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EVALUATION OF SRSND SIMULATOR AGAINTS FRAGILITY CURVES FOR PISCO QUAKE

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Abstract: An evaluation of the seismic response of structures using SRSND simulator developed for compute damage ratio in terms of repair cost on housing at Pisco is presented. The simulator consider the implementation of a simple algorithm for compute the seismic response of a building base on material, story height, state of conservation of the building and irregularities. The damage is compute by comparison with a damage matrix based on test results and also post quake survey developed after Pisco quake on Pisco city. Also fragility curves results for the same city has been developed by the authors and is used as comparison parameter for evaluation of the SRSND simulator results. Good agreement between both results has been found. Therefore confidence in the use of the simulator as a tool to predict losses on cities after a quake is shown.

1. INTRODUCTION

On the estimation of seismic risk analysis of cities, there are different parameters used as output of the process. The more likely used is the damage cost or the cost of reposition of the damage structures. Other parameters are the probability of damage for deterministic type of structure, the amount of collapse housing by material type and others. The evaluation of each of the output parameters need the evaluation of probability approach or empirical regression analysis based on damage survey after the event. Each of these results is linked with earthquake acceleration on a characteristic soil. Therefore, the evaluation of the seismic response of a building and the determination of the damage level need the knowledge of the soil condition, probable acceleration on the site, material influence, number of stories of the building, basic geometry and other input parameters.

In this paper a seismic response simulator with damage level estimation (Simulador Respuesta Sísmica y Nivel de Daño SRSND in Spanish) is presented. This simulator is used as a tool to predict the cost of reposition for a damage level as a consequence of an input acceleration of the ground. The development of the simulator, the input data on for the model and the parameters used on the quake response are presented. Then the validation if the model is performed by comparison with field survey results and also fragility curves developed from the survey of Pisco city after August 15th 2007 earthquake.

2. ESTIMATION OF SEISMIC RESPONSE

For the estimation of the seismic response on an approximate method is developed based on the peak ground acceleration of the soil where the structure has been build. For that purpose seismic hazard of the location is used as a first input. Next a catalog of building types that represent the study zone is needed. Therefore a field survey for typify the buildings must be developed. On the survey several variables are consider: seismic demand acceleration, material of the building, number of stories, structural predominant system, state of conservation, irregularities of plant, height and shape. Then we use the methodology propose by Miranda, that use a series of βi index to produce the seismic response based on a product of βi by the spectral displacement (Sd) for the predominant period of the building, divided by the height of the building(H), to reproduce the maximum inter story drift during an earthquake:

$$\left(\frac{\Delta\delta_j}{h_j}\right) = \frac{\beta_1\beta_2.\beta_3\beta_4}{H}S_d$$

The index β1, is an modal participation factor approximation given as a function of the story number:

$$\beta_1 = \frac{3N}{2N+1}$$

The index β2, is a ratio between the approximate maximum drift (calculate as SDOF system) against the drift on real system:

$$\beta_2 = \frac{\max\left(\frac{\Delta\delta_j}{h_j}\right)}{\left(\frac{U_r}{H}\right)}$$

The index β3 is the reatio between the force response (F^x) with the over resistance of the structure (F) formulated as a function of the assign ductility (μ) for the type of structural system:

$$\beta_3 = \frac{U^x + \Delta U^x}{U} = \frac{F^x.\mu}{F}$$

The index β4 produce an approximation of the ratio between the inelastic drift and the elastic drift that provide an approximate measure of the ductility:

$$\beta_4 = \frac{\varphi_{inelastic}}{\varphi_{elastic}}$$

The estimation of the period of the structure is the base for this diagnosis, which is extremely dependant of the type of building and number of stories. Therefore the drift in each story can be approximate and by comparison of drift limits based on experimental approach, the estimation of damage level using a damage matrix will produce the reposition cost of the building.

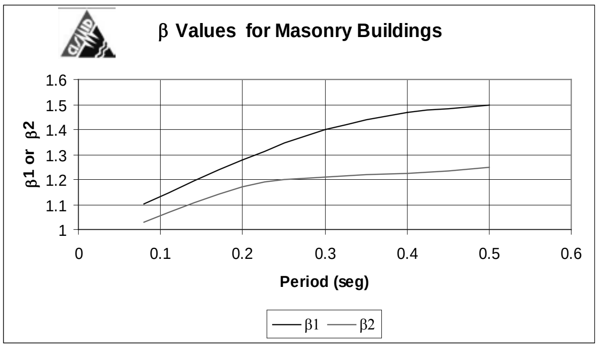

Figure 1: Values of β1 and β2 parameters

This procedure has been automated in our SRSND simulator to provide under a seismic scenario the estimation of the damage level of a city. For the βi values, multiple analysis of typical houses and ductility consideration has been calibrated with test results. Figure 1 shows the values of β1 and β2 for masonry buildings. Figure 2 presents the values of β3 factor as function of the period of the structural system considering assigned ductility (μ) of 6. Figure 3 presents the values of for β4 as function of the assigned ductility.

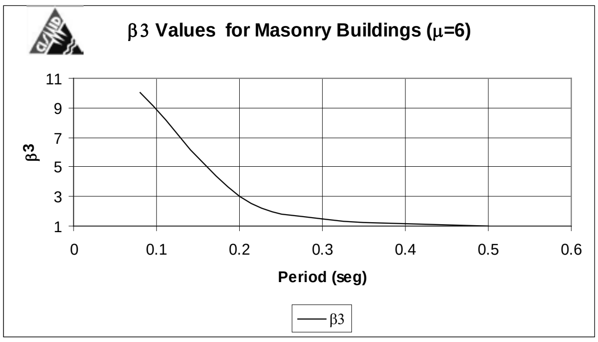

Figure 2: The β3 factor

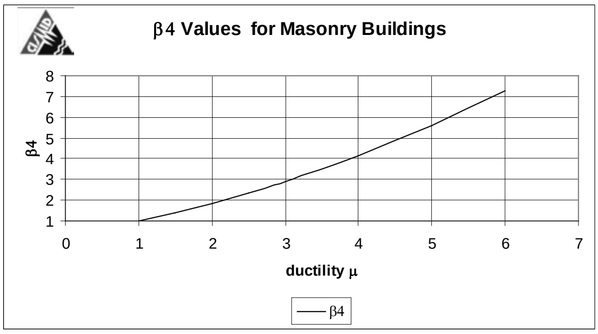

Figure 3: The β4 values as function of ductility

After the evaluation of the seismic response, the damage level can be computed using the following matrix:

Drift (Δδj/hj)	Damage Level	Occurrence
1/2000-1/1000	Non damage	none
1/800	Light damage	Initial crack
1/350	Severe damage	Diagonal open
> 1/200	Collapse	Non

3. VALIDATION OF SRSND WITH PISCO QUAKE FIELD SURVEY

On August 15th 2007 an earthquake of magnitude 8.0 Mw, stroke the south coast of Peru with epicenter at Latitude -13.49° and Longitude: -76.85° with depth of 26 Km. located 74 Km. west of Pisco city. The quake kill 593 persons, with 1,291 injured, and 48,208 collapse houses, and near 90,000 affected houses.

The authors with the support of professors and students of the Faculty of Civil Engineering of the National University of Engineering carried out a field survey on the Pisco city involved in the present report with the financial aid of Inter-American Development Bank (IDB) and World Bank (WB). Pisco city is located on the coast. However the damage characterization depends of the demand and also the site conditions where different kinds of soil profiles were found.

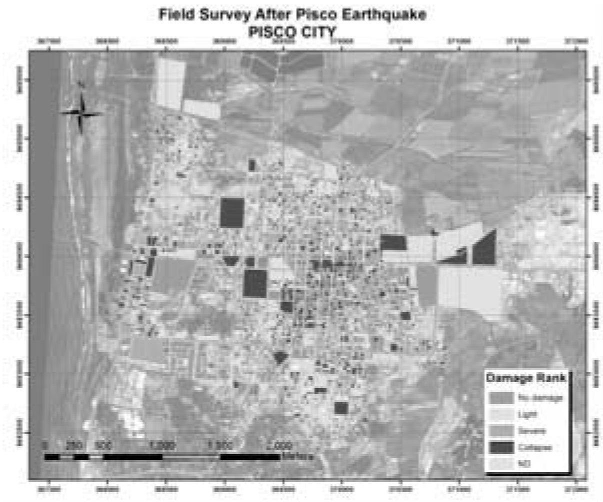

Figure 4: Results of Damage Survey in Pisco

Pisco has areas of soft soil represented by a mix of sand with gravel with high level of humidity and also a middle soil with gravel and compact sand. A campaign was developed to study Pisco city, to implement the damage characterization, and record the data on a GIS system.

Figure 4 presents the damage survey in Pisco city performed by CISMID. Here the red color represents the collapsed structures, in orange the severe damage buildings, in yellow slight damage and light green non damage structures.

Using the field survey data, the simulator SRSND performed the risk analysis results in terms of reconstruction cost using the damage matrix. Figure 3 and Figure 4 have a good agreement, showing that the simulator can emulate the response of the buildings and provide the cost of reconstruction.

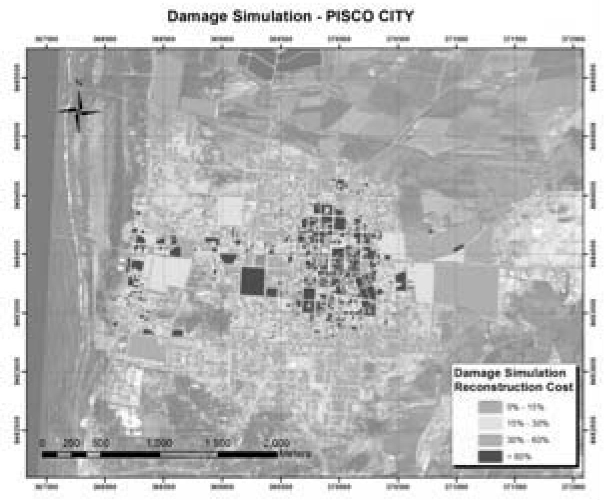

Figure 5: Damage simulation in terms of reconstruction cost

4. FRAGILITY CURVES FROM SURVEY DATA AND VALIDATION OF SRSND

In order to know the fragility of the structural systems damage under Pisco earthquake an analysis of the survey data has been performed in order to compute the probability of damage under an assigned peak ground acceleration. We must mentioned that one of our limits was the difficulty to have a representative soil profile during the quake, because the few records of after shocks and also the few stations that record these events.

Figure 6 shows the results of field survey on Pisco City, by damage for each type of material used in the city. From the total of adobe buildings, 82% collapsed, following by quincha buildings with 65% of collapse. Masonry buildings suffer less from the strike of the quake (slight damage and non damage) with 70% of them without high demand.

If we consider the total of buildings of Pisco city, Figure 7 presents the percentage considering the total number of the buildings. The adobe buildings that collapsed in the city represents 15% of the total and the masonry buildings that collapsed represents 10.7% of the total of housing.

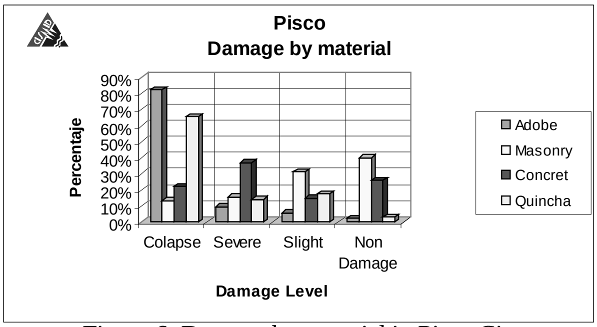

Figure 6: Damage by material in Pisco City

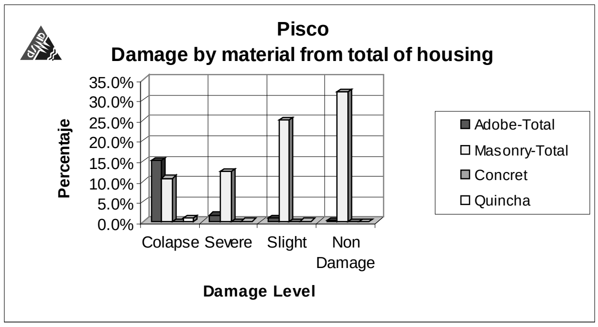

Figure 7: Damage related with total

In Pisco city the adobe structures suffer more than other materials. Also masonry buildings had less damage than the adobe but collapse in this case are more related with the soil profile and demand acceleration during the earthquake.

Mainly in Pisco city soil profile presents three big groups of peak ground acceleration: 0.42g, 0.462g and 0.588g. Under these demands buildings will experiment a probability of damage. Correlating these accelerations with the data of survey, soil profile and also material type we developed fragility curves for adobe structures and masonry structures, presented in Figure 8.

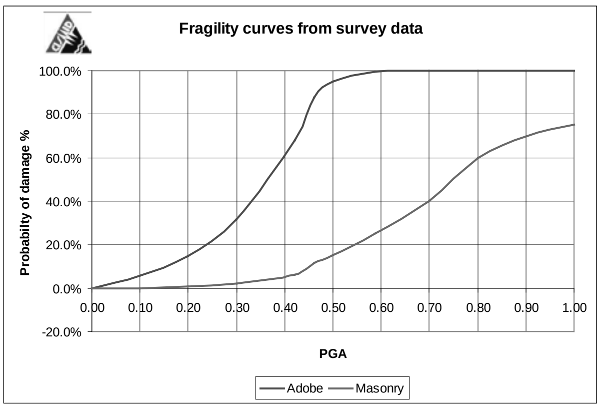

Figure 8: Fragility curves for adobe and masonry

Using these curves the probability of damage of each building can be computed. Then the results show that three groups were generated: 3118 buildings had less than 10% of probability of damage. Among 5193 buildings have a damage probability between 10 to 30 %, and 1866 buildings have a damage probability over 60%. This last situation means collapse and cost of reposition is 100%.

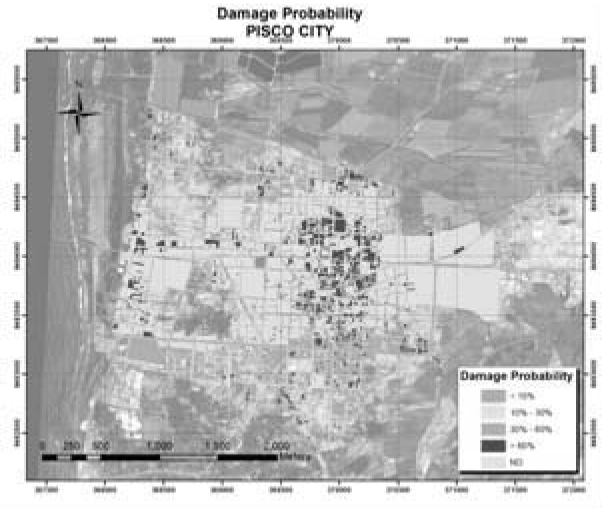

Figure 9: Damage Probability from Fragility Curves

Figure 9 presents the results of the damage probability in each building of Pisco city, considering the fragility curves presented in Figure 8. Here is possible to see the agreement with the SRSND and also the field survey results. These verified the simulation performed by SRSND and also validate the use of the developed fragility curves from survey and soil profile data.

5. CONCLUSIONS

- A simulator for the seismic response of buildings using survey data and approximation parameters βi has been presented. The simulator perform an approximate methodology based on a SDOF system that used the predominant period of the building to compute the seismic response and damage level.
- To compute the earthquake response the spectral displacement must be computed using the predominant period. Then with the use of the same parameter, the constant βi are computed for an assigned ductility. Curves for each parameter are introduced for the case of masonry buildings.
- For validation of the SRSND simulator a comparison with the damage survey after Pisco earthquake was performed. Here a good agreement among colors on Figure 4 and Figure 5, give a trustable results from the simulation
- Also survey results after Pisco earthquake is presented. Mainly the damage due to the earthquake in Pisco City has been caused by the soil conditions that may amplify the seismic waves, on building materials, like adobe, that have a bad behavior against seismic forces and construction quality that do not comply with the standards.
- As a consequence of 15/8/2007 Pisco quake, damage on housing occurs at Pisco, were the most damage construction system was the adobe walls house with 82% of collapse in Pisco.
- Masonry housing experiment less damage than adobe due to the confinement of the walls, with only 10% of collapse in Pisco.
- It is evident the correspondence between the damage levels and the soil conditions; therefore, soil profile of urban areas constitutes a very important tool for city planning and reconstruction plans.
- Damage levels were presented in a matrix related with drift values. These values can be correlated with the type of damage and also with the cost of retrofit its damage. It means the cost of restoration.
- It is demonstrated that even in a case of a strong ground motion if the masonry buildings are built following the national standards they do not collapse, given as result the safety of their occupants.

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References:

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.

CISMID-FIC-UNI. (2008). Microzoning of Tambo de Mora and Chincha Baja. Report for World Bank (WB) and FORSUR Ministry of Housing, Lima, PERU.

Journal of Structural Engineering ASCE (July 2002) .Approximate Lateral Drift Demands in Multistory Buildings with Non uniform Stiffness - Eduardo Miranda and Carlos J. Reyes.

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

Carlos Zavala y Ricardo Proaño – 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).

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