APPLICATION OF EARLY SEISMIC LOSS ESTIMATION (ESLE) IN DISASTER MANAGEMENT

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***ABSTRACT*:** To reduce the damages caused by earthquakes, scenario simulation technologies have been used in the decision-making support system. Developed by the National Center for Research on Earthquake Engineering (NCREE), Taiwan Earthquake Loss Estimation System (TELES) is designed to integrate research accomplishments on seismic hazard analysis, structural damage assessments and socio-economic impacts in Taiwan. It has been successfully used in preparing disaster mitigation plans and emergency response affairs by governments and cooperative institutions after putting lots of efforts. Furthermore, early seismic loss estimation (ESLE), based on seismic scenario database, is applied on various area including emergency response, transportation, insurance payout, etc for disaster management. In this paper, the methodology of ESLE and its application are described and its high potential on hazards mitigation and disaster management is demonstrated for a better and safer society.

KEYWORDS: early seismic loss estimation, hazards mitigation, disaster management

1 INTRODUCTION

As in Japan, earthquake is one of the disastrous natural hazards which people in Taiwan need to deal with since Taiwan is located in a seismically active region. It is necessary to have appropriate tools and strategies for damage assessment and risk management in order to mitigate seismic hazard. Therefore, the software called "Taiwan Earthquake Loss Estimation System (TELES)" was developed by National Center for Research on Earthquake Engineering (NCREE) in Taiwan to estimate potential seismic hazards, damage-state probabilities of structures and induced socio-economic losses, etc (Yeh *et al.*, 2003). The scenario-based data in seismic disaster mitigation plans for central and local governments as well as demand information for emergency response actions soon after occurrence of strong earthquakes can be provided by TELES (Lin *et al.*, 2007 SSMS). This paper intends to demonstrate the application of early seismic loss estimation (ESLE) using seismic scenario database built within TELES in the area of emergency response, rescue dispatch, rapid assessment of infrastructure and insurance payout.

2 SEISMIC SCENARIO DATABASE

When the study region is subjected to different earthquake scenarios, TELES can run in batch mode to obtain various kinds of analysis results. If the whole set of earthquake scenarios covers all the interested events with the annual occurrence rate of each scenario earthquake estimated by probabilistic seismic hazard analysis, the seismic scenario database can be built and applied in probabilistic seismic risk assessment. Furthermore, it can be used in early seismic loss estimation (ESLE) using quick queries to save computational time soon after occurrences of strong earthquakes. To build seismic scenario data base, the seismic-hazard source model and seismic source parameters in scenario database need to be carefully considered.

2.1 Seismic-hazard source model

The seismic-hazard source model is a description of the spatial and temporary distribution of earthquakes with various magnitudes and occurrence rates. In probabilistic seismic hazard analysis, there are usually three steps were involved including a. Identification of the probable seismic-hazard sources in the neighborhood of a study region. b. Selection of an appropriate ground motion model with attenuation relationships. c. The probabilistic calculation of the effect due to different seismic-hazard sources. As the fault-rupture model proposed by Der Kiureghian and Ang (1977), the known active faults are properly taken into consideration as type 1 sources. Besides, TELES focuses on simulating area sources around Taiwan at current stage for simplicity. In addition, the seismic source zoning scheme and the earthquake catalog used were similar to those used in Loh and Wen (2004). Based on the assumption of constant energy accumulation and release (Makropoulos and Burton, 1983), the upper bound magnitude in each zone can be estimated graphically. The parameters in the Gutenberg-Richter magnitude recurrence relation is also obtained by least square method or maximum likelihood method (Weichert, 1980).

Furthermore, the seismic sources can be divided into smaller grids. Assumed to be uniform within individual sub-zones or proportional to the number of historical earthquakes occurred in the grid, the annual occurrence rates per unit area of various earthquake magnitudes and focal depths in each grid can be assigned. The true annual occurrence rate of future earthquakes in each grid lies within the range of the previous bounds considering the uncertainty in earthquake occurrences and its tendency in some specific grids. However, assigning occurrence rates for earthquake scenarios on the expected annual losses of counties/towns using different rules is also applied.

2.2 Seismic source parameters in scenario database

As for seismic source parameters, the shallow and deep earthquake source zones are divided into grids with 0.2 degree intervals to establish the Taiwan seismic scenario database. Starting from lower bound magnitude to upper bound magnitude in each grid, a representative earthquake magnitude in each 0.2 magnitude interval is selected. The empirical relationship between the fault-rupture length and the earthquake magnitude is provided similar to that used in Loh and Wen (2004) since a fault-rupture model is preferred. Nevertheless, a minor modification has been made to match the observation in the Chi-Chi Taiwan earthquake in 1999. The number of fault-rupture directions ranges from one to four depending on the fault-rupture length to increase the precision of analysis results and to satisfy the assumption of type 3 sources. Besides, the fault-rupture width and dip angle are assumed to be zero and 90 degrees respectively although the other seismic source parameters can be considered in TELES. The focal depths of scenario earthquakes are assumed to be 10, 20, 30, 50, 70 and 90 kilometers as shown in Figure 1. Therefore, there are totally 105,000 scenario earthquakes defined in the database.

Therefore, the distribution of ground motion intensity and ground failure extent can be estimated through the empirical attenuation laws, site modification effects and soil liquefaction assessment models (Yeh *et al*, 2002) after defining the source parameters of scenario earthquakes. The damage state probabilities of various kinds of civil infra-structures, such as buildings, bridges and buried pipelines, can be obtained Based on the information of site-dependent ground shaking intensity and ground failure extent. All of the above-mentioned information were stored and constituted as seismic scenario database.

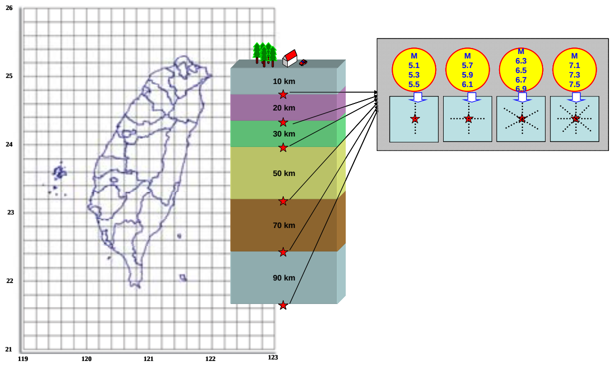

Fig. 1 Earthquake scenario definitions

3 EARLY SEISMIC LOSS ESTIMATION (ESEE) AND ITS APPLICATIONS

The Early Seismic Loss Estimation (ESLE) module in TELES was developed by the need of emergency response or decision-making support systems after earthquake (Yeh *et al*, 2003). The ESLE module is designed to be triggered automatically after receiving earthquake alerts from the Central Weather Bureau (CWB) of Taiwan. Then, the estimated loss such as damages, casualties, and insurance payout are automatically output in the form of raster maps and ready-to-use tables to reduce man-works (as shown in Figure 2). To fulfill the main goal of ESLE, the seismic scenario database described in the previous section need to be integrated in the ESLE module.

The seismic scenario database contains simulation results, such as ground motion intensity, soil liquefaction potential, amount of building damages, induced casualties or losses, and so on in each village, for scenario earthquakes with different magnitude, epicenter location and focal depth. Therefore, the only task that ESLE module remains to do when any earthquake happened is to search for analysis results that come from similar source parameters. Figure 3 shows the comparison of the assessment results caused by fault strikes with different directions.

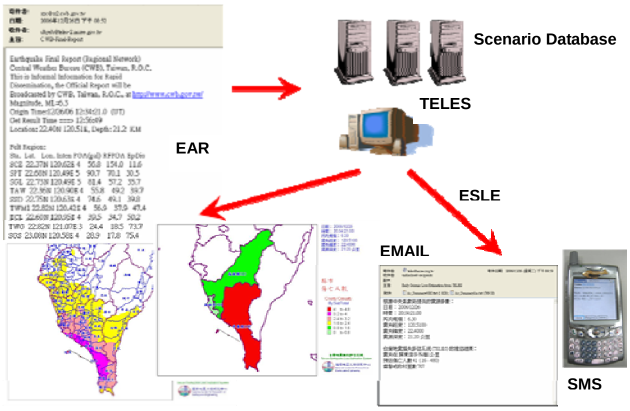

Fig. 2 Flowchart of ESLE operations

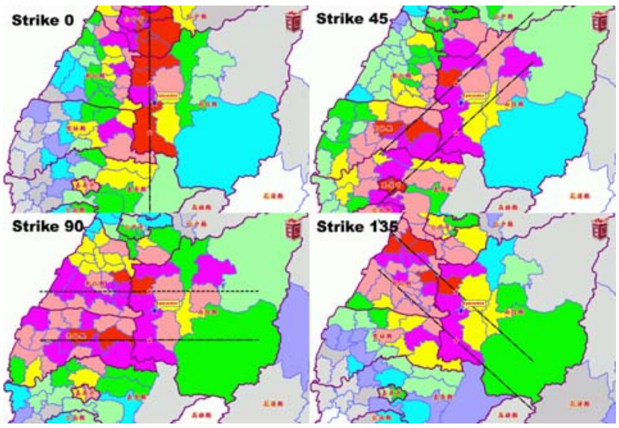

Fig. 3 The comparison of the assessment results caused by different fault strikes

The searching process of the ESLE module not only depends on the source parameters but also considers the PGA (peak ground acceleration) distribution. That is, the shake maps results produced by TELES will be compared with the records of TSMIP real-time stations within the email sent by CWB to help to choose the most possible earthquake scenario and its loss estimation result. Thus, the seismic scenario database can be used to increase the precision of analysis results and to shorten the emergency response time and at the same time.

After receiving the earthquake alert from CWB, the estimated results can be obtained within 30 seconds and TELES will dispatch the summary information automatically in simple message through mobile phone to emergency response personnel. The simple message may contain different descriptive information depends on the needs of different applications. Currently, the ESLE is applied in several applications such as emergency response, rapid assessment for bridges, and insurance loss after earthquake.

3.1 Emergency Response

For emergency response centers or decision-making support systems to properly dispatch rescue forces and medical resources to the right places after occurrence of strong earthquakes, the actual distribution and amount of damages/casualties are very important information. However, the essential facilities (i.e. the communication and electric power systems) to collect and transmit disaster data from local to central government agencies are also vulnerable in strong earthquakes. Plus, the emergency response time may be further delayed due to damages or congestions on the roads immediately after the strong earthquakes. Therefore, the ESLE was applied to save the emergency response time. When a strong earthquake ($M_L \geqq 5.5$) happened, ESLE will search for the most possible damages estimation from the seismic scenario database and then TELES will dispatch the summary information in simple message through mobile phone and email through internet to emergency response personnel automatically. The simple message may contain descriptive information such as the earthquake magnitude, the town name nearest to the epicenter, the amount of estimated casualties and the number of villages with PGA greater than 0.16g. The amount of material needed for the disaster relief such as medical teams, ambulance, shelter, food, water, etc. can be calculated and prepared. Considering the population migration patterns during different time periods, the estimated amount of casualties due to building damage or collapse can be obtained by application of total probability theory. Figure 4 shows the casualties estimation and distribution in Chi-Chi earthquake.

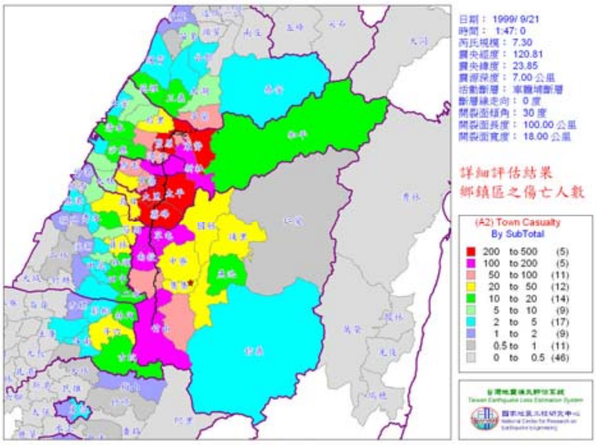

Fig. 4 Casualties estimation in Chi-Chi earthquake

The death toll estimates in different counties from ESLE are compared with those final statistics for several past events. It is observed that the total casualties estimate is predicted well. However, in some counties, the casualties may be over-estimated; while in the others, they are under-estimated. This is considered as normal in view of the large uncertainties in the analysis models. Nevertheless, the estimates are reasonable and may provide useful information for emergency responses and decision-making support systems in disaster management.

3.2 Rapid Assessment for Bridges

The rapid assessment for highway bridges after strong earthquakes is another important task. It is needed to remain the operations of the transportation facilities for the emergency response and disaster relief. The traditional method is sending out engineers to conduct visual inspection. It is a huge amount of work load since there are more than 20,000 important bridges in Taiwan. The application of ESLE on rapid assessment for bridges can save time and labor for bridge authorities after major earthquakes.

When a strong earthquake happened, ESLE will search for the most possible damages estimation from the seismic scenario database for bridges and then TELES will dispatch the summary information in simple message through mobile phone and email through internet to responsible bridge authority personnel automatically. The simple message may contain information such as the earthquake magnitude, the location of epicenter, a list of most vulnerable bridges which needed to be checked by engineers. Figure 5 shows the distribution of the damaged bridges on satellite image with the mark of earthquake fault and epicenter.

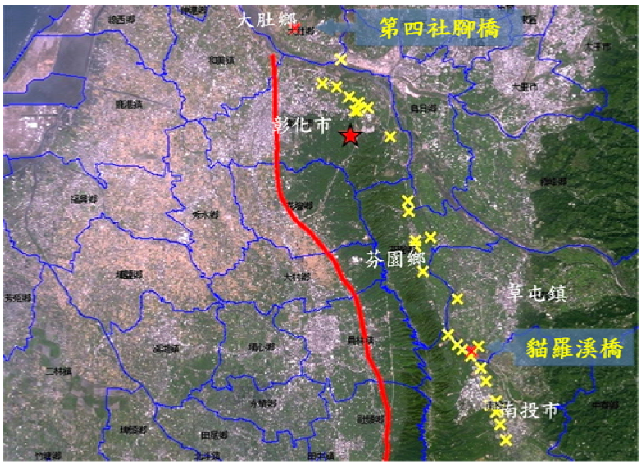

Fig. 5 Estimated distributions of damaged bridges after earthquake

When the engineer received the message, he can quickly go to check the most vulnerable bridge and take some proper action such as closing the road, planning and providing detour information. If the ESLE can be combined with road network and traffic flow analysis, then the detour information can be included in the simple message for the emergency response personnel. The ESLE can be a very useful tool for disaster management.

3.3 Insurance Payout

After 921 Chi-Chi earthquake, the residential earthquake insurance system was launched in Taiwan at 2001. The Taiwan Residential Earthquake Insurance Fund (TREIF), with a policy mission of managing, assuming and transferring earthquake insurance risk, plays an important role in this system. The fund has steadily strengthened and improved residential earthquake insurance mechanisms over the years in order to indemnify policyholders for quake-related losses quickly and effectively and fully achieves the policy functions of the insurance system.

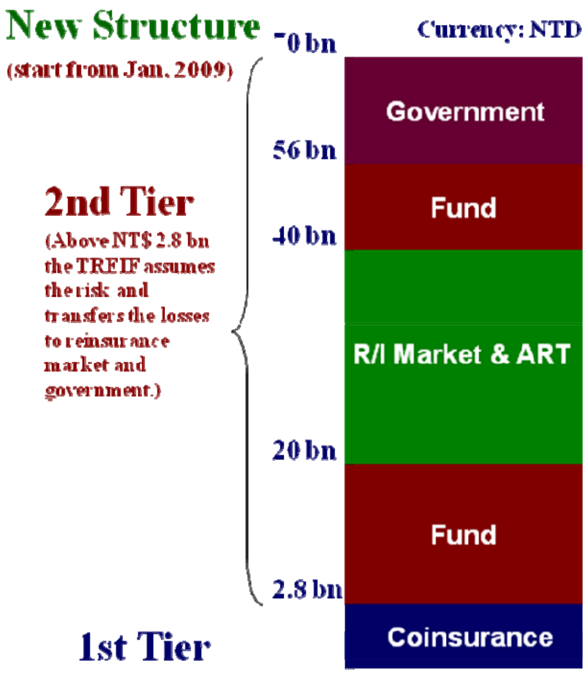

Fig. 6 The risk spreading mechanism of TREIF

Starting from 2009, the competent authority raised the limit of the risk spreading mechanism of this insurance to NT$ 70 billion in response to the growth of the cumulative liability amount under the residential earthquake insurance in recent years and forecasted liability growth trends in the future. As shown in Fig. 6, the limits for each tier are as follow:

Tier 1: NT$ 2.80 billion in risk, undertaken by the co-insurance pool. Tier 2: NT$ 67.2 billion, undertaken by TREIF and then transferred to other risk takers assumed by the domestic/overseas reinsurance markets or capital markets, TREIF itself, and government.

After major earthquakes, if the total insured loss exceed NT$ 70 billion, which is the top of the 2nd tier, the claim payments to each insured shall be reduced proportionately. Therefore, the TREIF staffs need to estimate the possible total insured loss right after any damaging earthquake so they can decide if they need to pay each insured claim in full or in portion. The ESLE was applied on TREIF to quickly estimate the total insured loss and the loss distribution for proper payout (in full or in portion) after any earthquake attack Taiwan. TELES will automatically estimate the result and dispatch the summary information in simple message through mobile phone to the staffs at TREIF after receiving the earthquake alert from CWB. The simple message may contain information such as the earthquake magnitude, the town name nearest to the epicenter, the highest intensity measured, and the estimated total insured payout.

4 CONCLUSION

Taiwan Earthquake Loss Estimation System (TELES), which is integration of research accomplishments on seismic hazard analysis, structural damage assessments and socio-economic impacts in Taiwan, has been used to help governments and cooperative institutions in preparing disaster mitigation plans and emergency response affairs successfully. Furthermore, early seismic loss estimation (ESLE), based on seismic scenario database, is applied on various area including emergency response, transportation, insurance payout, etc for disaster management. The applications of ESLE provide its high potentials on hazards mitigation and disaster management for a better and safer society.

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