Evaluating the Seismic Hazards by Chang-Hua Fault at Nantou County, Taiwan and Disaster Resistant Strategy

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Abstract. Because of geology and complex seismic source mechanisms, Taiwan suffers attacks of earthquake calamity. In this research, we investigate the seismic hazards caused by Changhua fault and focus on the hazards at Nantou County, Taiwan. The PGA and spectral intensities, SIs, including acceleration, velocity, and displacement (Sia, Siv, and Sid), are employed to estimate potential damages. The maximum seismic intensity will occur at Ming-Chien town and the buildings at Caotun Township and Nantou city will be destroyed seriously. The part of freeway 3 which connects Caotun Township and Nantou city has to be paid more attentions to prevent the destructive fractures. Based on the predicted seismic hazards, the best way to reduce the losses of lives and properties of people is preparing a well-rounded mitigation plan in advance. When an earthquake occurs abruptly, a community-based approach to establish an excellent self-aid and mutual-aid system is an efficient method for reducing the casualties. It requires a community-wide effort over a long period of time for making the community comfortable and safe. A detailed process of a community-based mitigation plan for the seismic hazards is discussed in the paper.

1. Introduction
In the past decays, there were many devastating earthquakes hit Taiwan and caused serious damages. The largest earthquake in Taiwan was Chi-Chi earthquake 1999, which began as a reverse thrust slip event along the Chelungpu fault, with significant surface breaks of approximately 85 km and vertical displacements of 1–8 m [1]. It not only claimed the lives of more than 2000 people but led to the economic losses about 9.2 billion. It is deeply miserable lesson for central Taiwan. Unfortunately, there still exist many active faults, for example Chang-hua fault and Tachia fault, and some blind faults distributed in central Taiwan. Therefore, the reasonable estimations of seismic hazards by a potential earthquake are very essential to disaster prevention. Kao, et al. [2] used the genetic algorithm for deducing peak ground acceleration attenuation relationships in southwest Taiwan. By their results, the PGA can be detected by epicentral distance for a specific station. Wang et al. [3] established Taiwan earthquake model (TEM) to assess the seismic hazard and risk for Taiwan. In the meanwhile, Lee et al.[4] employed probability method to evaluate seismic activities will occur in central Taiwan. By deterministic way, Ueong [5] found that the three-parameter SI system, Sia, Siv, and Sid were effective indexes for evaluating earthquake risks of buildings with specific natural periods. Liao, et al.[6] combined the seismic source models and spectral intensity to adequately measure the wide-range...
frequency bands of buildings shaking from a seismic wave due to a potential earthquake in central Taiwan. Based on the evaluation of the potential earthquake’s risk, the disaster prevent plane should be offered. Daines [7]. Perry and Lindell [8] though that the crucial points of risk managements were planning, training and written planes. Godschalk, et al. [9] suggested the disaster prevention planes and the implementation of strategies had to be discussed and operated well by all the members in community. Pearce [10] indicated the participations of community in the mitigation plane is the right as well as the sharing of responsibilities. Culture of prevention, standing losses and building back better are three characteristics of the disaster prevention community described by UNISDR [11]. Recently, most of the researches indicate the community-based plans and practical operations are the most important steps to prevent the people from the attacks from disasters. In this study, The seismic hazards by the method in Earthquake hazard in central Taiwan was evaluated using the potentially successive 2013 Nantou Taiwan earthquake sequences [6], and then mitigation plan was proposed by community to reduce the losses in the potential earthquake.

2. Methods

The acceleration spectrum $A(f)$ of the seismic wave at a distance $r$ from a fault with seismic moment $M_o$ is defined as [12][13]

$$A(f) = CM_S S(f) e^{-\frac{\pi f t_0}{Qf}} \frac{C}{r}$$

(1)

where $R_{mm}$ is the radiation pattern, $FS$ is the free surface amplification effects, $PRTITN$ is a constant, and $\rho$ and $\beta$ are the density and the shear wave velocity. $S(f_r, f_s)$, represented as source spectrum, is treated as a $\omega^{-2}$ model

$$S(f_r, f_s) = \frac{(2\pi^2)^{1/2}}{1 + (\frac{f_r}{f_s})^2}$$

(3)

where $f_r$ and $f_{max}$ in equation 3 are the corner frequency and the high cut-off frequency, respectively. $P(f_r, f_{max})$ represents attenuation of high frequencies at near site and is expressed as

$$P(f_r, f_{max}) = \left[1 + \left(\frac{f_r}{f_{max}}\right)^{1/2}\right]$$

(4)

The seismic wave $\text{As}(t)$ from the subfault $(i, j)$ on the fault plane can be calculated by the above process. Joshi et al. [14] modified the envelope function $e_{ij}(t)$ to get the acceleration recording $a_{ij}(t)$ as the product of the $\text{As}(t)$ with envelope function $e_{ij}(t)$

$$e_{ij}(t) = T_{ss} \times \left[\frac{1}{T_d} \times e^{(1-\frac{1}{T_d})}\right]$$

(5)

the $T_d$ represents the duration time and $T_{ss}$ is the transmission coefficient of incident shear waves.

$$a_{ij}(t) = A_{ij}(t) \times e_{ij}(t)$$

(6)

Finally, the wave propagation from the subfault to the observation point, respectively, represented as

$$A_{NS}(t) = \sum_{t_i=1}^{N} \sum_{t_j=1}^{N} a_{ij}(t - t_{ij})$$

(7)

$$A_{EW}(t) = \sum_{t_i=1}^{N} \sum_{t_j=1}^{N} a_{ij}(t - t_{ij})$$

(8)

where $t_{ij}$ is the delayed time.

The averaged SIs are averaged acceleration, velocity, and displacement SIs (SIa, SIv, and SId). Their definitions are

$$SIa(\epsilon) = \frac{1}{T_2 - T_1} \int_{T_1}^{T_2} S_a(\epsilon, T) dT$$

(9)
\[
SIv(\varepsilon) = \frac{1}{T_4-T_3} \int_{T_3}^{T_4} S_v(\varepsilon, T) dT 
\]

\[
SId(\varepsilon) = \frac{1}{T_6-T_5} \int_{T_5}^{T_6} S_d(\varepsilon, T) dT 
\]

where the parameters \( T_1 \)–\( T_6 \) can be dependent on the size of the earthquake and height of the buildings, and the spectral acceleration, velocity and displacement denoted as \( S_a(\varepsilon, T) \), \( S_v(\varepsilon, T) \) and \( S_d(\varepsilon, T) \). The spectral velocity and acceleration have the following relationships

\[
S_a(\omega, \varepsilon) = \omega S_v(\omega, \varepsilon) = \omega^2 S_d(\omega, \varepsilon) 
\]

3. Seismic hazards analysis

The Chang-Hua fault located at western Taiwan as shown in Figure 1. It passes through Chang-Hua city with massive population and Chang-Hua county along Bagua Mountain. Last movement of the Chang-Hua fault was on Dec. 3, 1848, indicating it hasn’t moved over 170 years from now, thus the seismic hazards must be evaluated by an effective method precisely.

![Figure 1](image1.png)  
**Figure 1.** the active faults in central Taiwan. The figure cited from [4].

![Figure 2](image2.png)  
**Figure 2.** the PGA distribution in the central Taiwan.

In this research, the PGA and spectral intensities SIs are estimated as indexes to evaluate the damages in Nantou county, Taiwan. Here, we assume the magnitude of the potential earthquake is 7.2 induced by the Chang-Hua fault. The PGA and SIs are demonstrated in Figure 2 to 5, respectively.

![Figure 3](image3.png)  
**Figure 3.** the SIa distribution in the central Taiwan

![Figure 4](image4.png)  
**Figure 4.** the SIv distribution in the central Taiwan

![Figure 5](image5.png)  
**Figure 5.** the SId distribution in the central Taiwan
4. Results and Discussion

From the estimated results in Figure 2 to 5, the following results can be summarized as follows:

1. The PGAs distributed around Caotun, Mingjian, Nantou, Zhongliao, Chushan and Lugu towns are quite large, it is equivalent to intensity 7 which is the maximum of seismic intensity defined in Central Weather Bureau (CWB) of Taiwan. The earthquake-induced hazards in these areas may cause landslide, large-scale rupture on the road surface, electric power outrages, knocking out water supply system and cutting off the communication system.

2. The height of most of the buildings in Caotun, Mingjian, Nantou, Chushan and Lugu towns are under 5 floors which is about 15m. If the S1a which corresponds to 1-6 floors exceeds 400 cm/s², the building’s damage will be caused. From figure 3, the values of S1a in these areas are larger than the threshold, therefore, the buildings in these areas warrant serious attentions.

3. The S1v corresponds to the height of building with 7-21 floors. Based on the figure 4, it is obvious that the building with 7-21 floors located at Nantou city may be damaged. Addition, the part of the freeway 3 connecting Caotun and Nantou may be heavily destroyed, so their maintenance and reinforcement are essential.

4. The S1d corresponds to the height of building taller than 21 floors. The emergency response plans for evacuation, the disaster prevention exercises, and the building inspections are crucial to safeguard people’s lives and property.

5. Disaster Prevention Strategy

According to the Federal Emergency Management Agency [15], disaster management can be categorized into four stages: (1) Prevention/Mitigation, (2) Preparedness, (3) Response, and (4) Recovery. The relationships between the four stages can be shown in Figure 6 [11].

![Figure 6: the key elements of disaster risk management](image)

Actual operation and practised training are based on the members in community. When the potential earthquake occurs, how the people can survive himself and then help each other to save other’s lives are very important. Because of the potential seismic disaster, the corresponding prevention strategy is divided into the four stages.

1. Mitigation step: (1). Setting up a disaster office in the community to deal with the things correlated with disaster prevention (2). Give the disaster prevention courses and scenario-based trainings to the members in community (3). Install the early warning software of CWB to obtain the new earthquake information and make an effort to get the escaping time (4). Loud speaker and battery power are available.

2. Preparedness step: (1) Divide the members in community into four teams, including first aid team, search and rescue team, protection team, fire and safety team [16] (2). Place and fasten objects at
proper position to avoid damaging people (3). Reinforcement of the buildings in the community by civil engineer is necessary (4) Invite the experts to discover the disaster-causing factors in the community (5). Based on the disaster-causing factors, discussing and making a disaster map is required to everybody in the community (6). An earthquake emergency kit must be prepared well (7). Find a suitable and open place that a family can gather together and communicate each.

3. Response step: (1) Remember “Drop, Cover, and Hold on” in the earthquake (2) When the shaking stops, look around. If there is a clear path to safety, leave the building and go to an open space away from damaged areas. (3) Pay attentions to the news boarded by the government to understand the newest variations around the environment (4). Passing the part with high potential hazards in freeway 3 when the earthquake occurs, you have to stop the car right now and leave it, hiding yourself beside the car. (5) Start the protection mechanism of the four teams in the community (6) Provide assistances to the disabled, elderly and people in need firstly (7) Be careful for aftershocks, which are normal following an earthquake.

4. Recovery: (1) After the main shock, when you come back home, you have to examine utility lines and appliances for damage. Due to broken gas lines, damaged electrical lines or appliances, the most common earthquake-related hazard, fire, could be released. (2) Open the windows and turn off the main gas valve, if you smell gas. (3) Assess the destructiveness of the building if some cracks have appeared in beams and columns apparently (4) Do not believe the rumors come from unreliable sources, no matter who repeats it.

6. Conclusion
In this research, I access the damages of the buildings with wide-ranged periods due to the potential earthquake caused by Chang-hua fault. From the results, the buildings in Caotun, Mingjian town and Nantou city may be destroyed severely. Besides, the part of freeway 3 connects Caotun town and Nantou city may be collapsed. The way to reduce the losses is designing a community-based disaster prevention plan and then faithfully implementing it. Based on the four stages of disaster management, I reorganize materials related the potential earthquake disaster prevention. The cooperation of the members in community as practised in the plan is necessary, and how to evaluate the effects of the execution in the next topic.

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