Analysis of sensitivity of the principal factors in the estimate of the probable maximum loss PML

Jorge Olarte & Sebastian Romaní
Japan Peru Center for Earthquake Engineering Research and Disaster Mitigation (CISMID). Faculty of Civil Engineering. National University of Engineering, Lima, Peru
IGR Ingenieros Consultores SAC. E: jolarte@uni.edu.pe

Luis Samaniego
El Pacífico Peruano Suiza Compañía de Seguros y Reaseguros, Lima, Peru.
E: LSamaniego@pacifico.com.pe

SUMMARY:
An analysis of sensitivity of the influence factor in the estimate of the probable maximum loss PML is presented. In this case, we present a methodology to estimate the probable maximum loss (PML) for insurance constructions. The methodology includes regional seismic hazard analysis, ground motion estimation, structural vulnerability evaluation and losses exceedance probability curves, generated using catastrophe modeling software. The principal factor will be estimated in a weighted way that influence in the estimation of PML applying to the Peruvian insurance industry: georeferencing of buildings, geotechnical characteristics; some characteristic of the buildings needed to estimate the structural vulnerability like different structural configurations, number of stories, year of the construction; also declared value of the policy with buildings, contents and business interruption buildings. Finally, it will show the distribution of risk for related loss for each principal factor and the incidence in the estimate of the probable maximum loss. The results are going to be compared with the average PML of the insurance company.

Keywords: Probable maximum loss, losses exceedance probability, insurance industry

1. INTRODUCTION

Since ancient times, the cities of Lima and Callao have suffered a series of earthquakes of great intensity, during which on many occasions have occurred material damage and loss of life. The main source of seismic events affecting this region is the subduction zone (Fig. 1), as defined by the interaction of the Nazca plate and the Sudamerica plate (Dorbath et al., 1990). This source can generate large-scale events, which historically (Silgado, 1978; Casaverde y Vargas, 1980), in the area of the central coast can overcome a magnitude of 8 on the moment scale Mw (Table 1).

Table 1. Earthquakes significant subduction in the central part of Peru, near Lima

Year	Magnitude[1]	Intensity[2]
1586	8.1	IX
1678	8.0	VIII
1687	8.3	VIII
1746	8.6	X
1940	8.2	VIII
1966	8.0	VIII
1974	8.1	VIII
1996	7.7	IV
2007	8.1	VI

[1] Moment magnitude scale, Mw
[2] Modified Mercalli intensity reported in Lima

The probable maximum loss (PML) is an estimator of the maximum size of losses that would be reasonable to expect such a portfolio over a given time of exposure. It depends on individual risks and geographical distribution, the PML is great if there is a significant concentration in high seismic risk, and is small if the portfolio is evenly distributed in a wide geographic area. Since the PML is the maximum loss you can expect the insurer if it did not have coverage with reinsurers, the same reserves should be equal to that of PML. Based on these calculations, a company can determine their level of exposure reliably and well established financial planning for the establishment of the reserve and catastrophic risks.

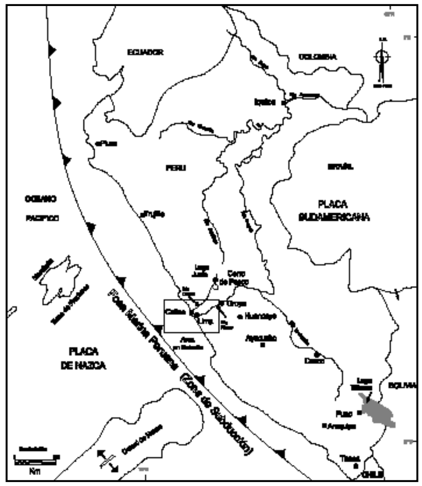


Figure 1. Distribution of tectonics for the study area (Dorbath et al., 1990)

2. OBJECTIVE

The aim of this study is to present an analysis of sensitivity of the influence factor in the estimate of the probable maximum loss PML. The principal factor will be estimated in a weighted way that influence in the estimation of PML applying to the Peruvian insurance industry: georeferencing of buildings, geotechnical characteristics; some characteristic of the buildings needed to estimate the structural vulnerability like different structural configurations, number of stories, year of the construction; also declared value of the policy with buildings, contents and business interruption buildings. Finally, it will show the distribution of risk for related loss for each principal factor and the incidence in the estimate of the probable maximum loss. The results are going to be compared with the average PML of the insurance company.

3. SEISMIC HAZARD

The seismic hazard is quantified in terms of return periods of seismic intensity in the behavior of relevant structures. The exceedance rate of a seismic intensity is defined as the average number of times per unit time, when the value of that seismic intensity is exceeded. It is possible to determine the seismic hazard counting how many times they have been exceeded in intensity values given on the site of interest. The first part of investigation is the tectonics and the seismicity in a given region.

Using a standard distribution of seismicity Poisson activity (McGuire R., 1974) of the i-th seismogenic source is specified in terms of the exceedance rate of the magnitude, $\lambda_i(M)$, which are generated there. The exceedance rates of magnitudes measures how often are generated in one source, tremors with magnitude higher than a given. In these cases, the seismicity is as follows (Eqn. 1):

$$\lambda(M) = \lambda_0 \frac{e^{-\beta M} - e^{-\beta M_u}}{e^{-\beta M_0} - e^{-\beta M_u}} \qquad (1)$$

where Mo is the relevant minimum magnitude, λ_0, βi and M_u are parameters that define the exceedance rate of the seismogenic sources.

The identification of seismogenic sources is based on the distribution map of epicenters, as well as the characteristics of tectonic area of influence (Gamarra, 2009). This allows us to bring together sources in subduction sources (interaction plate) and continental sources (surface seismic activity).

4. LOCAL SITE EFFECTS

It is widely known that a local site effects is a major factor responsible for damage to buildings during earthquakes severe. The seismic amplification is an effect of the local site condition and is strongly dependent on the geological and geotechnical conditions.

To determine the dynamic characteristics of the soil, have been made both microtremors and amplification of seismic evaluations in the areas most critical. This information has been incorporated into a geographic information system (GIS) and processed to produce a seismic microzonation based on geotechnical parameters. Fig. 2 shows the seismic microzonation in Lima and Callao.

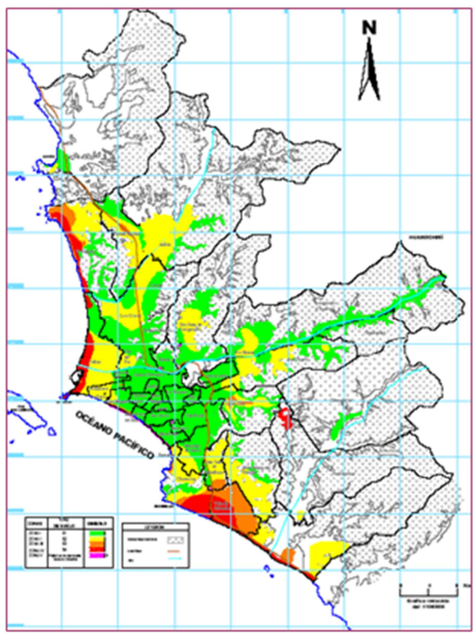


Figure 2. Seismic microzonation of 42 districts of Lima and Callao (CISMID, 2004)

5. PROBABLE MAXIMUM LOSS (PML)

The probable maximum loss (PML) of a portfolio is an estimator of the maximum size of losses that would be reasonable to expect such a portfolio over a period of seismic exposure. It is used as a fundamental data to determine the size of the reserves that the insurance company should maintain. In this model is defined as the estimated loss would occur for a given return period. Therefore, it is necessary to calculate exceedance rates of net losses of the portfolio, $\beta(P_N)$. If the j-th source is generated an earthquake, the net loss for the portfolio (Eqn. 2) will be:

$$P_{Nj} = \sum_i V_i \beta_{Nji} \qquad (2)$$

where V_i is the value of the i-th structure, β_{Nij} is the net loss in the structure i, if an earthquake occurs with th certain characteristics in the source j, and the sum is to include all buildings of the portfolio.

In this model assumes that the amount $P_{Nj}/ \sum_i V_i$ are also distributed as a random variable Beta. So the expected value of P_{Nj} (Eqn. 3) can be easily calculated as follows:

$$E(P_{Nj}) = \sum_i V_i E(\beta_{Nji} | \gamma_{ij}) \tag{3}$$

where γ_{ij} is the maximum drift experienced by the structure I, if an earthquake of magnitude known is generated at source j. However, to calculate the variance of P_{Nj}, be taken into account the correlation between different types of losses that can be generated in the building, contents and business interruption combined. Once you know the expected value and variance of P_{Nj}, the exceedance rates of P_N (Eqn. 4) can be calculated as follows (Ordaz et al, 1998; Ordaz, 1999):

$$\mu(P_N) = \sum_j \int_{Mo}^{Mu} -\frac{d\lambda_j(M)}{dM} \Pr(P_{Nj} > P_N | M, fuente\_i) dM \tag{4}$$

where $\lambda_j(M)$ is the exceedance rate of magnitude M at source j, and sum takes into account the effects of all seismic sources. Once these calculations can be performed to determine the PML for each case.

Finally, Fig. 3 shows the integrated methodology for estimating the probable maximum loss PML for a specific portfolio.

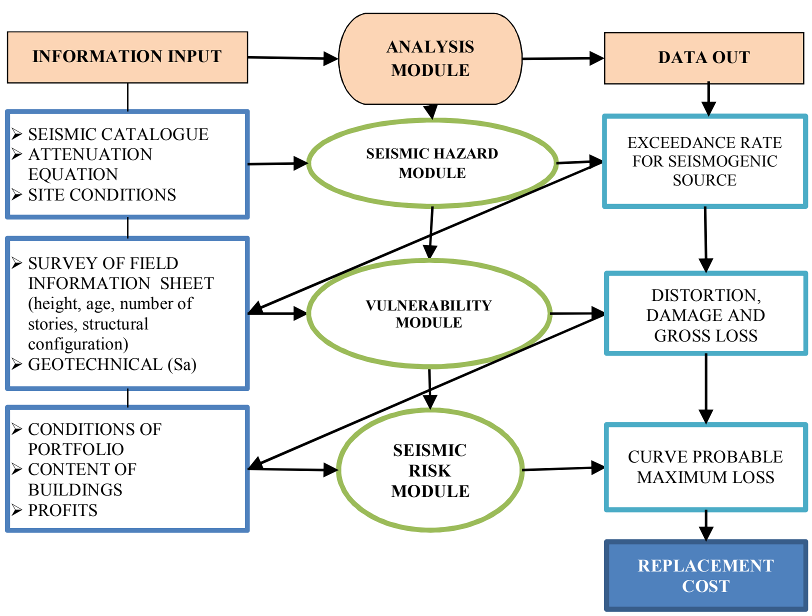


Figure 3. Flowchart to calculate the probable maximum loss PML, basic information of a specific portfolio (Olarte et al, 2003-2005)

6. VALUE DISTRIBUTION AND INSURANCE CONDITIONS

To process the distribution of risks exposed throughout the portfolio has been necessary to centralize information in a geographic information system (GIS) in order to incorporate all the necessary parameters for estimating the probable maximum loss (PML). Finally, we show the high concentration of risk in order declared value to the accumulation of risks insured high to low within the department of Lima and the Constitutional Province of Callao for all portfolio of The Peruvian Pacific Insurance Company and Swiss Reinsurance (Pacific Insurance) (Fig. 4).

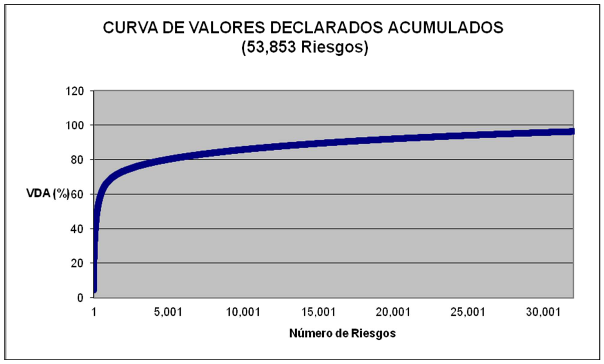


Figure 4. High concentration of risk in order declared value to the accumulation of high to low

In adittion, we illustrate the declared value percentage retained by structural typology: confined masonry (MP), reinforced concrete with walls (CP), reinforced concrete (CA), steel (AC) and industrial/commercial (IC) (Fig. 5).

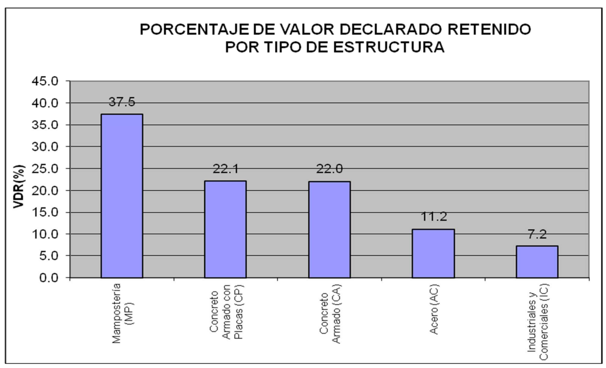
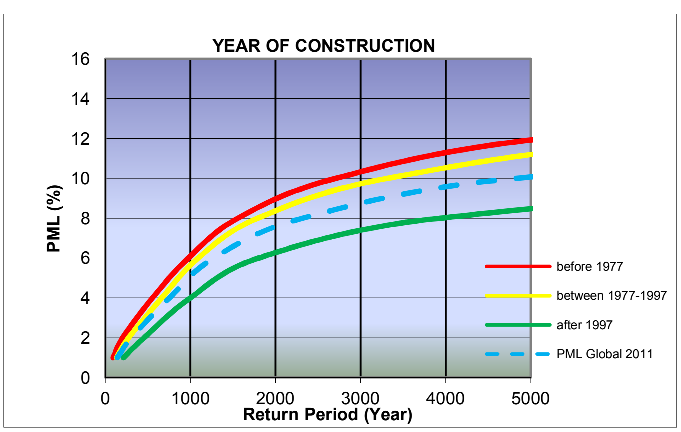


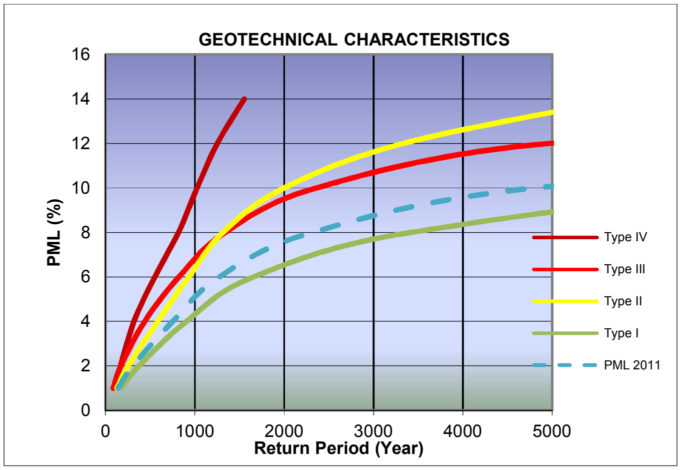
Figure 5. Declared value percentage retained by structural typology

Otherwise, if we consider the different periods of years of construction, the Fig. 6 show the incidence of this factor in global PML. In addition, the PML considering geotechnical characteristics with different soil type we show in the Fig. 7, where you can appreciate the 4 different soil conditions assigned according to the Ministry of Housing and Construction (E.030-RNC, 2006-2009).



Description	PML (1000 years)
Before 1997	6.1
Between 1977-1997	5.7
After 1997	4.0
PML Global 2011	5.2

Figure 6. PML considering the year of construction with different period



Description	PML (1000 years)
Type IV	9.7
Type III	6.8
Type II	6.4
Type I	4.3
PML Global 2011	5.2

Figure 7. PML considering geotechnical characteristics with different soil type

7. PROBABLE MAXIMUM LOSS OF SPECIAL STRUCTURES

To evaluate the special structures (transport, mining, construction, erection and hydroelectric), we have to make models of structural analysis, georeferencing of risks to determine the soil type, concentration and dispersion, review of declared values, travel routes, construction processes, schedules, and other special considerations related to insurance coverage in each case.

In the case of transport, for example, we show the electric railway viaduct Lima (Fig. 8) with various sections for structural analysis in all its extension (Fig. 9, 10, 11, 12 and 13). We must emphasize that the construction of electric railway viaduct Lima had two clearly defined periods: la existing structure was conducted between 1987-1990 (L=9.20 km; soil type=S_2 and S_3) while the new construction was conducted between March 2010 – July 2011 (L=12.28 km; soil type=S_1) for a total of 21.48 km.

The Fig. 14 shows the longitudinal and transverse stiffness of different sections considered in this study to estimate the PML of specific portfolio, while the Fig. 15 shows la inelastic lateral drift performance (longitudinal and transverse).

Finally, we present 4 different curves of PML (Fig. 16) that considers the following specific portfolios: special structures (including electric railway viaduct Lima), industry and commercial, residential buildings and PML Global 2011 of The Peruvian Pacific Insurance Company and Swiss Reinsurance (Pacific Insurance). The PML shows that the special structures have a greater probable maximum loss PML (5.9%), compared with the PML Global 2011 (5.2%) for an extended period of 1000 years return, value from the Superintendence of Banking, Insurance and AFP-SBS (2005-2010).

Figure 8. Travel routes of the Lima electric railway viaduct

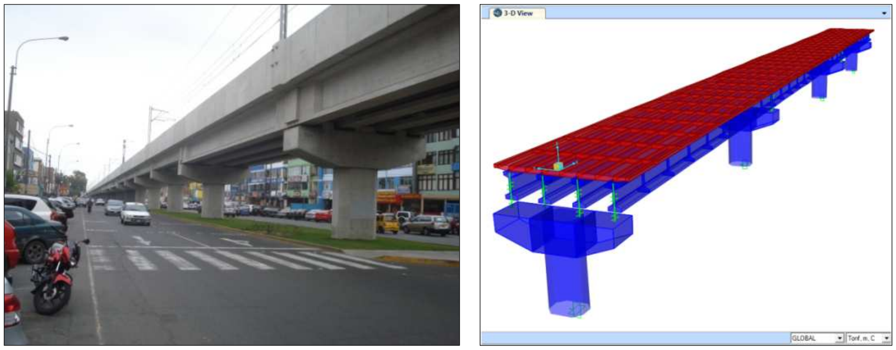


Figure 9. Section P1 (new construction) and the structural analysis model

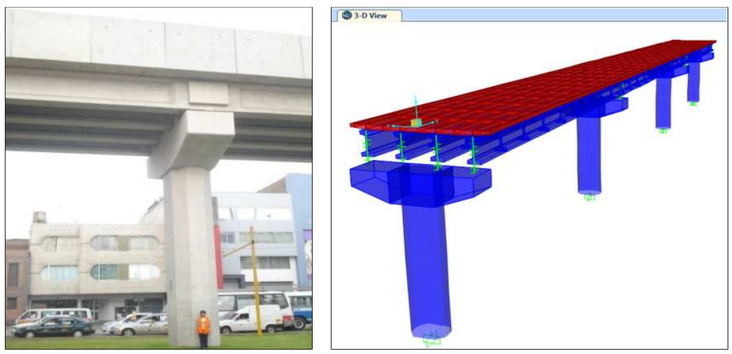


Figure 10. Section P5 (new construction) and the structural analysis model

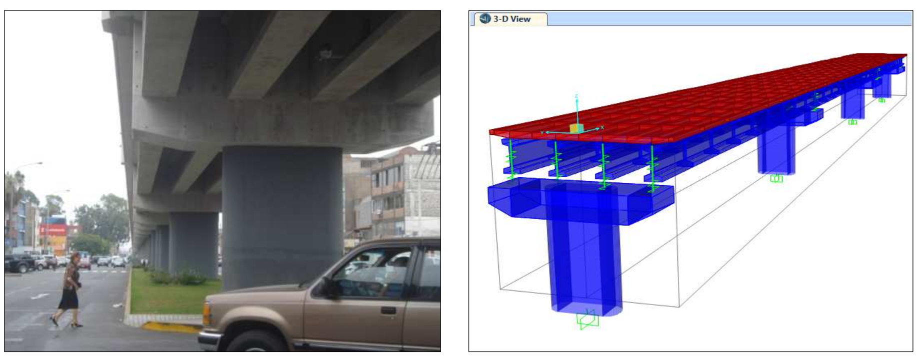


Figure 11. Section P2 (existing structure) and the structural analysis model

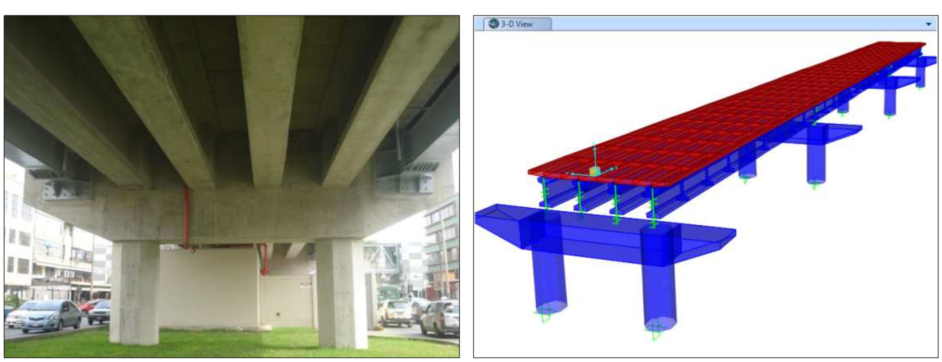


Figure 12. Section P3 (new construction) and the structural analysis model

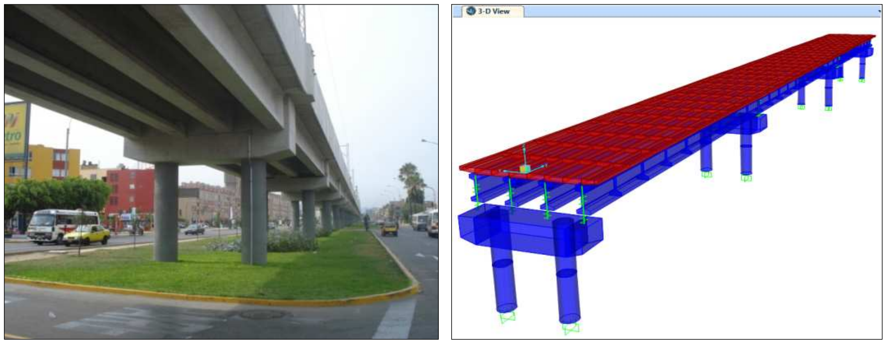


Figure 13. Section P4 (existing structure) and the structural analysis model

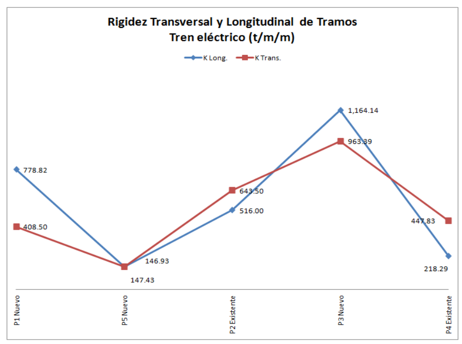


Figure 14. Longitudinal and transverse stiffness of different sections

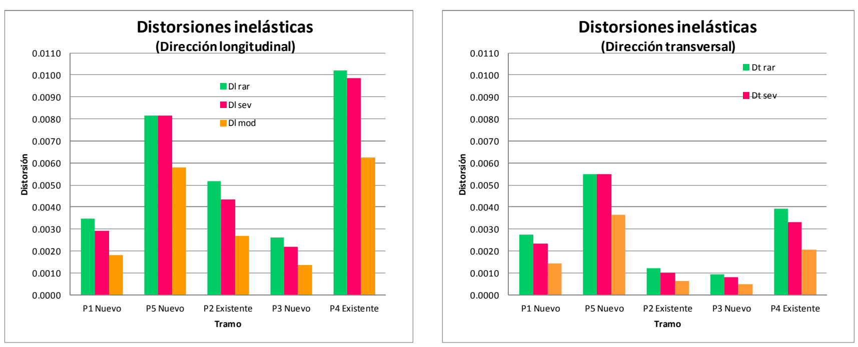
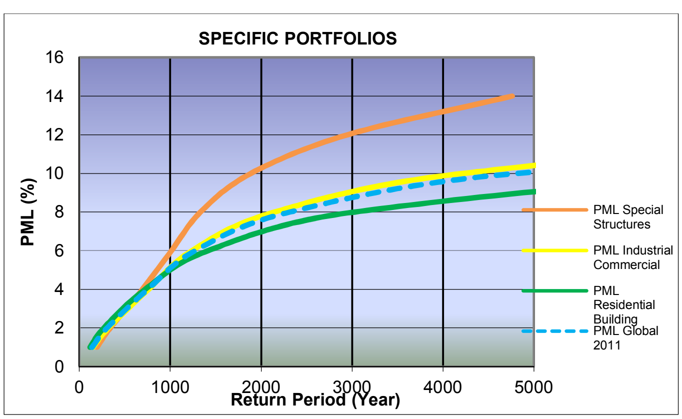


Figura 15. Inelastic lateral drift performance (longitudinal and transverse)



Description	PML (1000 years)
Special Structures	5.9
Industrial/Commercial	5.2
Residential Buildings	5.0
PML Global 2011	5.2

Figure 16. PML considering different portfolios with specific characteristics

8. CONCLUSIONS AND RECOMMENDATIONS

You can make the following conclusions and recommendations:

We propose a framework for assessing the seismic risk in which it has established the curve of the PML considering modules seismic hazard, structural vulnerability, value distribution and insurance conditions of portfolio. The procedure followed in estimating the PML is shown with a methodology internationally accepted by the scientific community to estimate insured losses of portfolios.

We can indicate a high incidence of the main factors affecting the PML, namely, year of construction, soil type and structural typology among others. In the case of year of construction indicate that the structures built Before 1977 have 6.1% of PML, the structures built Between 1977-1997 have 5.7%, and the structures built After 1997 have 4.0%. Finally, the PML Global has 5.2% and is located between After 1997 and Between 1977-1997. Otherwise, the results of soil type show that the type I has 4.3% of PML, type II 6.4%, type III 6.8% and type IV 9.7%. Finally, the PML Global has 5.2% and is located between soil types I and soil type II.

In the case of probable maximum loss of special structures (transport, mining, construction, erection and hydroelectric), models have been necessary to evaluate the PML including the georeferencing of risks to determine the soil type, concentration and dispersion, review of declared values, travel routes, construction processes, schedules, and other special considerations related to insurance coverage in each case. The PML shows that the special structures have a greater probable maximum loss PML (5.9%), compared with the PML Global 2011 (5.2%) for an extended period of 1000 years return, value from the Superintendence of Banking, Insurance and AFP-SBS (2005-2010).

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