Seismic Response Analysis of selected sites in Wenxian urban area, China

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SUMMARY:
Seismic response, referred in this paper is the primary research of seismic microzonation and based on various related parameters. In order to get more scientific and reasonable ground motion parameter microzonation, a great deal of data are collected and coordinated. By using topographic survey, seismic exploration and soil sample test, 2D and 3D model are created based on Wenxian mesa where the aftershock records obtained and showed obvious amplification on mesa top. The results of 3D model are uncertain due to many complicated factors and 2D model has got a good match with the observation. Seismic response analysis of four 2D models of the river valley cross section corresponds with the general observation that mainly the low-rise buildings were damaged during 2008 Wenchuan earthquakes. The study method in this paper can be used as a basis for seismic microzonation mapping.

Keywords: Seismic response, Earthquake observation records, Topographic effect, Seismic microzonation

1. GENERAL INSTRUCTIONS

Seismic microzonation is the first and most important step towards a seismic risk analysis and mitigation strategy in densely populated regions (Slob, 2002). To this end, a project on seismic microzonation is conducting in Wenxian urban area, Gansu China, where suffered from the deadly earthquake (Ms 8.0) in 2008 and distributed in the intensity of VIII. Due to very close to the Longmenshan Faults zone, a series of aftershocks have hit the region, even there has been a tremendous challenge (Ms 5.4 earthquake) in Nov.1, 2011. In order to get more scientific and reasonable ground motion parameter microzonation, a great deal of data (borehole data, geophysical surveys, laboratory tests and seismic records et. al) are collected and coordinated. Seismic response, referred in this paper is the primary research of seismic microzonation and based on various related parameters.

2. BACKGROUND

2.1. Seismic geologic conditions

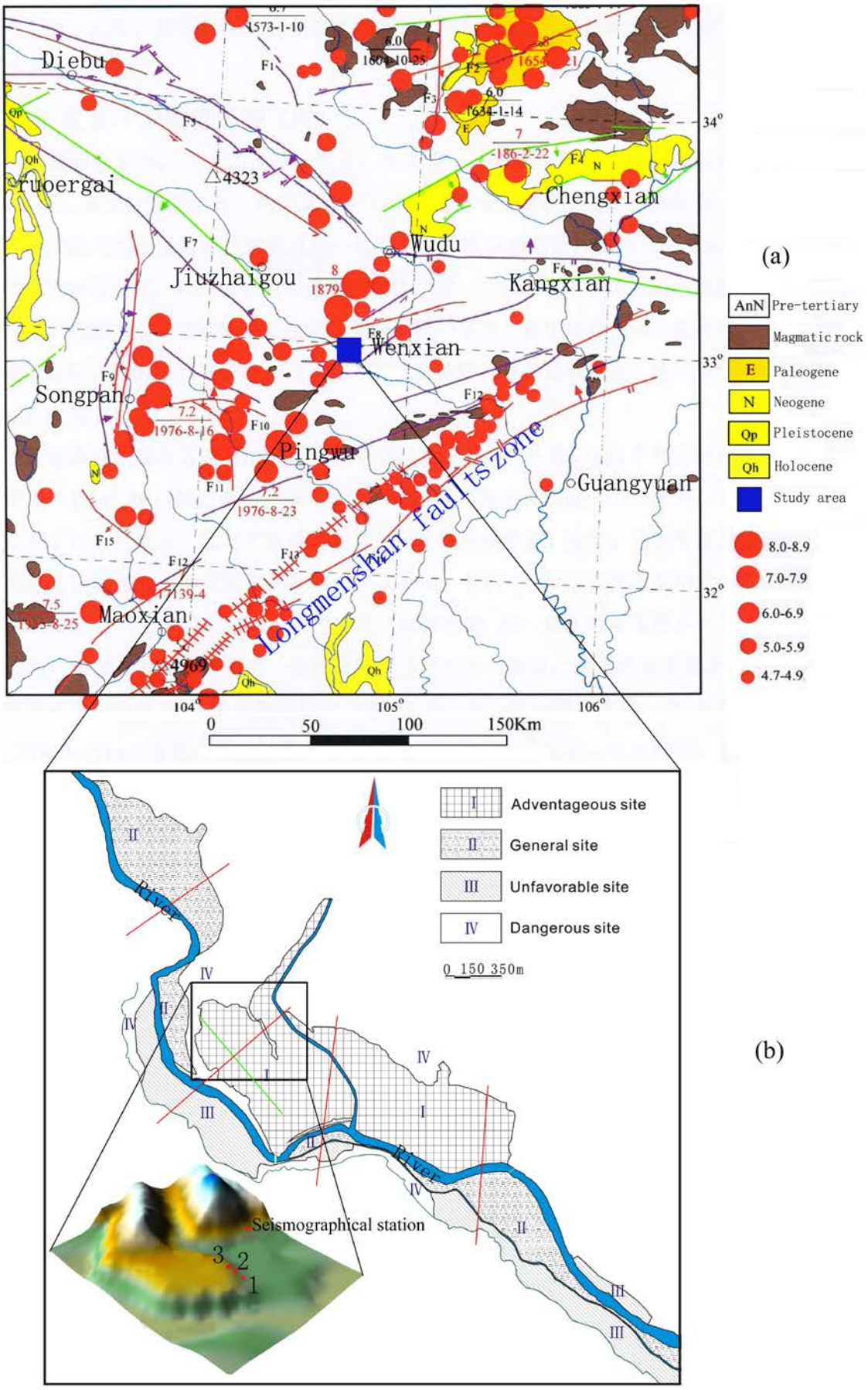


Figure 2.1. Seismic geology map (a) around Wenxian unban area and it's enlargement (b)

Wenxian, nestling among the hills, is located in the extreme south of the Gansu province, where belongs to the Qinling mountains, the elevation varies between 550~4187m, and the complex terrain alternate arduous hill and deep valley, the general trend of this area decreases from northwest to southeast. Wenxian sit in a seismic zone named Longmenshan faults zone, where earthquakes is characterized by high frequency and large magnitude. Figure 2.1(a) shows a map of seismic geology of a 150-kilometers area around Wenxian. Figure 2.1(b) shows an enlargement of Wenxian urban area. There are two of them scaled M 8 in 68 earthquakes (M≧5.0) recorded within 150 km of the study area from 186 BC to March 2010 (Earthquake epicentres are shown in Figure 2.1(a)), the intensity of Wenxian urban area were Ⅶ and Ⅹ when M 8 earthquakes occurred respectively in South Tianshui and in South Wudu. On May 12, 2008, a deadly earthquake measured Ms 8.0 broke out in Wenchuan County, Sinchuan China, and caused serious loss to Wenxian County also. Nowadays the seismicity in Wenxian County is considered to be strong.

There are two geomorphic units in Wenxian urban area: Strong crust raising middle & high mountain area and the stripped valley area. The main geomorphic skeleton structure is dominated by the former, while the later is composed of river terrace, high floodplains and ancient slide et al, whereabouts of living, farming and industrial areas. There are four types of construction site in our study areas showed in Figure 2.1(b).

2.2. Seismic records

A few days after the Ms 8.0 Wenchuan earthquake, 2008, the workers of Seismic Bureau of Gansu province deployed a temporary array of 3 three-component geophones on a mesa near the rock seismographic station in Wenxian County (Figure 2.1(b)). Nine (M≧4.0) of many aftershocks were recorded on No.1, No.2 and No.3 stations across the mesa, which is actually the north terrace of Baishuijiang River. Maximum ground motions were recorded at station No. 3 at the top of the mesa for nine out seven earthquake events (Lu, 2011).The strongest aftershock measured Ms 5.7 caused the highest peak ground motions at the top edge of the mesa station No.3 in both horizontal and vertical directions. Besides those records above mentioned, A Ms 6.4 earthquake was recorded on No.1 and No.2 on May 25, 2008. In this study, we choose three seismic records (see Table 2.2) on the rock seismographic station from three earthquakes (Ms 8.0, Ms 6.4 and Ms 5.7) as input to analyze the seismic response on the mesa.

Table 2.2. Seismic records for three earthquakes

Event (m/d/yr)	Magnitude (Ms)	Distance from the epicentre (km)	Did the seismic station get records?			
			Bedrock seismographic station	No.1 station	No.2 station	No.3 station
05/12/2008	8.0	249	Yes	No	No	No
05/25/2008	6.4	72	Yes	Yes	Yes	No
05/27/2008	5.7	88	Yes	Yes	Yes	Yes

3. SEISMIC RESPONSE ANALYSIS

3.1. Method of analysis

3.1.1. Introduction of seismic response model

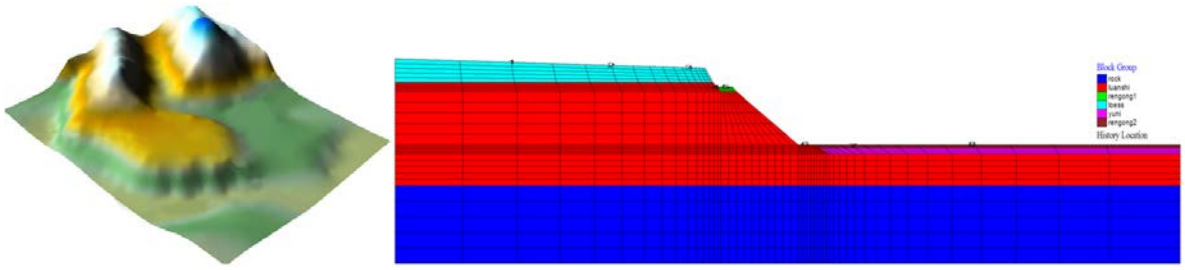
The temporary array is deployed across the southeast end atop the mesa about 40 m high (Yao, 2009). According to geological survey, the upper 11m is identified as consisting of loess and silty loam, underneath which from 11 m to 30 m is consisted of alluvial deposits. The mesa site studied in this paper is one of the important areas in urban construction plan of Wenxian County. As a part of the work of resuming production and rebuilding after the Wenchuan earthquake, the seismic microzonation of Wenxian urban area is under way. In order to get more scientific and reasonable

ground motion parameter microzonation, a great deal of data (borehole data, geophysical surveys, laboratory tests and seismic records et al) are collected and coordinated. So we take all the geological and geotechnical data advantages into our seismic response model. Due to limited space, the detailed geological and geotechnical data in whole Wenxian urban area will not be described in this paper.

3.1.2. Analysis of seismic response in selected sites

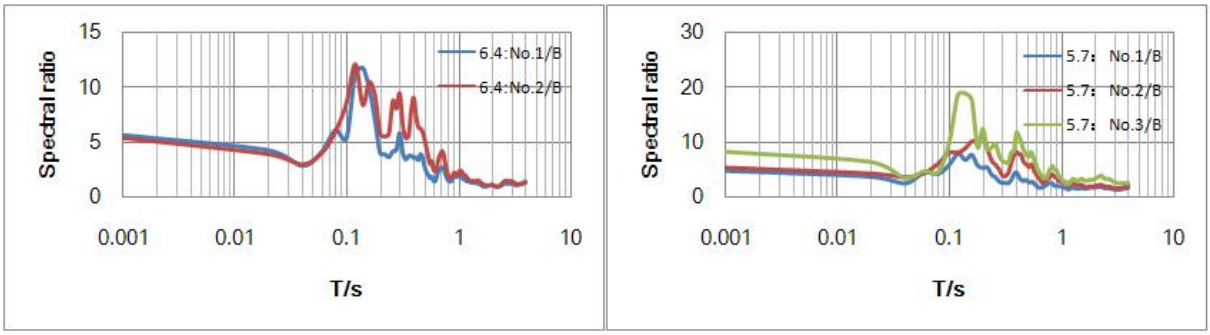
In our study, several plain sites in middle valley are selected to analyze and compare the characteristics of the seismic response on different type sites by 1D Soil model. Since topographic effects on seismic waves have received increasing interest as a result of some observations of large amplification on hill tops combined with the importance of some of the structures typically built on elevated topographies, especially in hilly area, such as south of Gansu province. Comparing to observation records, the result of 1D model analysis are unreliable due to the complex terrain. Therefore, 2D and 3D models (see Figure 3.1) are created based on Wenxian mesa where the aftershock records obtained by using topographic survey, seismic exploration and soil sample test.

We conducted a seismic field experiment in order to study topographic effects of Wenxian mesa on seismic ground motion. The field site provided a data set that used to evaluate the response of the mesa to dynamic seismic-wave input and to determine areas of the mesa and degradation in response to topographic amplification. According to aftershock records analysis (Lu, 2011) in Wenxian mesa, peak ground motions in all cases are the highest for motions in nearly N-S direction and larger than motions in nearly E-W direction, so are the seismic spectrum. We evaluated the spatial variation of ground across the mesa by comparing the spectral ratio of the recordings at No.1, No.2 and No.3 station with the bedrock station. Distinct resonance at all stations is observed between 0.1-0.2 s in N-S direction (Figure 3.2). For the analysis of the seismic response of the Wenxian mesa, the N-S component records of three earthquakes (Ms 8.0, Ms 6.4 and Ms 5.7) at the seismographic station are selected as input bedrock motion. Figure 3.1 shows 3D (a) and 2D (b) models of the Wenxian mesa. When inputting the bedrock seismic motion, the similar amplifications of ground motion on the mesa are presented by the 2D calculation (green line in Figure 2.1(b)), and the results of 3D model are uncertain in our study. There are still certain disparity between theoretical model and the actual condition due to many complicated factors. Consequently, 2D model is adopted in later analysis.



(a) (b)

Figure 3.1. Models of the Wenxian mesa (a) 3D; (b) 2D

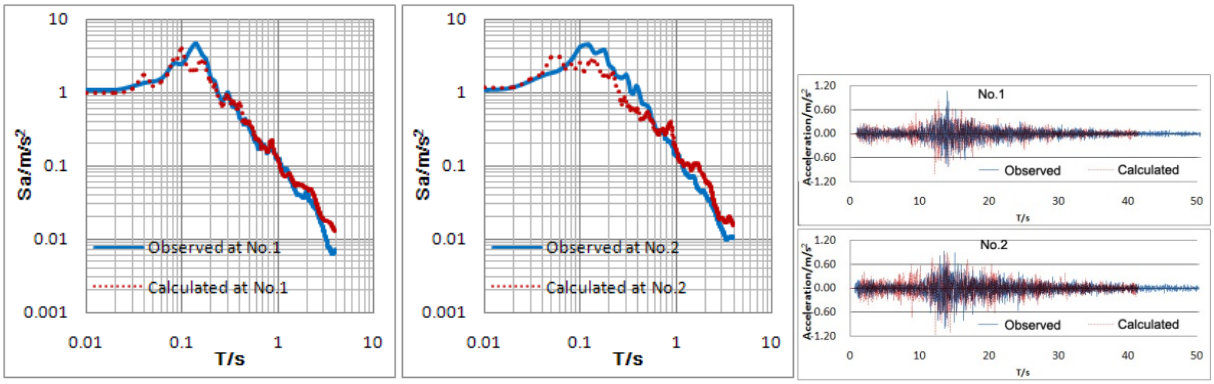


(a) Ms 6.4 (b) Ms5.7

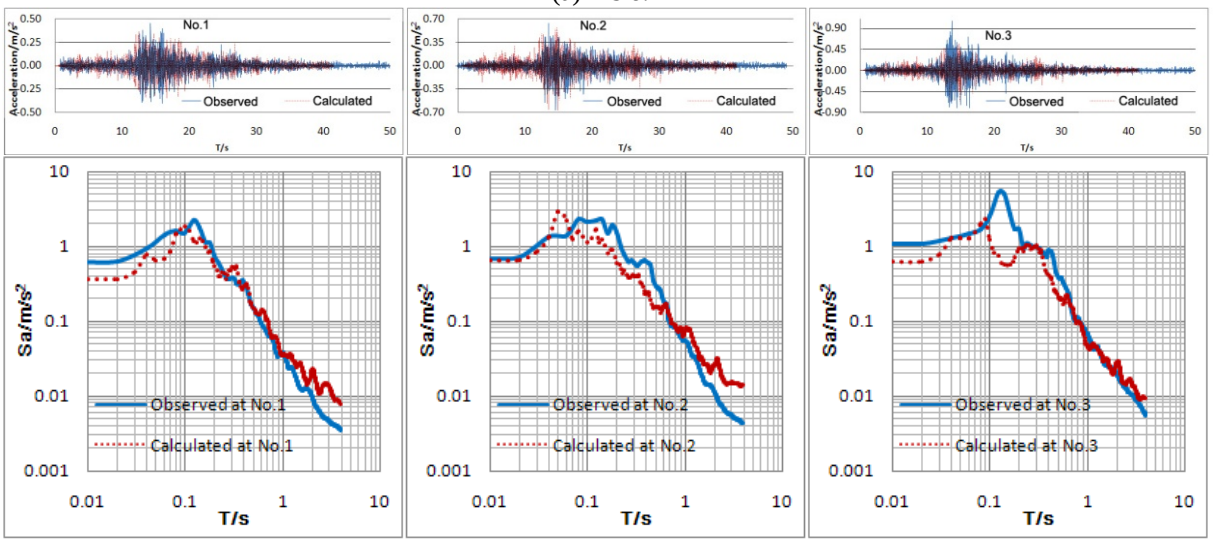
Figure 3.2. Spectral ratio of the N-S component from Ms 6.4 (a) and Ms 5.7 (b)

3.2. Comparison of the observation and calculation

Since ground motions are recorded on the Wenxian mesa during Ms 6.4 and Ms 5.7 earthquakes, we simulate the seismic response on it by inputting the corresponding bedrock ground motion. Figure 3.3 shows comparison of acceleration time histories and response spectra in the N-S component from observation and calculation, solid lines indicate the observed data, while dotted lines indicate the analytical results. The simulated results agree well with the observed data, what confirm that the analytical model is capable of modelling the behaviour of the actual mesa topography.



(a) Ms 6.4



(b) Ms5.7

Figure 3.3. Comparison of acceleration time histories and response spectra in the N-S component from observation and calculation

4. DISCUSSION

In order to get hold of the seismic response of all kinds of engineering geological units in Wenxian urban area, four 2D models of the river valley cross section (red lines in Figure 2.1(b)) are created, and analysis of seismic response is simulated under three ground motion inputting (Ms 8.0, Ms 6.4 and Ms 5.7). According to the seismic signal that was recorded for Ms6.4 and Ms 5.7 earthquakes, the value of acceleration response spectrum is exceptionally high between 5-10 Hz (0.1-0.2 s) range (Figure 3.2), which generally corresponds to the natural frequencies of houses with about 1-2 stories (Slob, 2002). So Figure 4.1 presents the spatial distribution of the spectral accelerations for 10 Hz and 5 Hz in Ms 5.7, Ms 6.4 and Ms 8.0, respectively. In brief, this study indicates that the 2 stories buildings are higher affected by earthquake than 1 story in Wenxian urban area.

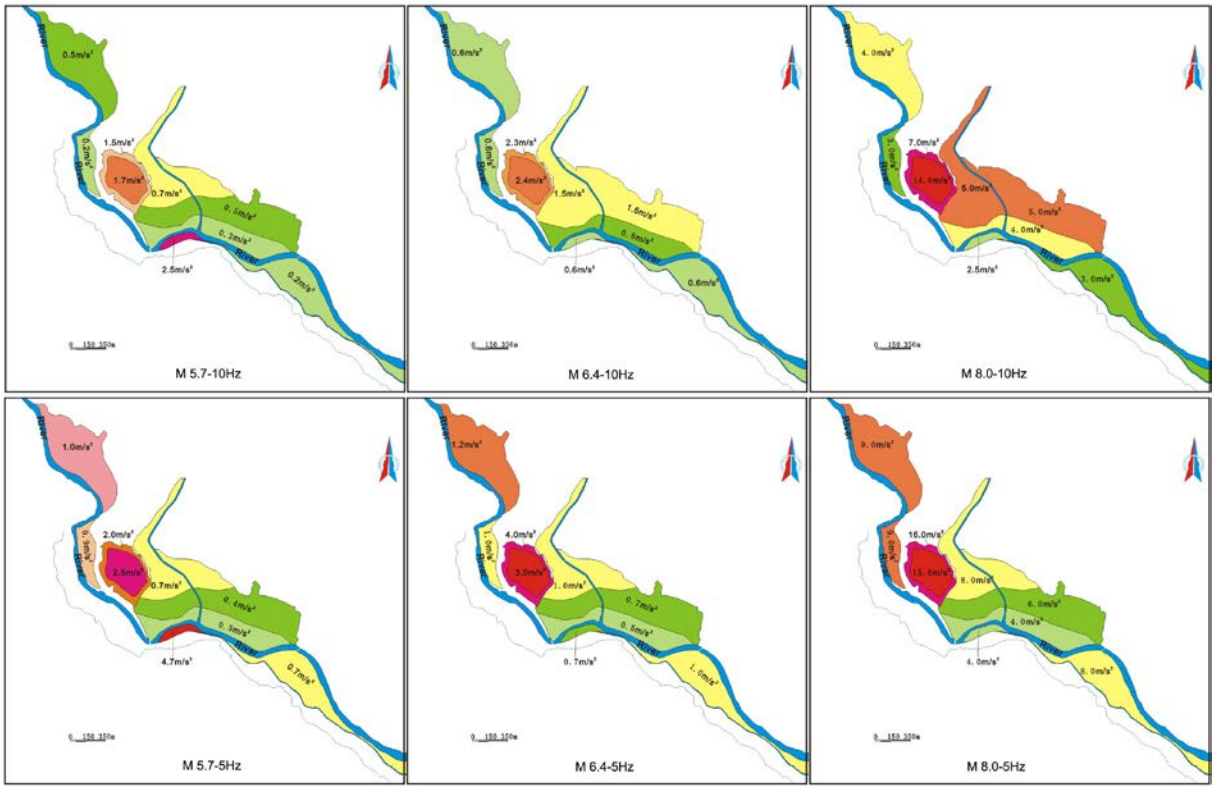


Figure 4.1. Spatial distribution of the spectral accelerations (in m/s^2) for 10 Hz (three upper figures) and 5 Hz (three bottom figures) in Ms 5.7, Ms 6.4 and Ms 8.0, respectively

5. CONCLUSIONS

(1) Wenxian model should be adopted in seismic response analysis of valley sites or seismic microzonation in complex terrain area. Seismic response of soil sites with topography lead to amplification and deamplification of the resulting ground motion, and the amount of variation is the diversity of the media and the irregular topography the result of joint action (Pedersen, et al.,1994; Bouchon, et al.,1996; Buech, et al., 2010; Lu, et al., 2011). In this study, the results of 3D model are uncertain due to many complicated factors and 2D model has got a good match with the observation, so 2D model can do the business in Wenxian ground motion parameter microzonation. On the basis of the GIS model including geotechnical, geomorphological and geological information, and the integration of the seismic response of mathematical model, it is possible to obtain a detailed delineation of the spatial variation in seismic responses, which can be used as an improved basis for seismic microzonation mapping.

(2) Wenxian mesa, one of the important areas in urban construction plan of Wenxian County provided a data set that used to evaluate the response of the hill to dynamic seismic-wave input and to determine areas of the hill and degradation in response to topographic amplification. Analysis in this paper corresponds with the general observation that mainly the low-rise buildings were damaged during 2008 Wenchuan earthquakes.

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REFERENCES

Bouchon, M. and Barker, J. S. (1996). Seismic response of a hill: The example of Tarzana, California. *Bulletin of the Seismological Society of America*. 86:1A, 66–72.

Buech, F., Davies, T. R. and Pettinga, J. R. (2010). The little red hill seismic experimental study: Topographic effects on ground motion at a bedrock-dominated mountain edifice. *Bulletin of the Seismological Society of America*. 100:5A, 2219-2229.

Lu, Y., Liu, K., Yao, K., Shi, Y. and Li, Q. (2011). Analysis on seismic records observed on shangcheng Platform in Wenxian, Gansu Province. *Northwesten seismological Journal*. **33:Supp.**, 393-397.

Pedersen, H., LeBrun, B., Hatzfeld, D., Campillo, M. and Bard, P.Y. (1994). Ground motion amplitude across ridges. *Bulletin of the Seismological Society of America*. **84**, 1786–1800.

Slob, S., Hack, R., Scarpas,T., Bemmelen,B. and Duque, A. (2002). A Methodology for seismic microzonation using GIS and SHAKE –A case study from Armenia, Colombia. *Proc 9th congress of the International Association for Engineering Geology and the Environment: Engineering geology for developing countries*. 2843-2852.

Shi,Y. and Lu, Y. (2009). The damage features of Wenchuan 8.0 earthquake in Gansu disaster area and countermeasures of reconstruction. *Northwesten seismological Journal*. **31:1**, 1-7.

Yao, K., Lu, D. and Liu, X. (2009). Using observational data from the aftershocks of Wenchuan great earthquake to study the influence of geography on peak ground acceleration. *Northwest Seismological Journal*. **31:1**, 46-50.