JOINT CONFERENCE PROCEEDINGS
9th International Conference on Urban Earthquake Engineering/ 4th Asia Conference on Earthquake Engineering
March 6-8, 2012, Tokyo Institute of Technology, Tokyo, Japan

LOSS ESTIMATION ON LIMA CITY USING A RETROFITTING COST ESTIMATION TOOL

Carlos Zavala[1], Miguel Estrada[2], Jorge Morales[3] and Jenny Taira[4]

1) Professor, Structural Laboratory CISMID-FIC, National University of Engineering, Peru
2) Professor, Geomatics Laboratory CISMID-FIC, National University of Engineering, Peru
3) Research Student, Geomatics Laboratory CISMID-FIC, National University of Engineering, Peru
4) Research Assistant , Structural Laboratory CISMID-FIC, National University of Engineering, Peru
czavala@uni.edu.pe, estrada@uni.edu.pe, jorg_28@hotmail.com; jenny_taira@hotmail.com

Abstract: Lima city the capital of Peru had experience big earthquakes in last century, like 1940, 1966 and 1974, the last big quake that strike the city. Since that quake, 37 years have pass and return period became shorter and shorter. Due to this worried, the damage estimation and loss estimation in terms of retrofitting cost is developed using tool that implement a simple approach for compute the earthquake response of buildings base on damage function. For that purpose six districts of different socio economical levels has been studied to produce damage estimation functions. These functions were implemented on tool CCRE a simplified tool based on SRSND, a simulator for computing cost estimation of retrofitting. Results were computed for six district on Lima city and extrapolated based on the damage functions and cost estimation functions using socio economical criteria. Simulations, provide the idea of the expected damage for the next quake, and became a tool for decision makers.

1. INTRODUCTION

Lima city is the capital and the largest city of Peru. It is located in the valleys of the Chillón, Rímac and Lurín rivers, in the central part of the country, on a desert coast overlooking the Pacific Ocean. Together with the seaport of Callao, it forms a contiguous urban area known as the Lima Metropolitan Area. With a population approaching 9 million, Lima is the fifth largest city in Latin America, however is located on an earthquake prone zone. Lima had experience big earthquakes in the last century, as shown in Table 1, where in the last century earthquakes of 1940, 1966 and 1974 produce strong damage on urban areas.

Table 1: Large quakes in Lima City

DATE	EPICENTER	Max. MMI
9/7/1586	Lima coast	IX
13/11/1655	Lima, San Lorenzo island	VIII
20/10/1687	Lima South coast	VIII
28/10/1746	Lima North coast	X
30/3/1828	Lima, in front of Callao port	VII
24/5/1940	Lima	VIII
17/10/1966	North coast and Lima	VIII
3/10/1974	Lima	VIII

One of the strongest earthquakes was produced in October 1966, several inhabitants of the Huacho area were killed, and over 20,000 were homeless in Huacho, the most severely damaged village. At the time of this shock a religious festival (perhaps associated with that mentioned earlier, established in commemoration of the great Lima catastrophe in October 1746) was being held in Callao; several died when some churches collapsed. Landslides and huge ground cracks were noted along the Pan American Highway, and over 2,000 houses sustained severe structural damage in Lima.

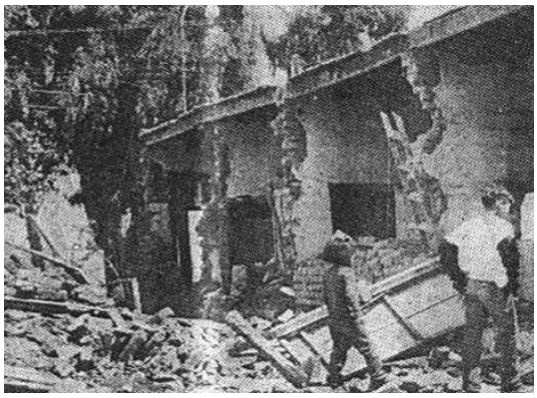

Figure 1: Destruction in La Molina area 1966 quake

On October 10th 1974 and strong shock centered approximately 80 kilometers southwest of Lima rocked the southern coastal area of Peru inflicting heavy damage in the Lima area. The quake, which killed 78 and injured several thousand, was Lima's worst earthquake disaster in terms of lives lost since May 31, 1970, when a magnitude 7.9 shock killed an estimated 50,000 on Chimbote quake, the strong earthquake registered in Peru.

Figure 2: Collapse church´s roof -1974 quake

Since 1974, Lima city has not experience an strong earthquake, so seismic gap has been generated in Lima´s surrounding area. Since 2007 Pisco quake, the largest quake that strike Peru recently, the central government and the researchers are trying to take the attention of the decision makers on city offices, in order the start to apply a policies for reduce the seismic risk. Therefore, the authors in a join research with the Ministry of Housing and Construction propose a tool to compute the seismic risk, CCRE-CISMID, simplified version of risk analysis base on the SRSND simulator (Zavala et. al. 2007), to produce the lost estimation on housing. The implementation a simple approach for compute the earthquake response of buildings base on damage function is presented. For that purpose six districts of different socio economical levels has been studied to produce damage estimation functions considering, using socio economical criteria.

2. THE STUDY OF LIMA´S SIX DISTRICTS

On 2003 the first study for seismic risk estimation was developed by CISMID, under the support of APESEG. Since that study, valuable information has been collected by our researchers and students, and Pisco quake data contribute for the generation of SRSND for calibration of damage diagnosis on buildings. Therefore, an update of the risk analysis is needed to improve the model of lost estimation. The improvement has been developed using the data and field survey of six districts, developed in a join research project with Ministry of Housing and Construction (PGT-CISMID). Villa El Salvador, San Juan de Lurigancho, La Molina, Chorrillos, Comas and Puente Piedra districts microzoning and diagnosis have been developed. Also results from 3 districts studied under SATREPS (Chiba University-CISMID/FIC/UNI) project has been consider for the present study.

2.1 Update Microzonification Map

The update microzonification map was developed by the Geotechnical Lab staff (Aguilar & Lazares, 2011) that consider field study of the soils and recompilation on existing data of soil profiles. Zones in purple are debris areas, red color shows bad soil, brown color shows soft soil, yellow color is a middle soil and green color shows good soil. Each zone has an expected peak ground acceleration(PGA) that will be used as input data for the earthquake response of structures. Also the tsunami inundation zone, presented as a red line (Estrada & Adriano, 2011) has been include in the microzoning map.

Figure 3: Lima Microzoning Map (2011)

2.2 Building stock and vulnerability

Survey work was developed on the six update districts, were some new areas nor included on 2003 diagnosis has been included. In this areas a representative house for each block was study, in order to evaluate the seismic response using a simplify analysis using influence parameters, such socio economical condition, type of material, etc.

2.3 Socio Economical condition and model estimation

The city of Lima (include the harbor of Callao) has a total of 43 districts, as is presented in Figure 4.

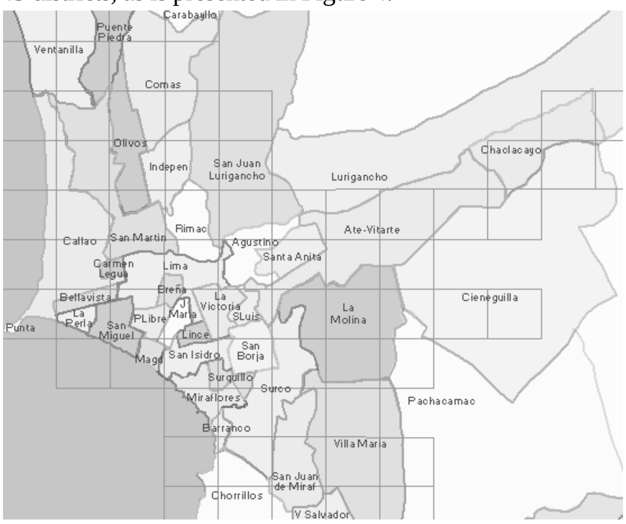

Figure 4: Districts on Lima city

Among the districts the north and south are districts where the amount slums are quite considerable.
On other zones of the districts like in center south or south east the concentration of high income class is notorious.
From PGT-CISMID study districts, as an example, let´s consider one district (La Molina) belong to high upper class, another district belong to middle class (Chorrillos) and four districts area popular zones (Villa El Salvador, San Juan de Lurigancho Comas and Puente Piedra). Considering Figure 5, we can analyze the distribution of socio economical level.

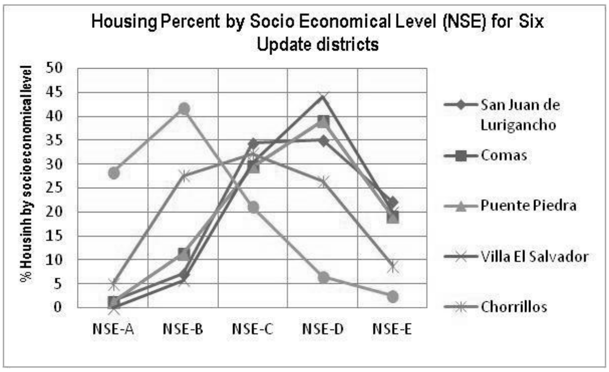

Figure 5: Housing by socio economical level

The four popular districts with low socio economical have join a group by itself and middle class district is just with a peak at socio economical level C, and high socio economical level district as La Molina have peaks as A and B levels. Therefore , type of housing and cost of reposition must be different for each of the socio economical level groups.

2.4 Risk evaluation considering damage functions involving socio economical level

For the evaluation of the risk, the retrofit cost for house unit is consider as output parameter of the presented process. We can consider the methodology propose by Miranda (1999) and implemented on SNSRD and presented by Zavala (2007, 2010). Then a simplified analysis of the response to take into account only an equivalent first mode of vibration of the structure to take advance of the spectra component of pseudo displacement is considering in the scheme.
As an example we introduce the damage function in terms of drift response (γ) on masonry buildings, is compute using the following equation:

$$\gamma = \frac{(X_i - X_{i-1})}{h} = \left(\frac{\left(\frac{ZUSC}{R}\right)}{\left(\frac{2\pi}{T}\right)^2} \right)(0.75\mu) \qquad (1)$$

where X_i and X_{i-1} are the response displacement on story i and story i-1, h is the inter story high, Z is the PGA that depends of seismic microzonification, U is the building importance factor (1 to 1.5) , S is soil type factor (1 to 1.4), C is the amplification factor (function of the soil period and structure period), R is a reduction factor (3 in the case of masonry structures), T is the period of the building (here consider as function of the interstory height (h)), μ is the expected ductility on the structure .

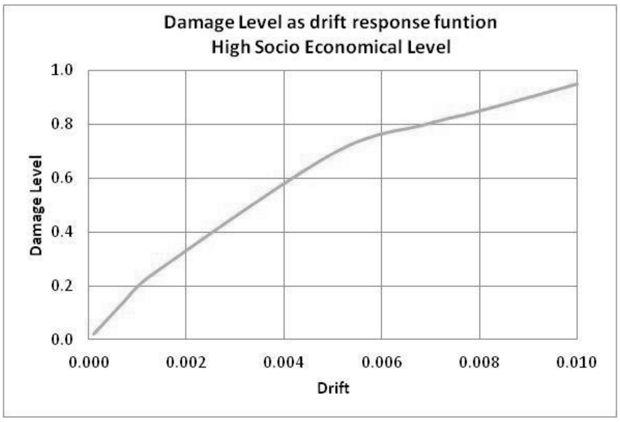

Figure 6: Damage Level on La Molina District

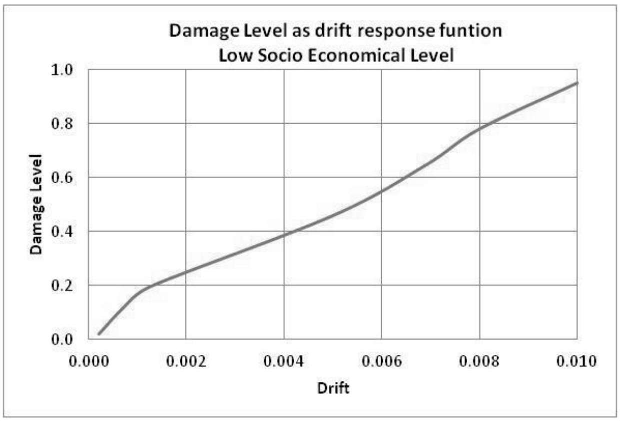

Figure 7: Damage Level on Popular Districts

Based on test results presented by Zavala (2004) and complemented with numerical simulations on non linear models, damage matrix can be computed in terms of damage functions. Therefore, involving the socio economical variable, damage level is computed with the functions calculated from a regression analysis of the six districts results, presented in Figure 6 (for high socio economical level district) and Figure 7 (for low socio economical level district).
Using the damage level expressed in percent, the damage cost retrofit functions are proposed and presented in Figure 8 where each socio economical level has a function. Under this diagnosis the update of Lima risk analysis is performed, and presented in Figure 9.

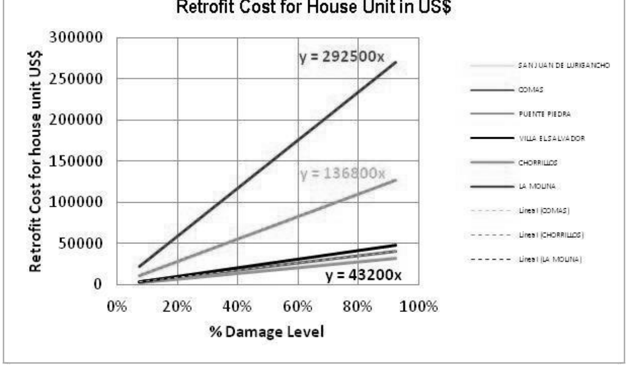

Figure 8: Retrofit cost in US$ for house unit

This results consider not only the seismic risk, also consider the tsunami hazard and the socio economical condition in the updated districts.

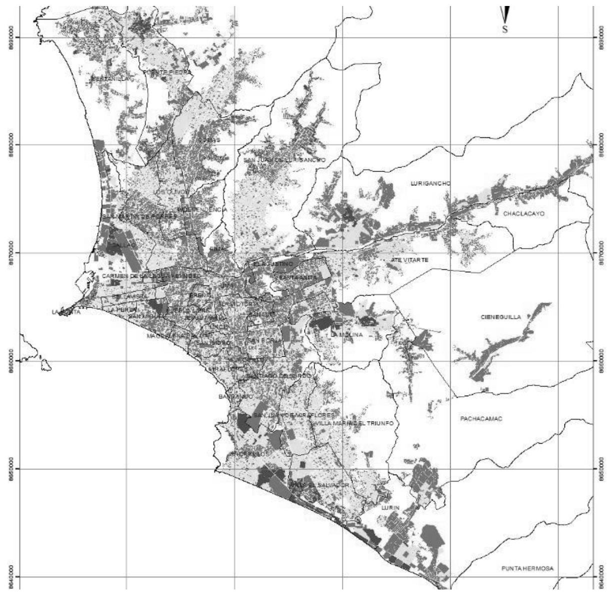

Figure 9: Updated Lima Seismic Risk map

All this algorithm was implemented on CCRE tool a simplified version of SRSND, that implement equation (1) and functions presented on Figures 5,6,7. The results of the application is presented on Figure 8, were green areas represent a retrofit cost less than 15%, yellow zones shows retrofit cost between 15% to 30% and red zones represent cost over 30% that will represent reposition of the house.

As was mentioned before on of the keys of these process is the improve of the results of 2003 CISMID risk analysis. As an example the results of La Molina district is presented on Figure 10. These results shows zones in red that represents the most seismic risk areas for this district.

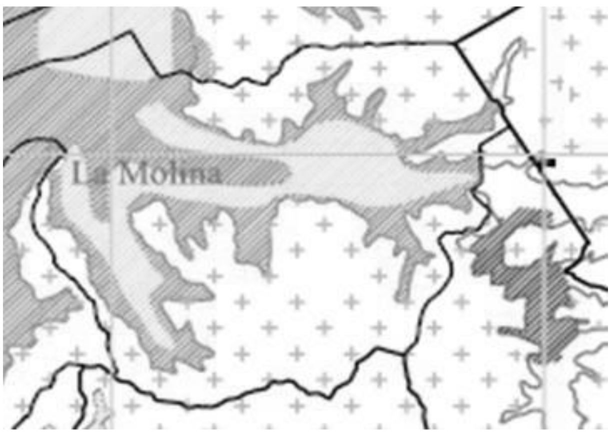

Figure 10: CISMID Risk analysis (2003)

In order to show the improve of the analysis we present on Figure 11 the results of the simulation using the scheme presented in this paper using the socio economical level functions for the appropriate areas.

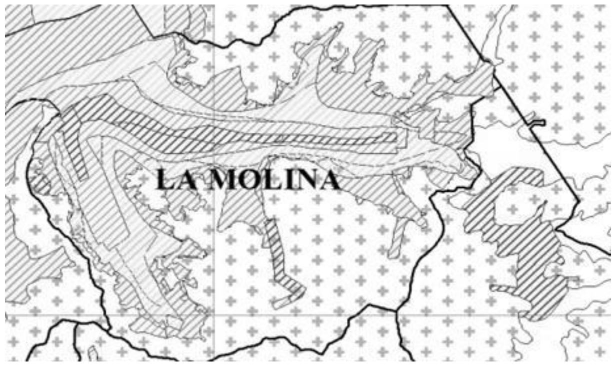

Figure 11: CISMID Risk analysis (2011)

From Figure 11 and Figure 10 is possible to notice the improve of the simulation scheme, showing new zones in risk on the district.

3. CONCLUSIONS

- Lima city is bigger city in Peru and since 1974 does not experience am strong quake. Therefore strong earthquake is expected and the worried is increasing among researchers. However we need to open the eyes of the decision makers and politicians in order they considering measures for reduces the seismic risk in the dangerous zones of the city.

- A simplified procedure has been presented in this paper for evaluate the seismic risk in terms of retrofit cost of housing unit. This process introduce the use of damage functions for each socio economical level, to improve the results of the diagnosis. This functions has been calibrated with the survey results of Pisco quake 2007 presented by Zavala (2010).

- The application of the damage functions were executed on six districts of Lima city on the PGT-CISMID project and Japan Peru SATREPS project has been consider on the development of an update risk analysis of Lima city. Improve of the results has been presented and given trust for the simulation scheme.

References:

Aguilar Zenon, et. al. CISMID-FIC-UNI. (2007). Microzoning of Pisco, San Luis de Cañete and Huaytara. Report for Inter American Development Bank (IDB) and Secretary of the Presidency of First Minister (PCM), Lima, PERU.

Miranda Eduardo, Journal of Structural Engineering ASCE. (1999.) Approximate lateral deformation demands in multistory buildings.

Zavala Carlos y Proaño Ricardo – XIV Congreso de Ingeniería Civil Iquitos Perú (Octubre 2003.)Estimación rápida de la Respuesta Sísmica en base a sistemas de un grado de libertad para el calculo de vulnerabilidad sísmica (in Spanish).

Zavala Carlos et al. CISMID/FIC/UNI/ (Noviembre 2007) SRSND Simulador Respuesta Sísmica y Nivel de Daño (in Spanish).

Zavala Carlos et. al (2004) 13th World Conference on Earthquake Engineering -Vancouver, Canada- Full scale on line test on two story masonry buildings using handmade bricks.

Zavala Carlos et al. (2011) 8th CUEE Conference Procedings Evaluation of SRSND simulator againts fragility curves for Pisco quake