



Risk Analysis and Probable Maximum Loss

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Abstract

Risk Analysis and Probable Maximum Loss (PML) estimates are defined. PML estimates were first used by insurance companies to quantify their risk, after the 1925 Santa Barbara earthquake. To improve their PML estimates, structural engineers working for insurance companies classified buildings based on earthquake resistance. One of the first seismic building codes was the byproduct. In the 1980s, two landmark documents were published: one by Karl Steinbrugge and the other by the Applied Technology Council. Currently, several PML procedures are in use, with varying purposes and corresponding levels of effort. The HAZUS methodology and an upcoming ASTM Standard Guide are the latest developments.

Introduction

The major components of a Risk Analysis can be summarized in one sentence: Hazard causes Damage leading to Loss of a certain Scope.

- Hazard: Natural Disaster (Earthquake, Tornado, Tsunami, Flood), Financial (Inflation, War), etc.
- Damage (from Earthquake): Structures (Buildings, Bridges), Lifelines (Transportation, Utilities), etc.
- Loss: (from Earthquake to Buildings): Direct (Human, Material), Indirect (Business Interruption, Market Share), etc.
- Scope (of Material Loss to Buildings from Earthquakes): Region (Western United States, South East Asia), Portfolio (Large Multinational, Small Regional), Class (Highrise, Unreinforced Masonry), Individual.

The original definition of a PML as given by Steinbrugge and Engle is:

“The probable maximum loss for an individual building is that monetary loss expressed in dollars (or as a percentage of insured value) under the following conditions:

1. Located on firm alluvial ground, and
2. Subjected only to the vibratory motion from the maximum probable earthquake.

The building class probable loss (class PML) is defined as the expected maximum percentage monetary loss which will not be exceeded for 9 out of 10 buildings in a given earthquake building class under the conditions stated.”

Although PML estimates are a small subset of Seismic Risk Analysis which in turn is a subset of Risk Analysis, their recent popularity have led many to believe that Risk Analysis is PML estimation.

The popularity of PML estimates stems from two major factors:

1. The appeal of defining the earthquake resistance of a building with a single number, easily understood by non-technical decision-makers, is undeniable. Owners, lenders, and potential buyers of buildings have joined insurers in requesting PML estimates.
2. Substantial financial decisions are being made based on PML estimates. Owners evaluate their holdings, single building or portfolio, to determine the cost-effectiveness of seismic retrofits. Lenders use 20% as a cutoff point or “deal-breaker” in approving real estate loans. And potential buyers

often request PML estimates as part of a due-diligence investigation.

Past

In 1925, Santa Barbara was shaken by a moderate earthquake and partly destroyed. This brought back memories of the 1906 San Francisco earthquake, and a veritable stampede for earthquake insurance began. Premiums increased six folds from the year before. Losses rose to 38% of premiums; the highest percentage ever. Insurance companies were not prepared. They needed to quantify their risk accurately to be able to set their rates adequately.

The Board of Fire Underwriters of the Pacific (BFUP) established an Earthquake Department to rate buildings in the San Francisco and Los Angeles areas for earthquake insurance purposes. Two objectives were set:

1. Developing a classification system for buildings based on earthquake resistance, for the purposes of setting insurance rates.
2. Developing a set of standards which when applied to existing buildings could segregate the ones with earthquake resistant properties from the ones with little or no earthquake resistance, and when applied in the design of new buildings would add enough earthquake resistance to ensure minimum damage after severe shocks.

The first objective was achieved in 1928. Eight classes were incorporated in the 1928 Earthquake Tariff and associated with insurance rates. Class I was considered least susceptible to damage and Class VIII most susceptible.

The second objective was achieved in 1929. One of the first seismic building codes was born. The Standards adopted by the Board may be summarized as follows:

1. Provision for the lateral force produced by an earthquake acceleration of about 3 ft/sec^2 .
2. Rigidity of construction, obtained through the factors of:
 - (a) Adequate footing interconnection on uniform ground.
 - (b) Rigid type of bracing, preferably that furnished by properly designed rigid wall and partition construction, in which adequate tensile as well as compressive strength is

incorporated in walls and partitions. Bracing to be symmetrically located about center of mass of building.

- (c) Regular shape, avoiding use of long, slender, laterally unsupported wings. Natural period of vibration of various parts must be about the same.
3. Separation of buildings so they do not pound together.
 4. Penalty for buildings located on uniform saturated ground.

From the end of World War II in 1945 to 1950, earthquake insurance premiums more than doubled. The Earthquake Grading System, was introduced by the Pacific Fire Rating Bureau (PFRB), successor to the BFUP. The system is based upon grading the lateral force adequacy of building components. Tables contain "charges" or penalties for each building component. The lower the earthquake performance of a building component, the higher the "charge" or penalty. The total building "Point Grade" is the sum of all of its component "charges". The building "Point Grade" corresponds to a certain "Word Grade" and a Probable Loss %. One of the first PML procedures was born.

The first of two landmark documents on PML estimates was published in 1982: *Earthquakes, Volcanoes, and Tsunamis: An Anatomy of Hazards* by Karl Steinbrugge.

In Chapter 9, Probable Maximum Loss, a PML calculation procedure is outlined. The first step is building classification. The second step is obtaining a class PML from tabulated values based on the building classification. The third step is modifying the class PML based on: occupancy type, walls (exterior, interior), diaphragms (floor(s), roof), ornamentation (exterior, interior), mechanical/electrical systems, unusual conditions, hazardous exposures (tank and overhanging walls, pounding of adjacent buildings), and site dependent hazards (proximity to active faults, foundation materials, landsliding potential).

The second landmark document on PML estimates was published in 1985: *ATC-13, Earthquake Damage Evaluation Data for California* by the Applied Technology Council.

This document contains estimates of percent physical damage at seven levels of earthquake intensity for 78 existing facility classes in California, including 36 building classes. Damage estimates represent the

consensus opinion of more than 50 earthquake engineering specialists.

Present

Most PML estimates are based on the two landmark documents mentioned above. Judgment of experienced engineers is often used to supplement and modify the PML estimate to take into account specific features of the building under consideration.

Based on the level of effort involved, PML estimates in use today can be classified as:

1. Preliminary: Used for screening purposes only. An engineer performs a limited review of existing drawings and selects an ATC 13 class PML with little or no modification. No report is produced. This work is usually performed in less than one day.
2. Standard: Used in most cases. A FEMA 178 analysis is performed after a review of the existing drawings. The procedure outlined in ATC 13 is followed with substantial modifications based on the results of the FEMA 178 analysis and the experience of the engineer with similar types of structures. A report is usually produced in less than one week.
3. Advanced: Used as part of a comprehensive evaluation report or to check a previous PML estimate. Site visits and a complete review of existing drawings are necessary. A FEMA 273 nonlinear static analysis is performed to identify the location and extent of damage for multiple levels of ground shaking. A cost estimate is obtained for each level of ground shaking, which serves as a PML estimate. An evaluation report at this level usually requires several weeks.

Future

Two new developments are the HAZUS methodology and the ASTM Standard Guide:

1. HAZUS stands for "Hazards US". It is "a software program that uses mathematical formulas and information about building stock, local geology and the location and size of potential earthquakes, economic data, and other information to estimate losses from a potential earthquake. HAZUS is capable of using two separate geographic

information systems (MapInfo® and ArcView®) to map and display ground shaking, the pattern of building damage, and demographic information about a community. Once the location and size of a hypothetical earthquake is identified, HAZUS will estimate the violence of ground shaking, the number of buildings damaged, the number of casualties, the amount of damage to transportation systems, disruption to the electrical and water utilities, the number of people displaced from their homes, and the estimated cost of repairing projected damage and other effects."

HAZUS uses several state-of-the-art methods:

- Ground shaking demand is characterized by response spectra rather than the MMI scale.
 - Building capacity is characterized by nonlinear static analysis.
 - Fragility curves estimate the probability of damage to structures, components, and contents.
 - Loss functions de-couple damage from loss prediction.
2. ASTM Task Group E50.02.07 is in the final stages of preparing a Standard Guide on property condition assessment reports. "The Guide provides requirements for the performance of five different types of earthquake loss studies intended to serve different financial and management needs of the user: building stability, site stability, building damageability, contents damageability, business interruption. Four levels of investigation, from 0 to 3, are given to serve the particular varied purposes and degrees of accuracy for which the results are desired. The guide is organized in 13 sections with an associated commentary. It will be available from ASTM as soon as it is approved."

Conclusions

PML estimates are useful tools, with important strengths and limitations. The strength of PML estimates is in bridging the gap between technical engineering evaluations and non-technical decision-makers. The first limitation of PML estimates is the fact that they were developed by insurance companies to determine earthquake insurance rates for classes of buildings. Applying the same principles to single buildings takes experience. It is not uncommon to find large differences in PML estimates provided by different engineers using different assumptions. The

second limitation relates to the two landmark documents, the source of most of the values produced today. Both documents are outdated. For example, new information about pre-Northridge steel moment resisting frames is not included, and new structural systems such as steel eccentric braced frames are not addressed.

Currently, PML estimates can be classified as preliminary, standard, or advanced based on the level of effort involved. The needs of the user dictate the level of effort.

The HAZUS methodology and the upcoming ASTM Standard Guide are the latest developments. Both expand the classic scope of PML estimates from “monetary loss” to buildings to include other topics in Risk Analysis.

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