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Earthquake Damage Assessment System for New Taipei City

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ABSTRACT

Over the past few decades, there have been many examples of earthquake damage and associated structural damage. These experiences have shown that the impact and economic losses caused by earthquake disasters are serious and far-reaching. In order to help the government initiate rapid early emergency responses to reduce the losses from earthquake disasters and to enable earthquake disaster situation simulation, an earthquake damage assessment system has been constructed. Based on the current disaster assessment model, this study deduces the post-earthquake disaster situation from the grid information and enables a more flexible and convenient follow-up by providing a simple operation interface that can be easily expanded. This system can be used by local governments to develop relevant earthquake disaster relief responses.

1. INTRODUCTION

Taiwan is situated on the Ring of Fire, between the Eurasian and Philippine Sea tectonic plates, and interpolate earthquakes occur frequently on the island every year. New Taipei City is located in Northern Taiwan and has an area of approximately 7.5 times that of Taipei City. A large number of its transport facilities and public buildings are inevitably under the threat of a devastating earthquake. Earthquakes have caused considerable structural damage worldwide in recent years, and this hazard can have a severe and lasting socioeconomic impact.

Because of Taiwan's location in a seismic zone, the epicenter of earthquakes in the nation is often close to land and urban areas, and the extremely short advanced warning time currently achievable demonstrates the importance of seismic disaster prevention. Although earthquake engineering methods (e.g., aseismic design, base isolation, and seismic vibration control) effectively mitigate seismic hazards,

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nonengineering methods such as disaster prevention planning and risk dispersion can supplement disaster resistance at community levels and improve the functionality and performance of earthquake relief efforts. If an effective earthquake damage assessment system can be constructed, hazardous scenarios can be simulated before an earthquake occurs. Relevant prevention and relief efforts can then be developed accordingly, including effective implementation of disaster prevention, disaster relief, accident handling, disaster investigation, and reconstruction. In addition, when an earthquake occurs, such a system can immediately retrieve the seismic report data from Taiwan's Central Weather Bureau (CWB) database and quickly estimate related seismic hazards, aiding post-seismic emergency response and effective disaster relief.

This study performed a regression analysis on the attenuation relationship based on the peak ground acceleration (PGA) of earthquakes with magnitudes >5.0 recorded at strong motion stations in Taiwan from 1990 to 2003. The territory of Taiwan was divided into grids through mesh generation to estimate the PGA value of each grid using the PGAs of adjacent strong motion stations. Information such as the number of collapsed buildings and casualties within each grid was calculated according to each grid's number of public and private buildings and population data. To estimate the post-seismic damage to Provincial Highway bridges, fragility curves were calculated according to regression analysis on data relating to these bridges. The assessment system developed in this study also collected abundant information in its database, including the population, number of public and private buildings, and key facilities (e.g., hospitals, police and fire stations, power plants, and gas stations). This study incorporated the object-oriented technology (OOT) in the system architecture design and implementation to enhance computational performance, extensibility, and data output and to make the interface friendly. The entire system is centered on the estimation program, and other elements that control the system operation include the data model, calculation core, interface extensibility, and visual display.

For the system implementation, Microsoft Windows was used as the operating system, the .NET Framework was used to construct this system and MySQL was adopted to deal with the database problem. This system is integrated with MapWinGIS that offers users GIS (Geographic Information System) service. The interface to extend system functions used IronPython as the scripting language for users to do program coding for system extensions. The visual presentation of the seismic analysis results comprises the number of collapsed buildings in each grid, number of casualties in each grid, number of dysfunctional bridges, and estimated post-seismic status of key facilities. The research outcome may serve as a reference for disaster drills and early stage post-seismic emergency response organized by the government.

2. EXISTING EARTHQUAKE DISASTER PREVENTION SYSTEM OF NEW TAIPEI CITY

The population of New Taipei City is 3.97 million and the population density is 1934.47 people/km^2. New Taipei City has a special environment that includes the Shanchiao fault; this belongs to the second type of activity fault and has a total length of about 74 km. In addition, according to the Central Geological Survey of the Ministry of Economic Affairs, the Luzhou, Sanzhuang, Xinzhuang, and Banqiao districts are listed as high potential areas for soil liquefaction, and the seismic site effects of the Taipei basin have a long vibration time and a high strength. Therefore, if an earthquake occurred near the metropolitan area of the fault, it would likely cause serious casualties and economic losses.

As a result of the 2016 Taiwan earthquake, in which the Weiguan Jinlong building collapsed in Tainan City, 117 people were killed, and 501 people were seriously injured, twelve bureaus of New Taipei City jointly developed a plan for earthquake prevention and relief work on June 20, 2016 to improve the earthquake disaster prevention system and strengthen the disaster prevention performance.

3. ESTABLISHMENT OF AN EARTHQUAKE DISASTER ANALYSIS SYSTEM

Based on the aforementioned, this study developed the earthquake damage assessment system (EDAS) for New Taipei City. The data required to implement EDAS comprises the basic information of key buildings and bridges at all administrative levels, the population data for each grid, GIS layers of fill areas and of soil liquefaction potential, data of connecting CWB's earthquake rapid reporting system, GIS layers of the administrative subdivisions in New Taipei City, and house tax records in New Taipei City.

The software architecture of EDAS is designed to enable plug-in modules. The design can perform estimations using various computing modules according to data integrity or parameter configuration. In addition, plug-in modules can increase the system's applicability and enable system customization, with subsequent calculations or applications of the plug-in modules enriching the flexibility of the system. The visual presentation of EDAS provides grid maps of New Taipei City and operating functions for basic layers that enable navigation and data retrieval. The ESRI shapefile format is the standard format of EDAS and is compatible with other GIS data.

This study constructed EDAS on Microsoft Windows using C#, an object-oriented programming language. EDAS employs an ActiveX component, MapWinGIS, and the PROJ.4 library to draw maps and manage GIS operations of maps. Besides, EDAS is integrated with IronPython, enabling users to write Python programs to extend the functions of EDAS. Finally, Windows Presentation Foundation (WPF) was used to develop a friendly graphical user interface and to facilitate the visualization of map data and related information.

4. CASE STUDY

This study used EDAS to perform pre-seismic and post-seismic analysis for a New Taipei City as a case study. Because EDAS can estimate seismic damage according to seismic data provided by the CWB earthquake repaid reporting system, this study retrieved the seismic data of an actual earthquake detected by CWB to carry out a post-seismic damage estimation.

4.1 Pre-earthquake simulation

The following simulation estimates the damage to different types of buildings and the important buildings and bridges in the villages of New Taipei City assuming a magnitude 6.5 earthquake with a depth of 5 km occurring at 12 A.M. on 2018/01/01 in the Yelan Offshore area (Coordinate Location: 121.8°E, 25°N). The estimated results are shown in Fig. 1, Fig. 2.

This study used the EDAS system for the example case study of New Taipei City. Because the system can be connected to the Central Weather Bureau earthquake warning system to access archival earthquake data and follow-up disaster estimation operations, this study will extract a disaster estimate from the seismic data released by the Central Weather Bureau's seismic express system for use in the post-earthquake simulation case.

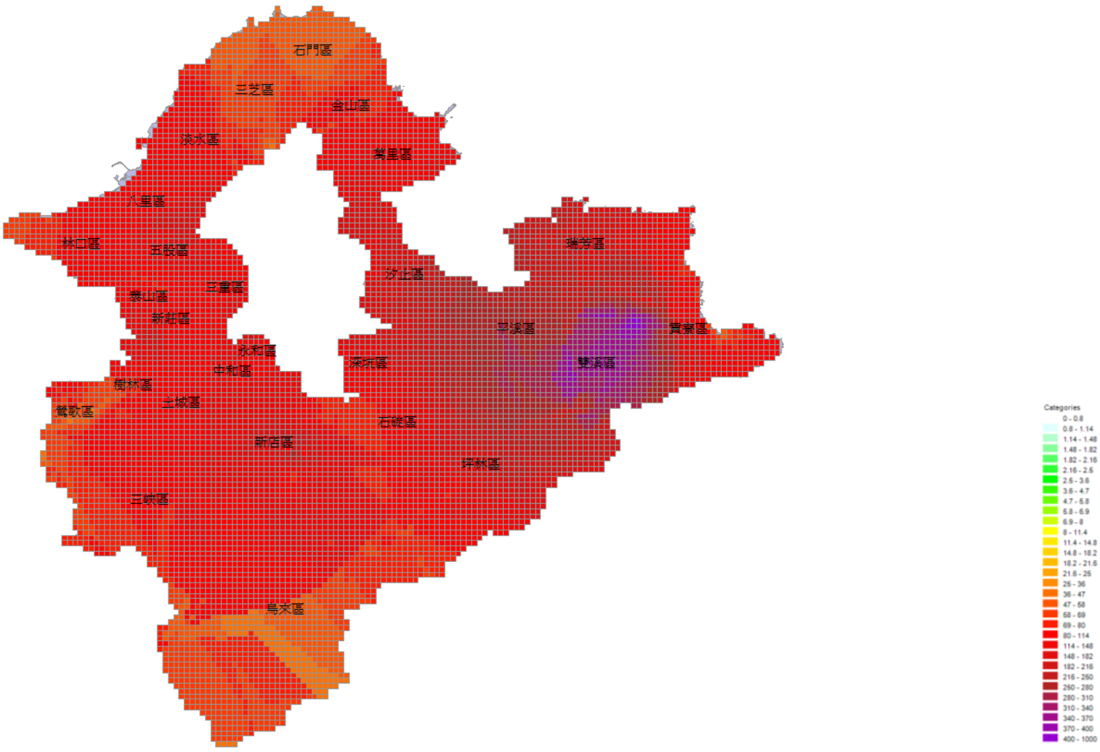

Fig. 1 PGA distribution of the simulated earthquake

The numerical examples have illustrated that the proposed finite elements could be very useful for geometrically nonlinear analysis as well as free vibration …

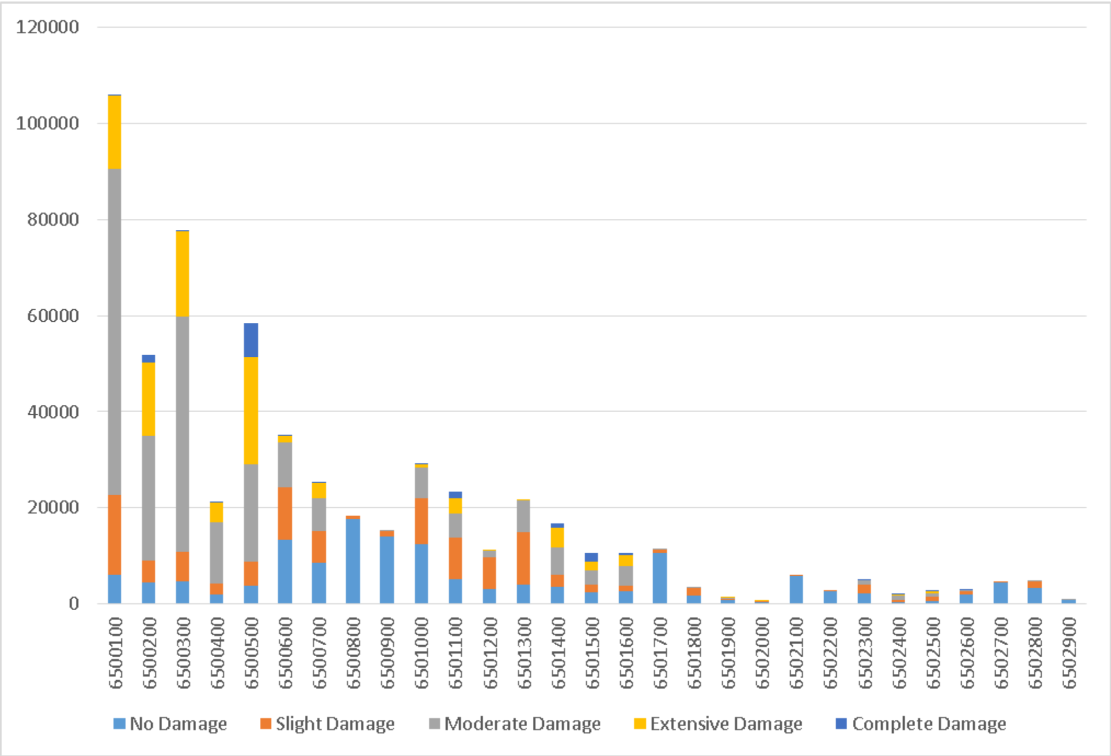

Fig. 2 Damaged building distribution for the simulated earthquake

4.2 Post-earthquake simulation

In addition to seismic simulation of the attenuation law of each station, EDAS uses the real PGA published by the Central Weather Bureau to replace the calculation result of the stations to simulate seismic disasters. This section summarizes the information recently obtained by the Central Weather Bureau. The seismic data received by the Central Weather Bureau are as follows: Time: 2016/5/11 11:17:15; Seismic position: 121.98°E, 24.69°N; Richter magnitude scale: 6.1; Seismic depth: 8.9 km.

After the system receives the seismic data, it automatically starts to analyze the disaster situation in New Taipei City. The PGA is estimated by the actual PGA of the station measured by the Central Weather Bureau. The results are shown in Fig. 3 and Fig. 4.

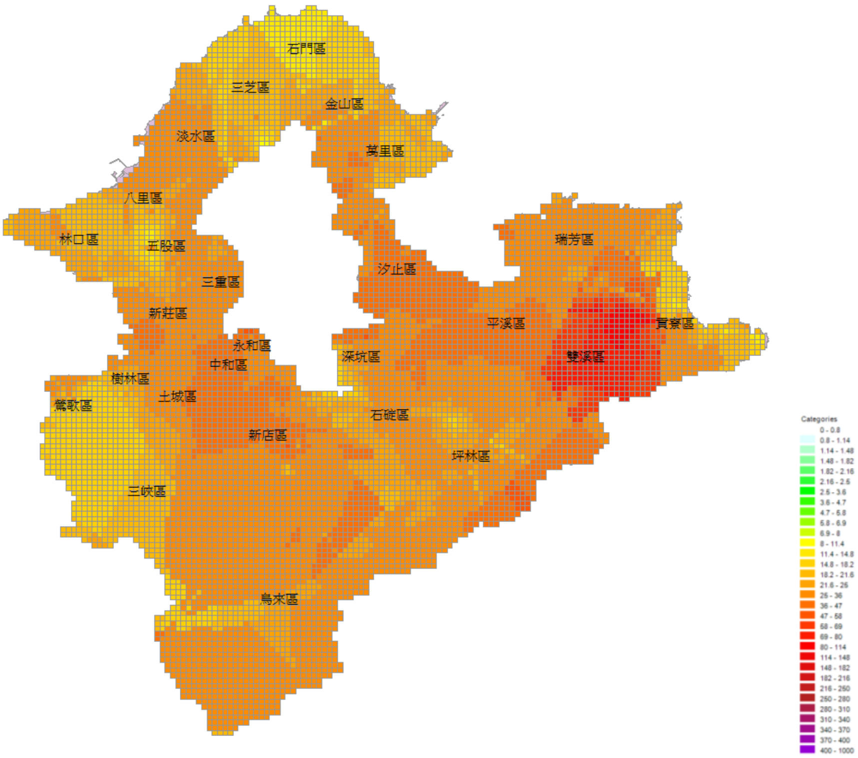

Fig. 3 PGA distribution of the earthquake

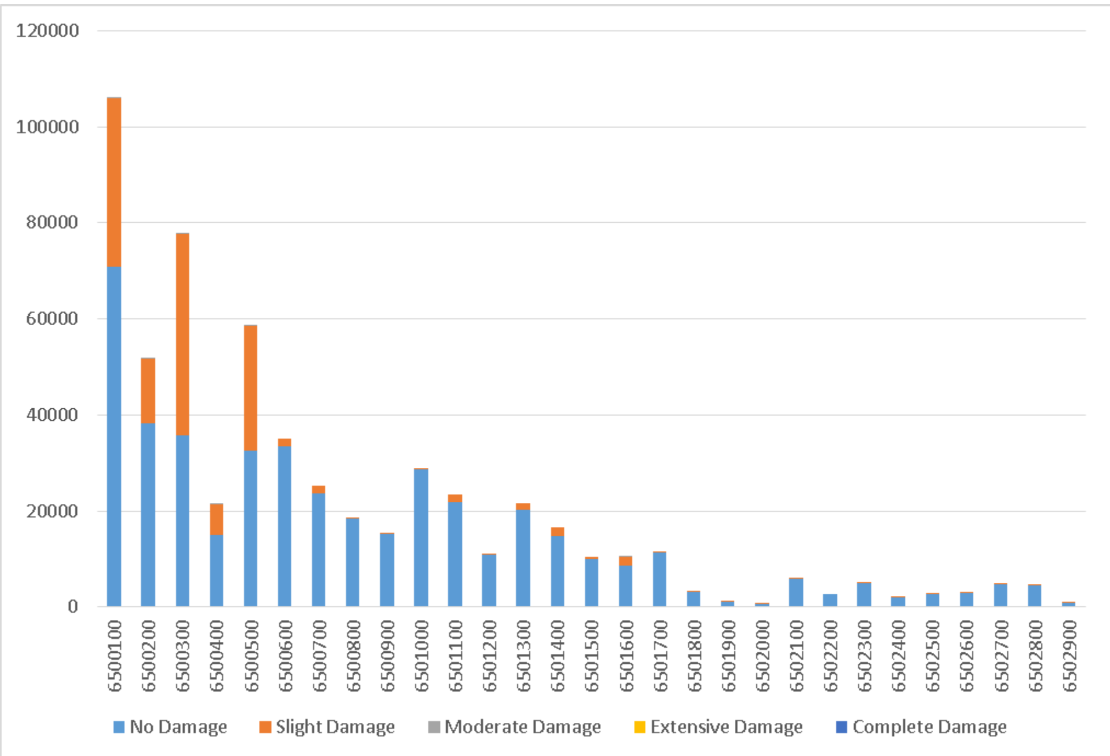

Fig. 4 Damaged building distribution for the earthquake

From the above analysis, it can be seen that the system developed by the institute can obtain seismic data immediately after the earthquake, and then automatically analyze the PGA value of the station published by the Central Weather Bureau. In addition, to support local emergency disaster relief units, the New Taipei City government will also carry out seismic assessment and reinforcement, road and bridge safety assessment, disaster relief material transport route planning, and other emergency responses to the system forecast results, as the earthquake disaster response center start time, the establishment of the level, the standard operation procedures for the emergency mobilization mechanism.

4. CONCLUTION

(1) In this study, the PGA in each grid was compared with that published by the Central Weather Bureau to verify the accuracy of the attenuation law regression formula. The results of the comparison show that the parameters of the surface acceleration attenuation law of each station should be in accordance with the practical application.

(2) Based on the current disaster assessment model, this study deduces the post-earthquake disaster situation from the grid information, and makes the follow-up expansion more flexible and convenient by the simple operation interface and the easy expansion structure.

(3) The EDAS established in this study is developed using object-oriented technology, and the analysis results are visualized using a rich database. Not only are the results able to reduce the complicated steps of disaster recovery, they can also be used by the government as a pre-disaster and early emergency response exercise.

(4) In this study, taking New Taipei City as an example, the earthquake disaster loss assessment is carried out through simulation of different earthquake events. As a result of the assessment of the damage to public buildings and bridges, the relevant units will be able to formulate regional disaster prevention plans and provide information for the fire protection program

(5) After the completion of the analysis, the results can be published via websites, mobile phone newsletters, and so on, to inform the disaster relief unit personnel to support related post-earthquake relief operations. And according to the local government earthquake disaster prevention system needs, it can support the expansion of disaster relief operation procedures for the system in line with the requirements for customization. In this study, the PGA in each grid was compared with that published by the Central Weather Bureau to verify the accuracy of the attenuation law regression formula. The results of the comparison show that the parameters of the surface acceleration attenuation law of each station should be in accordance with the practical application.

REFERENCES

Kanai, K., (1961). “An empirical formula for the spectrum of strong earthquake motions”, *Bulletin of the Earthquake Research Institute,* **39**: 85-95.

Campbell, K.W., (1981). “Near-source attenuation of peak horizontal acceleration”, *Bulletin of the Seismological Society of America,* **71**(6): 2039-2070.

Joyner, W.B. and Boore, D.M., (1981). “Peak horizontal acceleration and velocity from strong-motion records including records from the 1979 imperial valley, California, earthquake”, *Bulletin of the Seismological Society of America*, **71**(6): 2011-2038.

Liu, K.S. and Tsai, Y.B., (2005). “Attenuation relationships of peak ground acceleration and velocity for crustal earthquakes in Taiwan”, *Bulletin of the Seismological Society of America,* **95**(3): 1045-1058.

Yeh, C.H., (2003). “Taiwan Earthquake Loss Estimation System – TELES”, *National Center for Research on Earthquake Engineering Report*.

Sung, Y.C., Hsu, C.C., Hung, H.H. and Chang, Y.J., (2013). “Seismic Risk Assessment System of Existing Bridges in Taiwan”, *Structure and Infrastructure Engineering*, **9**(9), 903-917.