed with building performance expressed in terms of average annual repair cost in dollars. The resulting cost distribution is used to determine the loss associated with a 2% probability of exceedance over a 50-year period of time and converted from dollars to percentage of replacement cost.

Fragility specifications provided in "Performance Evaluation Calculation Tool"- PACT are utilized for structural components. To input structural fragility groups shall be selected from a list of structural systems pre-defined in PACT. These selections list the most typical specifications for the building and will be used by PACT to generate a floor-by-floor distribution of specifications. In order to estimate the non-structural damage loss of the building, the relevant components should be provided in terms of their type, quantity and damage parameter for each floor. This task is a very hard and complicated issue since it need to interaction between architectural, mechanical and electrical disciplines contributed in the design phase of the hospital. As an alternative and effective approach this data shall be gathered using best estimates provided by "Performance Evaluation Calculation Tool"-PACT.
After completion of the floor-by-floor input of fragility specification data, nonstructural performance groups shall be identified and input using the Performance Groups input phase. The performance group quantities identified with the Normative Quantity Estimation Tool are median estimates. For distributed systems (piping, ducting, ceilings, etc.), the median estimates are accompanied by dispersions that reflect the variability in component quantity for the selected occupancy.

2.4. Analysis Method and Building Analysis Model

The structure is analyzed using nonlinear response history analysis. A three-dimensional analytical model is assembled according to the most architectural and formwork plan, a structural model of the hospital complex was constructed. The mathematical model used in the nonlinear response history analysis has shown in Figure 5.

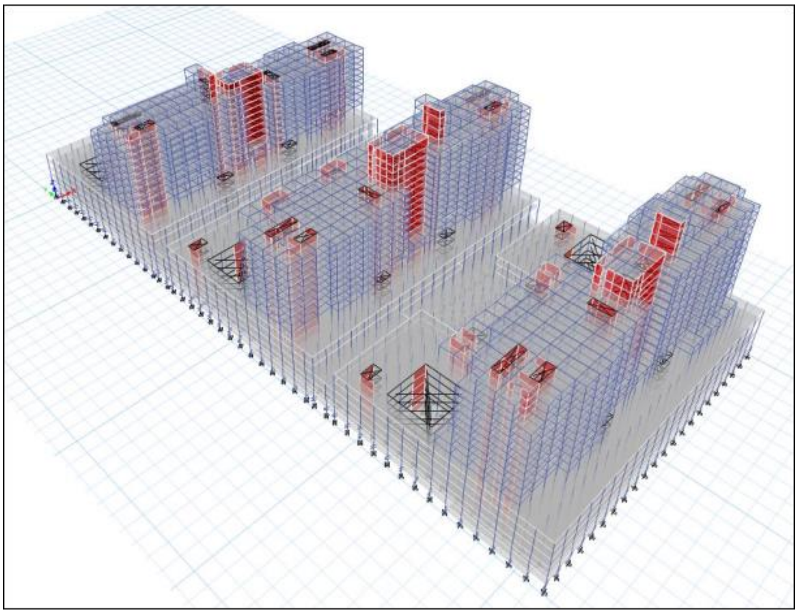

Figure 5. Mathematical model of the hospital complex used in NLRHA

The building response analysis performed for the ground motion set of 2% probability of exceedance level composed of “seven ground motions pairs” which are selected and scaled for each of the eight intensities. The intensity levels are determined based on the spectral acceleration at the fundamental period of the structure which is used to calculate the scale factor for each intensity level. The scaling is performed by using the hazard curve that is defined for the spectral acceleration at the fundamental period.

As the result of NLRHA for each intensity level drift and floor acceleration response has been obtained. These parameters shall be used to estimate the seismic loss of the structural or non-structural members whether response is acceleration or displacement sensitive.

3. ANALYSIS RESULTS AND PERFORMANCE EVALUATION

The result of the structural analysis in terms of floor the acceleration and drift response for each intensity level has been provided as an input for “Performance Evaluation Calculation Tool” - PACT. The assessment results as the “Time Based Results” in tabulated tables and graphs are given which shows annual probability of exceedance for repair cost of different amounts as well as average annual loss values. The acceleration and drift response results used as the basic input for the PACT analysis is shown in Figure 6 and Figure 7 below.

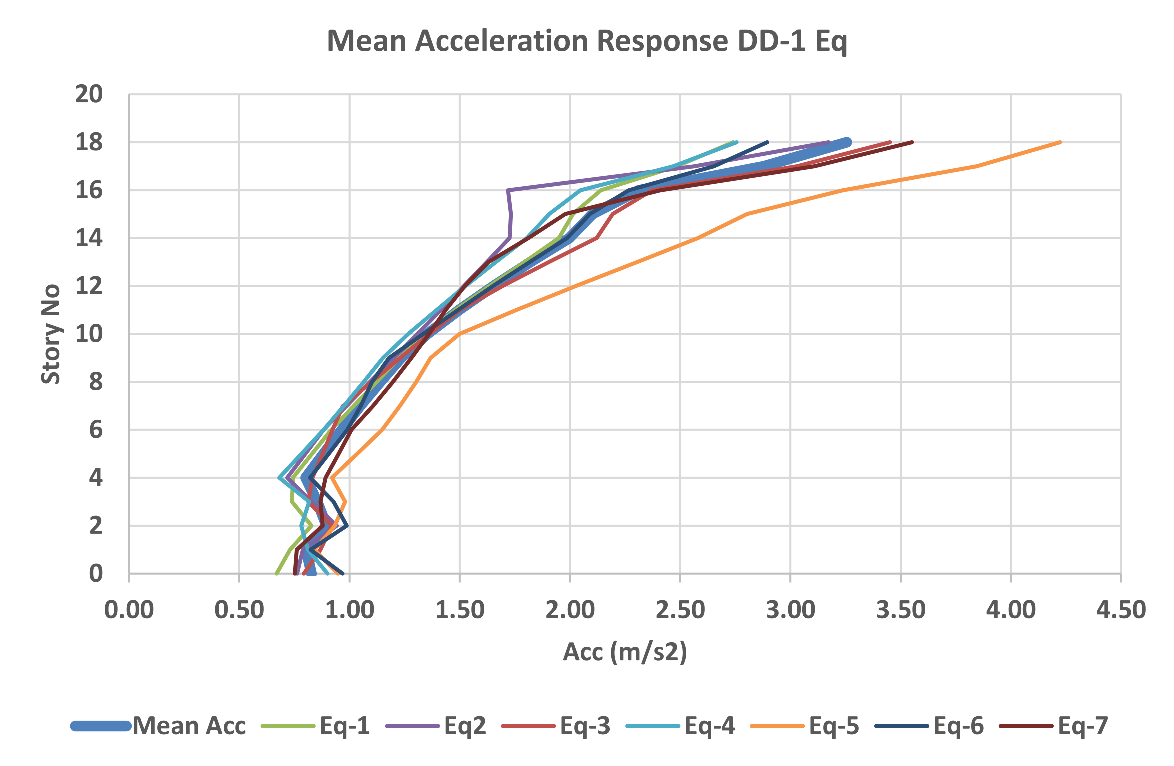

Figure 6. Acceleration response results of NLRHA for DD level earthquake

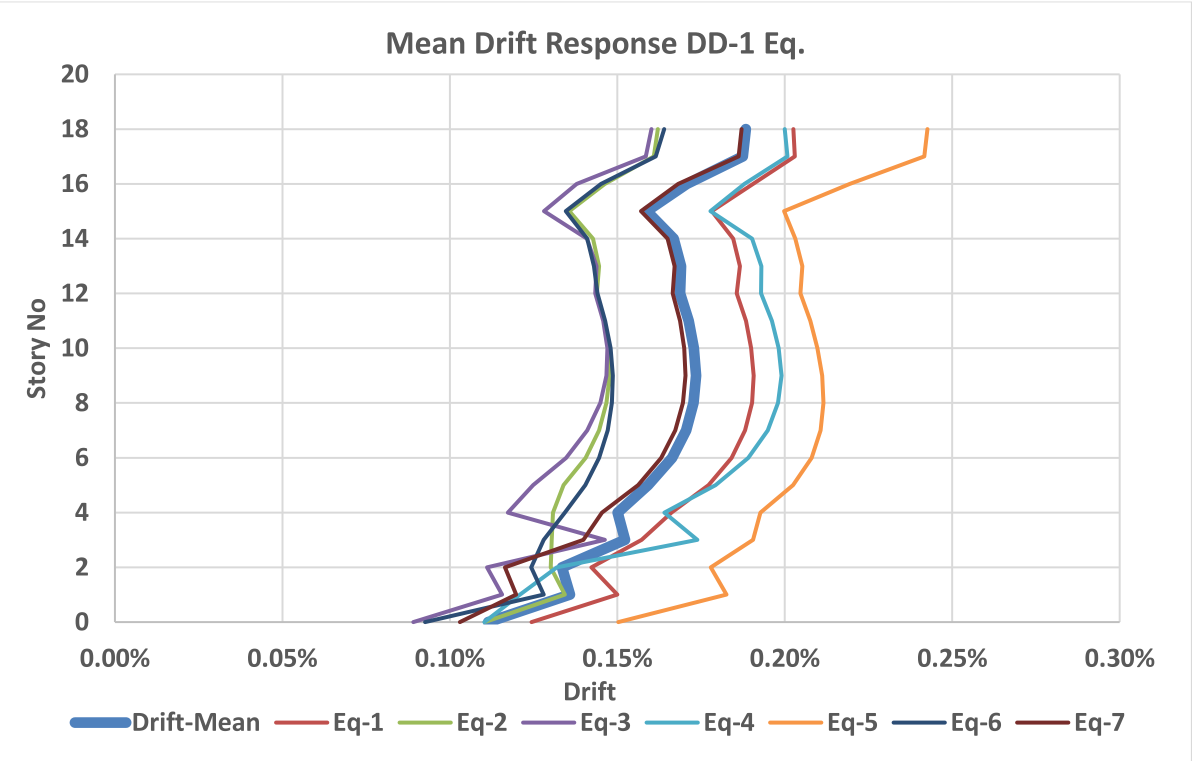

Figure 7. Drift response results of NLRHA for DD-1 level earthquake

As the result of the structural and non-structural damage assessment based on the increasing earthquake intensity levels. The annual loss probability for each intensity level is given in Figure 8.

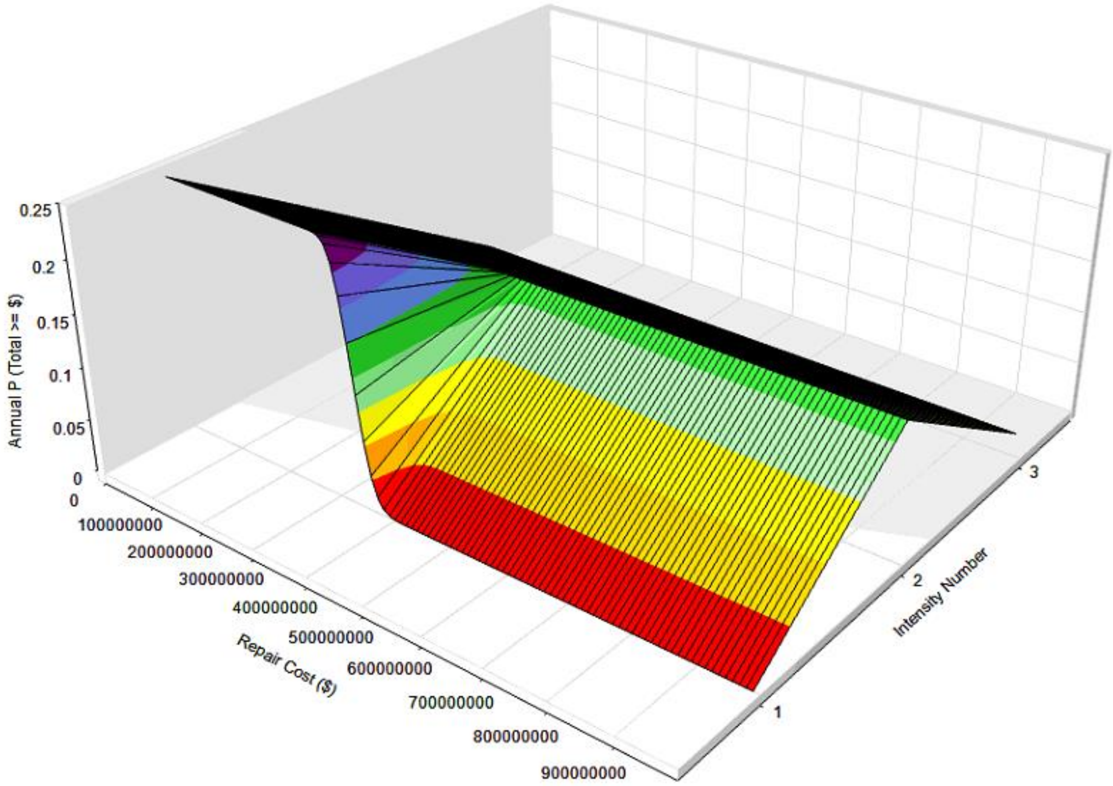

Figure 8. Annual loss probability for each intensity level (Repair cost curves)

5. CONCLUSIONS

Based on the structural analysis performed by using incremental dynamic analysis the damage states of structural and non-structural members have been determined. The structural and non-structural properties of Hospital Health Complex have been determined based on the actual structural, architectural, mechanical and electrical project documents.

As the most recent approach defined in Performance Based Design philosophy, the FEMA P-58 methodology considers all aspects of seismic damage in terms of structural and non-structural members. The results are represented in probabilistic fashion in terms of "repair cost" or "probable maximum loss" which has more meaning the non-engineers such as investors, land owner or insurance sector. This approach could be a part of performance-based design process, or as part of assisting owners and tenants in making occupancy and ownership decisions. The methodology could be used in development of a building seismic performance rating system that could be used by the lending industry as one criterion associated with loan transactions. The new generation seismic design approach should follow the methodology defined in FEMA P-58 which shall result on more disaster resilient buildings with very high investment cost.

The structural and non-structural damage and resulting economic loss of the building under consideration has been determined based on the methodology defined in document named as FEMA P-58: Seismic Performance Assessment of Buildings.

A time- based loss estimation calculation has been performed using PACT – Tool developed within FEMA P-58 project. The time period considered in the analysis 2475 years that corresponds to MCE (Maximum Credible Earthquake) level that has "Immediate Occupancy" target performance.

The probable maximum loss for 2475-year return period is determined as 23%. The annual average loss ratio (AAL) has been determined as 0.00009414.

Needless to say, these assessments can be further refined, especially, by better evaluation of losses associated with non-structural entities.

7. REFERENCES

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