PROBABILISTIC SEISMIC RISK ASSESSMENT USING FRAGILITY FUNCTION FOR DWELLING IN METROPOLITAN LIMA AREA

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Abstract

The seismic risk is the cause of a seismic hazard, such as a major earthquake significantly affect a country's sustainable development. The population potentially exposed to earthquakes in the world increased from 1.4 to 2.7 billion between 1975 and 2015 (Atlas of the human planet, 2017). In that sense, the scientific community is working on the reduction of seismic risk since 1990 and nowadays within the Sendai Framework. Therefore, quantify vulnerability is mandatory to prevent. Fragility functions are a widely used tool to assess the vulnerability through the probability of response damage occurrence of a structure at different seismic demands. These functions are very useful for researchers, engineers, insurance companies, territorial planners, and decision-makers.

In Lima city, 83% of dwellings are constructed applying a confined masonry structure (Diaz, 2019) because of the low cost and workability. However, the vulnerability of these buildings can lead to severe earthquake damage due to a lack of technical supervision. Additionally, studies conducted by Japan Peru Center for Earthquake Engineering Research and Disaster Mitigation (CISMID) in the framework SATREPS project (Science and Technology Research Partnership for Sustainable Development) concluded that Metropolitan Lima Area has a seismic gap that will present a severe earthquake with a magnitude moment of 8.9 approximately.

This research aims to quantify the vulnerability and assess the seismic risk of Metropolitan Lima Area with typologies of confined masonry dwellings established in field survey in represents districts of Lima, through fragility function and seismic demand. An experimental database of confined masonry walls and statistical database obtained from a survey made in fieldwork from 40 districts in Lima city are used to proposed typologies of a dwelling according to the type of material, the number of floors, and wall density respectively. The dwellings were analyzed in nonlinear dynamic analysis, including parameters to control the hysteretic curve that was founded from experimental tests. On the other hand, seismic scenarios were considered with a different return period from Lima city. Finally, fragility function is developed base on the probabilistic method, and the probability damage matrixs were obtained under six seismic scenarios.

Keywords: seismic risk, vulnerability, fragility function, seismic scenarios, confined masonry dwellings

1 Introduction

The seismic risk estimation in a city is a great step for helping people exposed to seismic hazards. However, it not only depends on estimate the seismic risk to save people, but all institutions must also work in an interdisciplinary team to manage seismic risk through preparedness plans that are essential for the protection of resilient individuals and communities.

Earthquake records in Peru show that Metropolitan Lima Area had great experiences in large earthquakes, produced in the years 1940, 1966,1970, and 1974 with a maximum magnitude of approximately 8.0, causing loss of life and damage in urban areas. Face this natural disaster, it is necessary to estimate the seismic risk measuring the seismic hazard and developing fragility functions that quantify the vulnerability of housing and or buildings to a different scenario seismic intensity.

Studies conducted by the Japan-Peru Center for Earthquake Engineering Research and Disaster Mitigation (CISMID) under the SATREPS project (cooperation from Japanese Government to the National University of Engineering (UNI)) had concluded that the coastal region of Metropolitan Lima area or Tacna department will suffer a potential event of great magnitude of approximately 8.5. Also, other research conducted by National Fund for Scientific Development (FONDECYT) and CISMID-UNI had concluded that 83% of a dwelling of metropolitan Lima area are built with masonry [1] where the majority of these are built without an engineer supervisor.

Indeed, the population must be prepared for an expected seismic event, quantifying vulnerability and seismic hazard to estimating the seismic risk for Metropolitan Lima Area, due to the significant quantity of people dead in the world is because of earthquakes

2 Study zone

Lima, the capital of Peru is located on the central coast of the country. It has a 1 285 215.6 Km^2 of surface and has 9'674 755 population that represents 29.7% of the population in Peru. Lima was established in the Rímac river valley, and it was found on January 18th, 1535, and well kown as "City of the Kings."

The metropolitan Lima area has 50 districts, which 43 districts are from the province of Lima, and 7 districts are from the Constitutional Province of Callao in which all the districts are divided into 05 zones call Lima North, Lima South, Lima East, Callao, and Lima Center as shown in the figure 1 and table 1 respectively.

Table 1 – 05 zones distributed in Metropolitan Lima

Lima North	Lima South	Lima East	Callao	Lima Center
Puente Piedra	Pucusana	Lurigancho	Ventanilla	La Victoria
Carabayllo	Pachacamac	Cieneguilla	Carmen de la Legua	Cercado
Santa Rosa	Villa María del Triunfo	Ate	Callao	San Luis
San Juan de Lurigancho	Lurín	El Agustino	Bellavista	Breña
Ancón	Punta Negra	Santa Anita	La Perla	Surquillo
Comas	San Bartolo	Chaclacayo	La Punta	San Miguel
Independencia	Punta Hermosa	La Molina		Lince
Los Olivos	Villa el Salvador			Magdalena
San Martin de Porras	San Juan de Miraflores			Miraflores
Rímac	Chorrillos			
	Barranco			
	Surco			
	Santa María del Mar			

San Juan de Lurigancho is the district with more population and has 1 117 629 habitants, San Martin de Porres has 744 050 habitants and Ate Vitarte has 670 818 habitants, Villa Maria del Triunfo has 437 992 habitants and villa el Salvador has 1 142 habitants, Punta Negra has 8 243 habitants and San Bartolo has 722 habitants

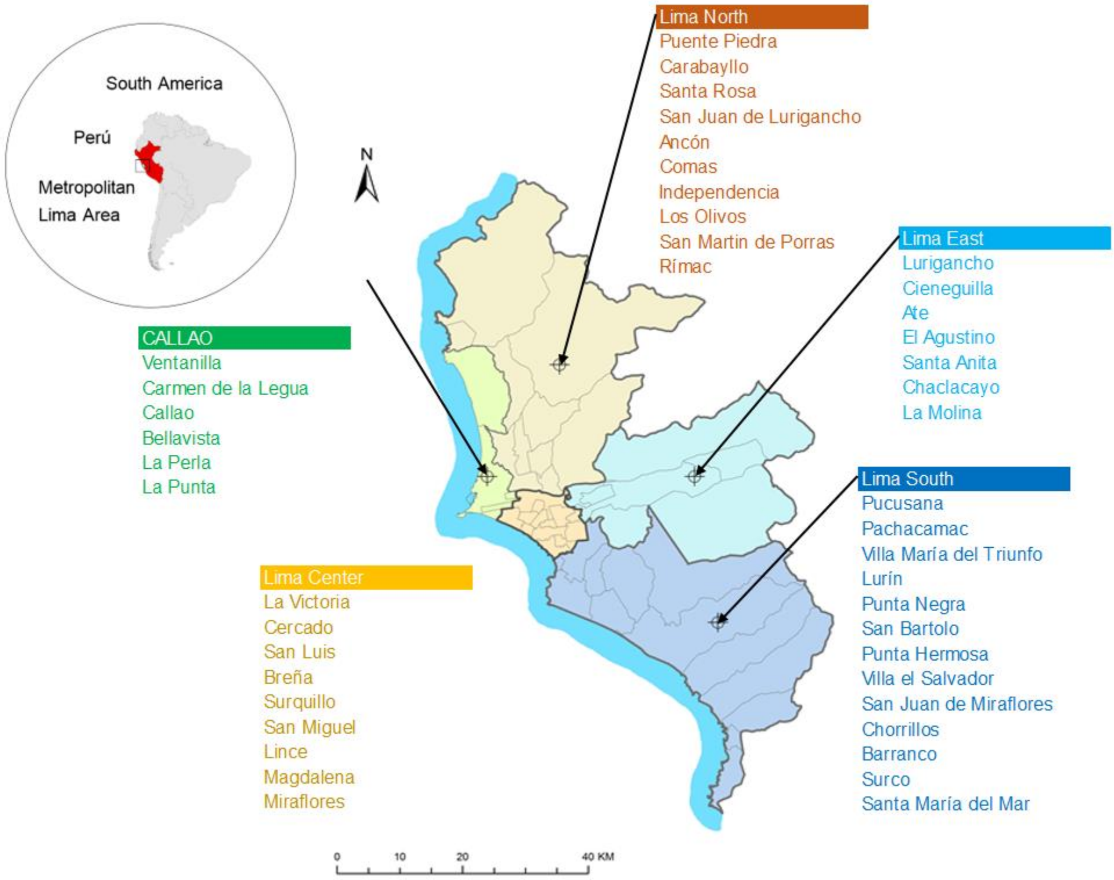


Fig. 1 Metropolitan Lima Area

3 Methodology

The methodology to develop the risk is the same for all tools that the scientific community use as CAPRA, GEM, HAZUS, SELENA and RADIUS. The natural disaster risk assessment models are based on the quantification of 03 components: Hazard, potentially harmful event; Exposition, data set of all the elements susceptible to being damage by threat, and vulnerability, which is related to the threat or hazard and the exposed elements.

This research has developed the seismic risk basing on the probabilistic method. 03 steps to process the seismic risk is presented following: The first step is to analyses and collect information about past studies done in Perú in probabilistic seismic hazard. In our case, Aguilar (2017) [2] expert in the theme realized studies with the first component, which is the hazard.

The second step is to find and collect information about the exposition of the area of study. For our case is the Metropolitan Lima Area in which had defined the taxonomy of dwelling correlating some characteristics such as structural system, type of material, wall density, and the number of stories. All the information were obtained from a database of CISMID and about structural or architectural planes from well know friends.

The third step is to develop de vulnerability of the dwellings through fragility functions. To develop the fragility functions consist of the following 03 steps: The first one is using experimental databases of confined masonry walls. In which, the mechanical characteristic of the material and the structural behavior of the wall were analyzed to measure the damage limit state based on distortions, and the capacity curves of the dwellings were calibrated with a capacity curve model of tetra linear model. The second one is to define the capacity curve per floor of all the dwelling classified for the taxonomy described above. In addition, the third step consists of finding the seismic response of the dwellings through non-linear dynamic analysis in which 06 seismic records and 01 wave seismic synthetic were used.

4 Exposition Model

4.1 Building Inventory

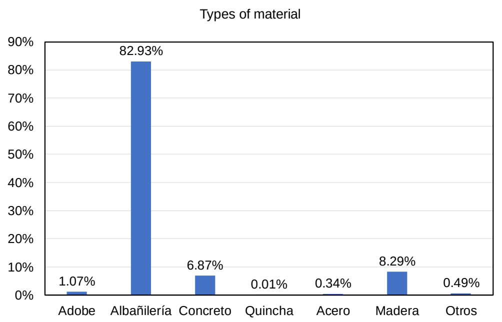
The building inventory is collected by a visual survey that were generated by CISMID. Thanks to the financing of other institutions of the Peruvian government such as: Ministry of Housing Construction and Sanitation (MVCS), the National Center for Estimation, Prevention and Reduction of Disaster Risk (CENEPRED) and the Ministry of Economy and Finance (MEF) through budget program 0068 of Vulnerability Reduction and Emergency Disaster Assistance (PREVAED PP0068)

Building inventory is obtained by the methodology of CISMID, in which representative building has been verified, of a total of 30% of block evaluated in each district of Metropolitan Lima Area. The principal information collected from the survey is the number of floors, type of material, and type of use, structural system, and conservation system.

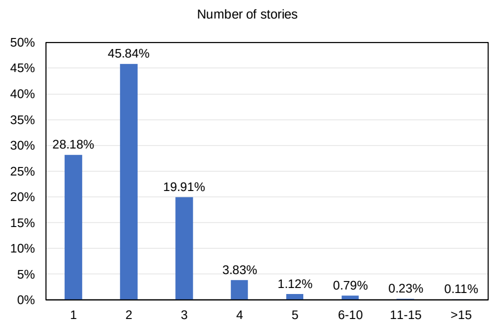
4.2 Characteristic of dwellings in Metropolitan Lima Area

The characteristic and the configuration of dwellings has been changed with the years in Metropolitan Lima Area. For example, the type of material for construction in dwellings was built first by adobe and quincha. However, it has been found that the units of bricks made by fired clay are more resistant and easier to find this material in the zone. In the present, the most used material for built multistory dwellings are made by reinforcement concrete. In that sense, CISMID has been carrying out studies to find the vulnerability and seismic risk since 2010 thanks to agreements with state institutions. Forty districts have been evaluated in Metropolitan Lima Area until 2018. As a result, large databases were obtained in which the principal characteristic of representative dwellings is the type of material, number of stories, type of use, and structural system.

The predominant material for dwellings observed in the region of the Metropolitan Lima Area is made of fired clay brick with 82.9%. In case of the number of stories: dwellings of two stories represent 45.84%, 01-floor dwellings are in 28.18%, 03 story dwellings are in 19.91%, and 04 story dwellings are in 3.84 % as shown in Fig. 2.



(a)



(b)

Fig. 2 Types of material (a) and number of stories (b) [1]

Another characteristic observed in the confined masonry dwellings is the wall density that means the number of walls confined in the two directions of the structure: one in the direction of the facade of the house and the other perpendicular to the facade. A set of structural or architectonic planes between 02 and 05 stories were collected in different districts of Metropolitan Lima Area. The districts are San Juan de Lurigancho, San Martin de Porres, El Rimac, Independencia, Los Olivos, and La Punta, where 87% of dwelling does not meet the minimum requirements walls density located in the facade direction of the dwelling. However, the walls density perpendicular to the facade of dwellings accomplishes the higher percent of the minimum requirement of the seismic standard in walls density, as shown in the Table 2.

Table 2 – Minimum wall density values E-070 [3]

SOIL	Standards Value		Number of Stories				
			1	2	3	4	5
SOIL	So	0.80	0.64%	1.29%	1.93%	2.57%	3.21%
	S1	1.00	0.80%	1.61%	2.41%	3.21%	4.02%
	S2	1.05	0.84%	1.69%	2.53%	3.38%	4.22%
	S3	1.10	0.88%	1.77%	2.65%	3.54%	4.42%

Nota: S1: Hard Rock S2: very rigid soil S3: Intermediate soil S4: Soft soil

In the decade of the 1970s, with the experiences of the earthquake as 1970 and 1974 in the Metropolitan Lima Area, it has been concluded that a higher density of walls has less damage to the dwelling [4]. On the other hand, the units of solid brick (Handmade) were mostly used in these years. However, the shape and resistance of the bricks have been changing and industrial King Kong brick and Industrial tubular brick are well known and used now.

4.3 Proposal for taxonomy of dwellings

The geometry of the dwelling in the Metropolitan Lima Area is generally rectangular, with an area in the plant between 90m2 and 120m2 approximately. 83% of dwellings have masonry as the predominant material. However, they are considered informal buildings due to they are built by two kinds of brick that it is not allowed to use in load-bearing walls: solid brick (Handmade) and tubular brick (Industrial).

The structural system is made of a confined masonry wall with the number of stories between 01 to 05 stories, wall density of 1.7%, 2.3%, and 2.9%. The total number of dwellings to evaluate are 42 typologies of confined masonry dwelling, where each wall density represents the 14 taxonomy propose. For example, 04M2L1.2L2 means a four-stories dwelling where two first floors (first and second floor) are built with handmade solid brick (ML1), and the last two stories are built by industrial tubular brick (ML2).

Table 3 – 14 Taxonomy propose for Metropolitan Lima Area

N°	Taxonomy of dwellings	N°	Taxonomy of dwellings
1	1ML1	8	3M3L2
2	1ML2	9	4M2L1.2L2
3	2M2L1	10	4ML1.3L2
4	2ML1.L2	11	4M4L2
5	2M2L2	12	5M2L1.3L2
6	3M2L1.L2	13	5ML1.4L2
7	3ML1.2L2	14	5M5L2

5. Seismic Hazard

Peru is a country with high seismic activity, and the seismic hazard for a sever seismic scenary will be catastrophic and can bring as human and material lost consequences. Therefore, there are two ways to quantify the seismic hazard: deterministic or probabilistic method. In this research, the seismic hazard is developed by a probabilistic method [2]. The probabilistic method characterizes the uncertainty in the location, size, frequency and site effects and combines them to calculate the probabilities of each site with different levels of soil movement intensity.

The probabilistic seismic hazard analysis (PSHA) from Metropolitan Lima Area has been developed to take into consideration four steps. The first step, recognize the seismic record catalog from Peru and the characteristic of tectonic of the region. The second step, identify and characterize the seismogenic sources. The third one, determine the equation for the ground motion prediction (GMPE) for each seismic source and finally estimate the seismic hazard curve with probabilistic analysis.

The methodology to develop the probabilistic seismic hazard (PSHA) in metropolitan Lima Area was used by Cornell (1968). This methodology was systematized by Mc Guire (1974, 1976) in the computer program called RISK, a basic tool for the analysis. As a result of the program show the seismic hazard curve expressed in terms of spectral acceleration and annual probability of leave as show following.

The record catalog of Peru has been collected by the different institution as Peruvian Geophysical Institute (IGP); The International Seismological Center catalogue (ISC); The National Earthquake Information Center (NEIC); The National Oceanic and Atmospheric Administration catalogue (NOAA); and the Global Centroid Moment Tensor catalogue (Global CMT). As a result, it shows in Fig. 3, the annual probability curve of leave for rock acceleration in the Peruvian coastal area that were calculated with a computer program, CRISIS, developed by Ordaz et al (2015).

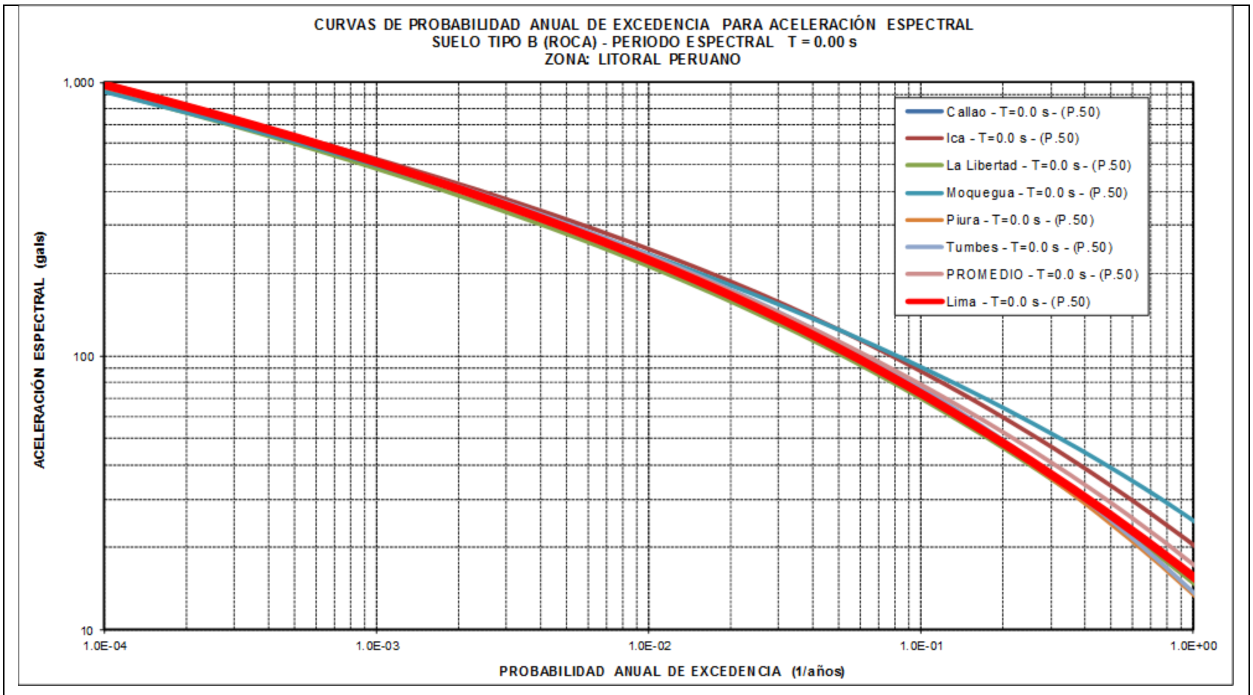


Fig. 3 Annual probability curve of absence for spectral acceleration Aguilar et al (2017)

The seismic standard in Peru is design for building to support a severe earthquake with a return period of 475 years with a 10% of probability in 50 years [5] . As show in the Table 4.

The PSHA model developed by Aguilar [2] was utilized in the present study according Table C2-1 of ASCE41-13 “Seismic Evaluation and Retrofit of Existing Buildings”.

Table 4– Seismic Demand for Metropolitan Lima Area

Seismic Demand	Probability of leave	Probability of occurrence	Average Return Period	Denomination
I	50%/30 year	0.0233	43 years	Very slight
II	50%/50 year	0.0139	72 years	Slight
III	20%/50 year	0.0044	225 years	moderate
IV	10%/50 year	0.0021	475 years	Severe (NTE E030)
V	5%/50 year	0.0010	975 years	Rare
VI	2%/50 year	0.0004	2475 years	Very rare

6. Vulnerability

To estimate risk, it must quantify the vulnerability. The fragility of the building is related to its seismic vulnerability and can be quantified by fragility function. Fragility function represents a probability of building exceed a certain limited damage state under a probabilistic seismic demand of the Metropolitan Lima Area.

6.1 Limit Damage state

The limit damage states were proposed by Zavala et al. with the experiments carried out by laboratory of structures of CISMID and other studies carried out by the project of SATREPS [6] [7][8]. However, a new series of confined masonry walls were tested to actualize the database of the structural laboratory and adjust the limit damage state [9][10]. Table 5 shows the limit state in terms of distortion and damage state for confined masonry wall made by handmade solid brick (ML1) and industrial tubular brick (ML2).

Table 5.Damage and Limit State [10]

Distortion ($x10^{-3}$) ML1	Distortion ($x10^{-3}$) ML2	Damage State
$\gamma < 0.39$	$\gamma < 0.40$	No damage
$0.39 \leq \gamma < 1.11$	$0.40 \leq \gamma < 0.81$	Slight
$1.11 \leq \gamma < 2.81$	$0.81 \leq \gamma < 1.02$	Moderate
$2.81 \leq \gamma < 3.55$	$1.02 \leq \gamma < 1.5$	Severe
$\gamma \geq 3.55$	$\gamma \geq 1.5$	Collapse

Note:
ML1 is confined masonry wall made of artesanal solid brick
ML2 is confined masonry wall made of industrial tubular brick

6.2 Non-Linear Dynamic Analysis

The seismic behavior of a building under different seismic record can be quantified by its maximum responses. The dwellings in this research were modeled by a multiple degree of freedom, in which the capacity curve of the confined masonry walls of the dwelling were adjusted a tetra linear model or quad linear model adapted by professor Saito that can replicate the hysteresis behavior [11].

It has been compiled 06 earthquakes record and 01 synthetic wave developed by Pulido under the SATREPS Project [12] to amplify the response spectrum recommended by Seismic Peruvian Standard of 2018. These earthquakes record, see Table 6, are calibrated for 06 seismic demand of Metropolitan Lima Area proposed for Aguilar (2017) in which, every seismic demand has a range of peak ground acceleration (PGA): Very slight (I) [150-200] gals; Slight (II) [200-250] gals; moderate (III) [250-400] gals; severe (IV) [400-550] gals; rare (V) [550-750] gals and very rare (VI) [750-1000] gals.

Table 6– Earthquake record for Metropolitan Lima Area

Record Name	Date	Type	Mw
prq-6610171641	17/10/66	Record	8.1
prq-7005311523	31/05/70	Record	6.6
prq-7410030921	03/10/74	Record	6.6
Atico230601	23/06/01	Record	6.9
ICA15082007	15/08/07	Record	7.0
Lagunas15082007	26/05/19	Record	8.0
CMA_7_1.EW	--	Synthetic (SATREPS)	8.6

6.3 Fragility Function.

Fragility functions represent the probability that a structure will exceed a damage level based on a parameter that defines the seismic intensity. These curves are used to estimate the seismic risk of structures with similar characteristics and can be generated by field observations or analytical methods. Calculating the fragility functions consists of calculating a certain significant number of dwellings at different levels of seismic demand. This research has developed fragility function base on analytic and experimental method.

Eq (1) and Eq (2) represents mathematically a fragility function that it's a lognormal cumulative distribution function.

$$Fi(D)=\phi(\ln(D/\theta i)/\beta i) \quad (1)$$

$$\theta i=e^{1/M \sum m=1 \ln(Di)} \quad (2)$$

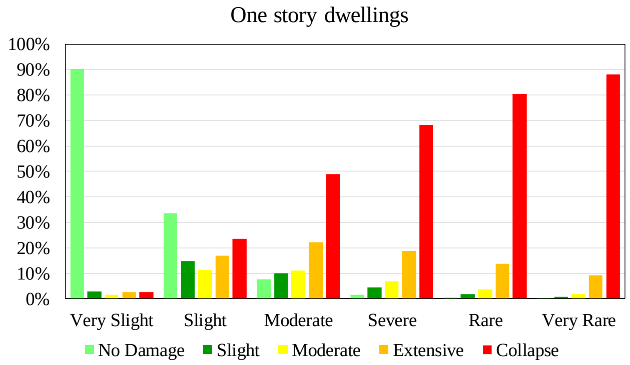
Where $F_i(D)$Fi(D): is the probability that a structure exceeds a certain limit state of damage under a seismic demand, D: is a seismic intensity, ϕ: is the standard cumulative normal distribution function (Gaussian), θi: is the average probability distribution value the damage state, βi: The standard logarithmic deviation or dispersion factor.

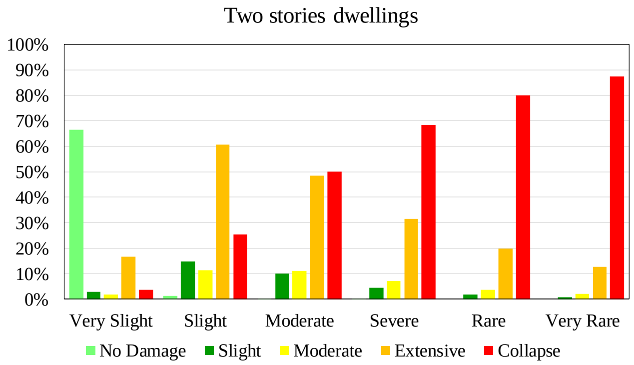
7. Results

A total of 1764 numerical simulation were performer, in order to develop the fragility function of dwellings of confined masonry

- One-story dwellings collapse in 2.7% under very slight seismic demand, while under severe seismic demand, 68% collapse.
- Two stories dwellings collapse in 3.5% under very slight seismic demand, while 68.4% collapse under severe seismic demand.
- Three stories dwellings under very slight seismic demand are in no damage level with 85.7%, while 68.2% are in collapse under severe seismic demand.
- Four stories dwellings are in slight damage level with 73.9% under very slight seismic demand, while 31.6% and 12.6% are in extensive damage level under severe and very rare seismic demands, respectively.
- Five stories Dwellings are in slight level with 76.7% under very slight seismic demand, while 19.8% and 12.5% are in extensive damage level under severe and very rare seismic demands, respectively.

The fragility functions of the dwellings in Metropolitan Lima Area were developed taking into consideration 14 taxonomy of dwelling, between 01 to 05 stories with the two type of material (Handmade solid brick and Industrial tubular brick) and the three types of wall density (1.7%, 2.3%, and 2.9%). The structures were analyzed under numerical simulation, including 06 levels of seismic demand to analyze probability damage level in the dwellings, as shown in Fig. 4, Fig. 5, and Fig. 6.

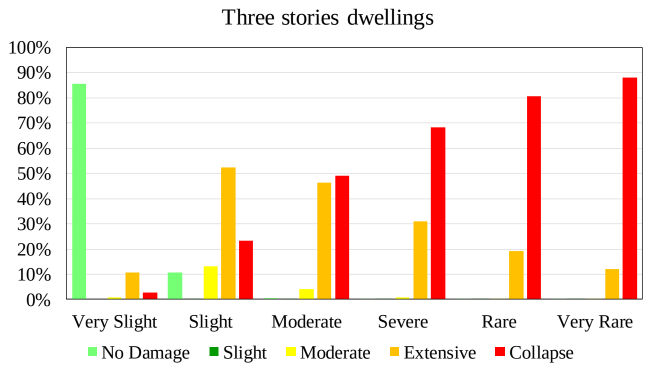


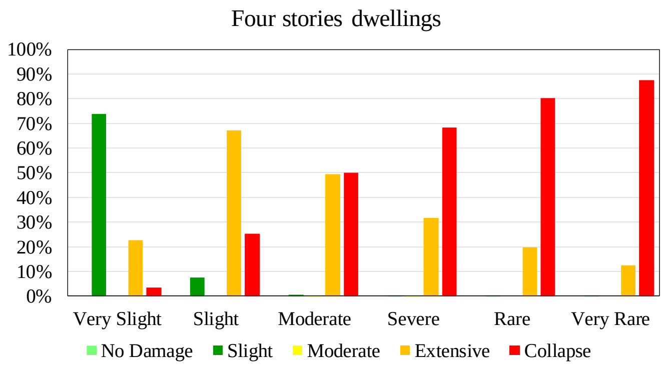


	I	II	III	IV	V	VI
No Damage	90.3%	33.7%	7.7%	1.6%	0.4%	0.1%
Slight	2.8%	14.8%	10.0%	4.3%	1.7%	0.6%
Moderate	1.7%	11.2%	11.1%	7.0%	3.8%	1.9%
Extensive	2.6%	16.9%	22.2%	18.9%	13.7%	9.3%
Collapse	2.7%	23.4%	49.0%	68.2%	80.5%	88.0%

	I	II	III	IV	V	VI
No Damage	66.4%	1.1%	0.0%	0.0%	0.0%	0.0%
Slight	12.5%	10.8%	1.0%	0.1%	0.0%	0.0%
Moderate	1.0%	2.3%	0.5%	0.1%	0.0%	0.0%
Extensive	16.6%	60.6%	48.4%	31.5%	19.8%	12.6%
Collapse	3.5%	25.3%	50.1%	68.4%	80.1%	87.4%

Fig. 4 Probability damage level and matrix for one and two stories dwelling

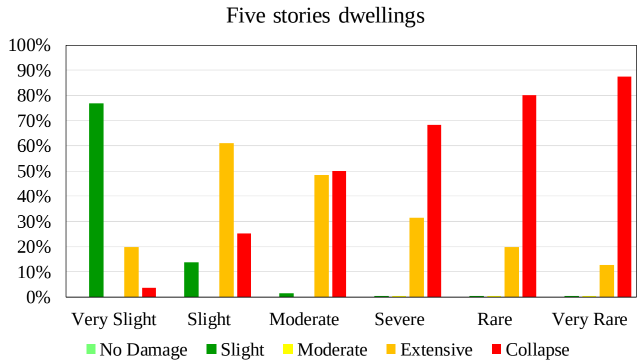




	I	II	III	IV	V	VI
No Damage	85.7%	10.6%	0.5%	0.0%	0.0%	0.0%
Slight	0.0%	0.4%	0.2%	0.0%	0.0%	0.0%
Moderate	0.8%	13.2%	4.0%	0.8%	0.2%	0.0%
Extensive	10.8%	52.5%	46.3%	30.9%	19.3%	11.9%
Collapse	2.7%	23.4%	49.0%	68.2%	80.5%	88.0%

	I	II	III	IV	V	VI
No Damage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Slight	73.9%	7.5%	0.4%	0.0%	0.0%	0.0%
Moderate	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Extensive	22.6%	67.2%	49.5%	31.6%	19.9%	12.6%
Collapse	3.5%	25.3%	50.1%	68.4%	80.1%	87.4%

Fig. 5 Probability damage level and matrix for three and four stories dwelling



	I	II	III	IV	V	VI
No Damage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Slight	76.7%	13.7%	1.5%	0.2%	0.0%	0.0%
Moderate	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Extensive	19.7%	61.0%	48.3%	31.4%	19.8%	12.5%
Collapse	3.5%	25.3%	50.1%	68.4%	80.1%	87.4%

Fig. 6 Probability damage level and matrix for five stories dwelling

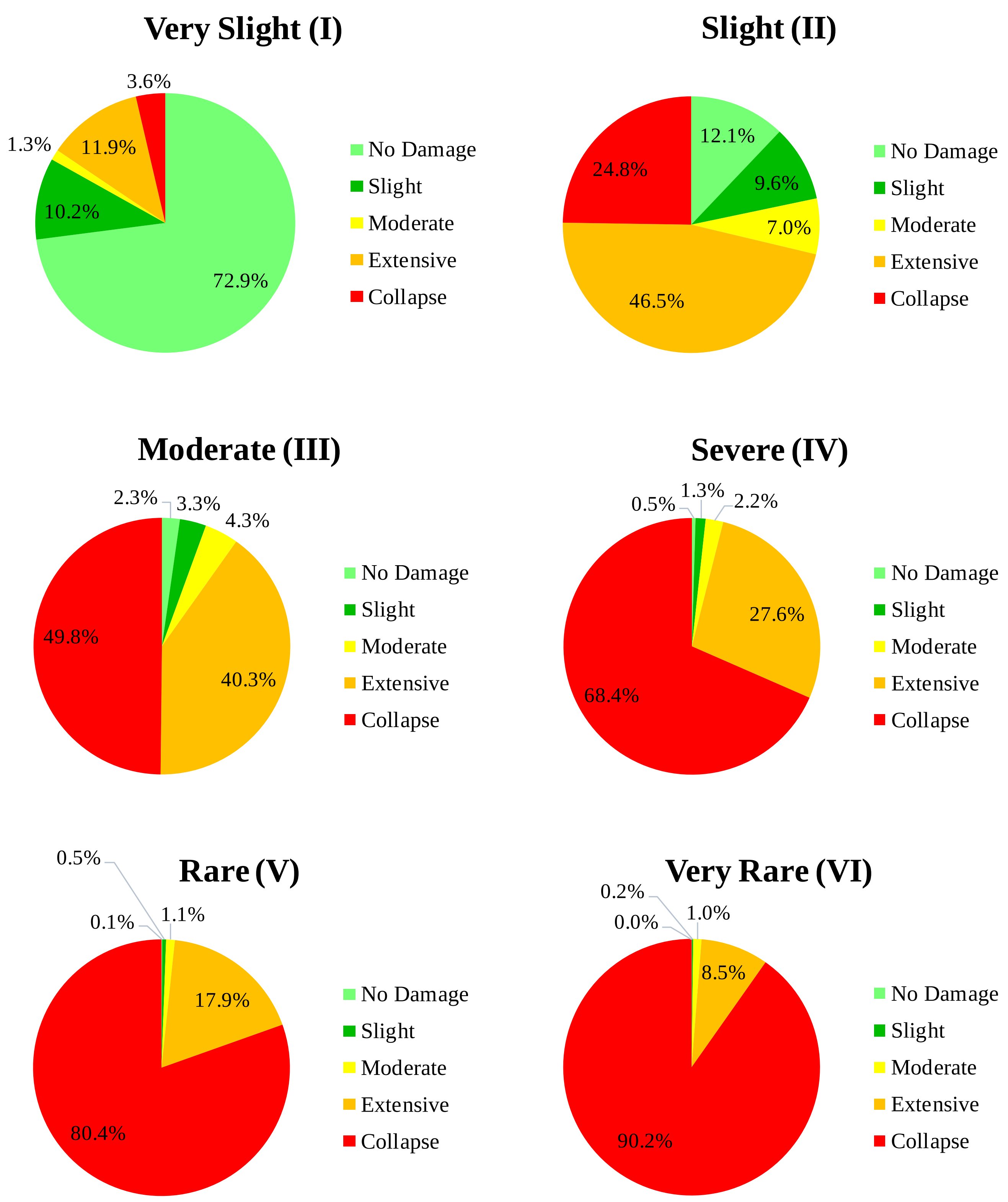


Fig. 7 Percentage expected of damage level under 06 seismic demands in Metropolitan Lima Area

- Non-engineering dwellings in Metropolitan Lima Area are in collapse damage level with 49.8% and 90.2%, in extensive damage level with 40.3% and 8.5% under moderate and very rare seismic demand, respectively.
- Dwellings higher than one story reach extensive damage level in 50%, whereas dwellings up to five stories collapse in 50% under moderate seismic demand.
- Dwellings of the Metropolitan Lima Area under very slight seismic demand presented 72.9% no damage level. While 3.6% collapsed, 11.9% extensive damage level, 10.2 % slight damage level, and 1.3% reached moderate damage level.
- For a severe seismic demand, dwellings of the Metropolitan Lima Area collapsed in 68.4%. While 27.6% presented extensive level damage and very few in no damage level
- Dwellings of the Metropolitan Lima Area collapse under very rare seismic demand with 90.2%, whereas under moderate seismic demand collapse in 49.8%.

8. Conclusions

A methodology to develop the seismic risk is described in this paper. The PSHA of Metropolitan Lima Area was utilized, and the vulnerability was developed with fragility function using database and experimental results from the structural laboratory of CISMID from Faculty of Civil Engineering of the National University of Engineering.

The main features of dwellings in Metropolitan Lima Area was considered as the structural system, number of floors, type of material, and type of use. The predominant material of dwellings in the Metropolitan Lima Area is masonry, with 82.9% of entire buildings. The most significant number of stories in dwellings are 02 stories with 45.84%, and the type of use in buildings are dwellings with 78.8%.

Fragility functions were developed under an analytical method with the experimental results of the structural laboratory of CISMID. 14 typologies between 01 to 05 floors with different types of material such as handmade solid brick and industrial tubular brick were proposed for 03 types of wall density, 1.7%, 2.3%, and 2.9%. Where, 06 earthquake records and 01 synthetic waves were considered to analyze and calibrate 06 seismic demand for Metropolitan Lima Area: Very slight, slight, moderate, severe, rare, and very rare. Having 14 taxonomies as representative dwellings were obtained 1764 seismic responses for Metropolitan Lima Area.

The seismic response of dwellings built with non-engineering material and wall density of 1.7%, 2.3%, and 2.9% must be improved their structural performance to prevent collapse under a very rare seismic demand and expected in metropolitan Lima Area. So, it must increment the wall density with a new confined masonry wall and the confined masonry walls built by handmade solid units and industrial tubular units must be retrofitted

Dwellings for an expected earthquake of magnitude 8.0 in Metropolitan Lima Area with an average of peak ground acceleration between 700gals to 1000gals represent a very rare seismic demand, where 90% of dwellings collapsed for this strong earthquake. In case of a severe seismic demand, 68.4% collapsed, and 27.6% are in collapse prevention. In both seismic demands, the seismic risk is very high for Metropolitan Lima Area.

In order to prevent a full collapse of dwelling in the Metropolitan Lima Area, the seismic capacity must be improved. The confines masonry walls in the dwelling must be retrofitted, and the wall density must be increased, especially in Lima North Zone and Lima South Zone because there is a higher percentage of dwellings between 01 and 02 stories. Finally, the probabilistic method to measure the seismic risk is very useful for the decision-makers that can take quantitative decision to reduce the seismic risk in Metropolitan Lima Area.

9. Acknowledgements

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