Variation on Loss Estimation Due to Taipei Basin Effects

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ABSTRACT :

Earthquake ground motions are strongly affected by regional and local site conditions. The intermediate and long period ground motions are especially sensitive to the basin effects. The most recent set of attenuation equations, the Next Generation of Attenuation (NGA), have recognized the basin effects and devised parameters to account for such effects. However, the basin formulation in the NGA equations does not capture the special complexity of any individual conditions. The particular detail of how a basin affects ground motions can have dramatic effects on ground motions and therefore on the damage potential of earthquakes. In view of this, we have conducted a study on the Taipei basin and its effects on earthquake losses in Taipei region. We used the available detail information on Taipei basin response to ground motions to estimate the damage and loss potential of earthquakes.

KEYWORDS:

Taiwan earthquake, basin effects, strong ground motions, loss estimation, seismic hazard.

1. INTRUDUCTION

The strong influence of site conditions that affect ground motion has been recognized and studied for several years (Field, 2000). Many researchers have identified the correlations between strong ground motion parameters and geology/site classifications. During the last decade, many authors have studied and documented the effects of basins on earthquake ground motion. They have developed complex numerical models to simulate the complex natures of the strong-motion wave propagation in basin (Graves, 1998; Day et al. 2006). More recently, Lee and others (Lee et al, 2008) simulated a 3D amplification effect in the Taipei basin by using a composite Finite-Difference method. The March 31, 2002 Hualien, Taiwan earthquake demonstrated the importance of the basin, local soil conditions, and critically reflected seismic-wave from the Moho on earthquake ground motions and damage potential in the Taipei region. The Hualien, Mw 7.1 earthquake caused only minor damage near its epicenter area, but significantly greater damage in the Taipei region, roughly 100 kilometers from the epicenter. In this study we demonstrate industrial loss variation due to basin depth and site effects, using a stochastic 10k simulated Taiwan earthquake catalog and loss simulation algorithms developed at AIR Worldwide Corporation.

2. TAIPEI BASIN AND VARIATION ON GROUND-MOTION AMPLIFICATIONS

The Taipei metropolitan area is located on top of an alluvium basin filled with Quaternary unconsolidated sediments overlying the Tertiary basement (see Figure 1a). Previous analysis of site effects in the Taipei basin showed that amplification at long and short periods can be correlated to the areas of sedimentation and near basin edges, respectively (Chen 2003). Since last decade, the Central Weather Bureau (CWB) of Taiwan has employed a nationwide strong-motion network, which accurately recorded the 2002 Hualien earthquake in northern Taiwan. As shown in Figure 1b, recorded Peak Ground Acceleration (PGA) values around the Taipei basin vary by a factor of four (Chen 2003; Loh et al. 2003). For this event, the Taipei basin exhibited large amplifications caused by critically reflected S-waves from the Moho and amplification of soft shallow sediments, as well as basin effects. Figure 1b compares a typical attenuation relation developed for offshore events by Atkinson and Boore (2003) and Youngs et al, (1997) with the recorded ground motion of the 2002 Hualien earthquake.

3. RECENTLY DEVELOPED EMPIRICAL ATTENUATION RELATIONS AND RESULTS OF A NUMERICAL BASIN EFFECT SIMULATION

Ground motion attenuation relations play an important role in regional hazard analysis. In this study we use the "Next Generation of Ground-Motion Attenuation Models" (NGA) relations for ground motion analysis. The NGA project developed new ground motion prediction relations through a comprehensive and highly interactive research program. The NGA ground motion models were developed for shallow crustal earthquakes in the western United States and similar active tectonic regions worldwide. These models are based on an expanded database of recorded ground motion, and benefit from an exhaustive effort to make the set of equations scientifically robust. NGA equations address the issue of basin effects by implementing the most recent numerical simulation results by Day and others (Day et al, 2006) who carried out a comprehensive series of 3-D basin response simulations for deep sedimentary basins in southern California (Power et al, 2008). For the Taipei Basin, Lee and others, using a composite grid method, demonstrated that the complex Taipei basin geometry and fairly low velocity of the Songshan formation resulted in extraordinarily strong shaking and amplification in the western part of basin (Lee et al, 2008).

4. TAIPEI-BASIN EFFECT ON INDUSTRIAL LOSS VARIATION

We conducted a study to evaluate the earthquake losses in the Taipei region with and without considering the basin effects. We evaluated the importance of the detail of the basin effects on loss analysis in Taipei. In order to keep a realistic spatial distribution of industry exposures, all AIR industrial exposures in Taipei basin have been redistributed into a fine grid exposure of 0.2 kilometers within the Taipei basin (20km x 17km). The NGA attenuation equation accounts for a sediment (basin) depth variation as well as local site conditions. First, we conducted a loss estimation analysis using only the NGA relation without considering the Taipei basin effect. In the second trial, Taipei sediment depth variations, reported in the Lee study, are considered. According to Lee et al (2008), Taipei basin depth varies from a few meters to eight–hundred meters in the western part of basin (Figure 2). We found that the level of predicted ground motions by NGA show an overall basin effect for this region and, according to Campbell and Bozorgnia (2008), the basin depth effects are almost close to unity up to 3 kilometers (Figure 3). In order to capture extraordinary Taipei basin amplifications that have been quantified for short and long periods as factors of 2 and 3 by Lee et al (2008) for a narrow band in western Taipei basin, we defined a band that makes the maximum contribution for abnormal ground motion amplification. Furthermore, we applied a variation of basin amplification factors keeping ratio between high and low frequency factors constant, to predicted ground motion by the NGA. Since Taipei basin amplification factor is function of input ground motions, we apply basin factors for intermediate and large magnitudes which have a potential contribution for creating considerable losses in the region. Figure 4 shows the spatial distribution of average annual industrial losses in the Taipei Basin using the NGA relations. For easy interpretation, the Taipei basin depth-contour map is included in the figure. Using reported basin and Songshan formation amplification factors in the western Taipei basin with some variation (Lee et. al., 2008); we find that there is a significant increase in average annual loss distributions in the western Taipei basin. Following Table shows results of each scenario and its effects on average annual loss variation for this region.

Table 4.1 Basin amplification factors for narrow band in western Taipei basin used in this study

Scenario	Basin Factor (High- & low frequencies)	Average Annual Loss Factor
1	NGA (no basin Factor)	Base case (1)
2	(2.0; 3.0)	7.6
3	(1.7; 2.5)	4.3
4	(1; 1.5)	1.5

5. RESULTS AND DISCUSSIONS

It has been well recognized that local site conditions and young sedimentation played a major role when deriving abnormal levels of ground motion in intermediate to long structural periods. During the past two decades, numerous of studies have explained the physical behavior of basin and local site conditions subject to weak and strong seismic waves. However, there is still uncertainty in quantifying basin effects on loss variation due to the basin's geometry, local soil variation, and earthquake source characteristics. In this study, taking advantage of the most recent empirical ground motion relations (NGA) and the results of numerical ground motion simulations for basin effects, we have conducted a loss analysis study for the Taipei region. Due to a depth-to-sediment variation less than 800 meters, overall basin effects captured by NGA relations cannot address very high amplification trends in the narrow west band of Taipei basin. This abnormal amplification appears in the region with a basin depth of 200 meters, with a very low velocity of Songshan formation. Similar anomalously amplification concentrated in Santa Monica basin in California during the 1994 Northridge earthquake suggesting that the basin substructure caused localized amplification of seismic waves by focusing the seismic-wave energy. However, the geometry and velocities of the geological structure are uncertain, therefore, the empirical relations as well as the NGA could not able to account for a special localized abnormal basin amplification. Using most recent Taipei basin information, we captured the spatial distribution of average annual industrial losses in the Taipei region. Furthermore, we applied variations on levels of expected amplifications for short and long structural periods that address uncertainty in basin location and geometry. The quantitative basin amplification factors, which include surface waves generated from S-wave and the northwestern edge of the basin boundary and focused upon the deepest part of the basin, represent large-amplitude waves due to basin reverberations with noticeable wave radiation toward the east and south of Taipei basin. We found that the average annual loss distribution from the 10k stochastic catalog for the Taipei region (the western part of Taipei basin) increased significantly by a factor of 1.5 to 4. This emphasizes the importance of basin and local site effects on a realistic picture of the seismic hazard in the Taipei metropolitan area.

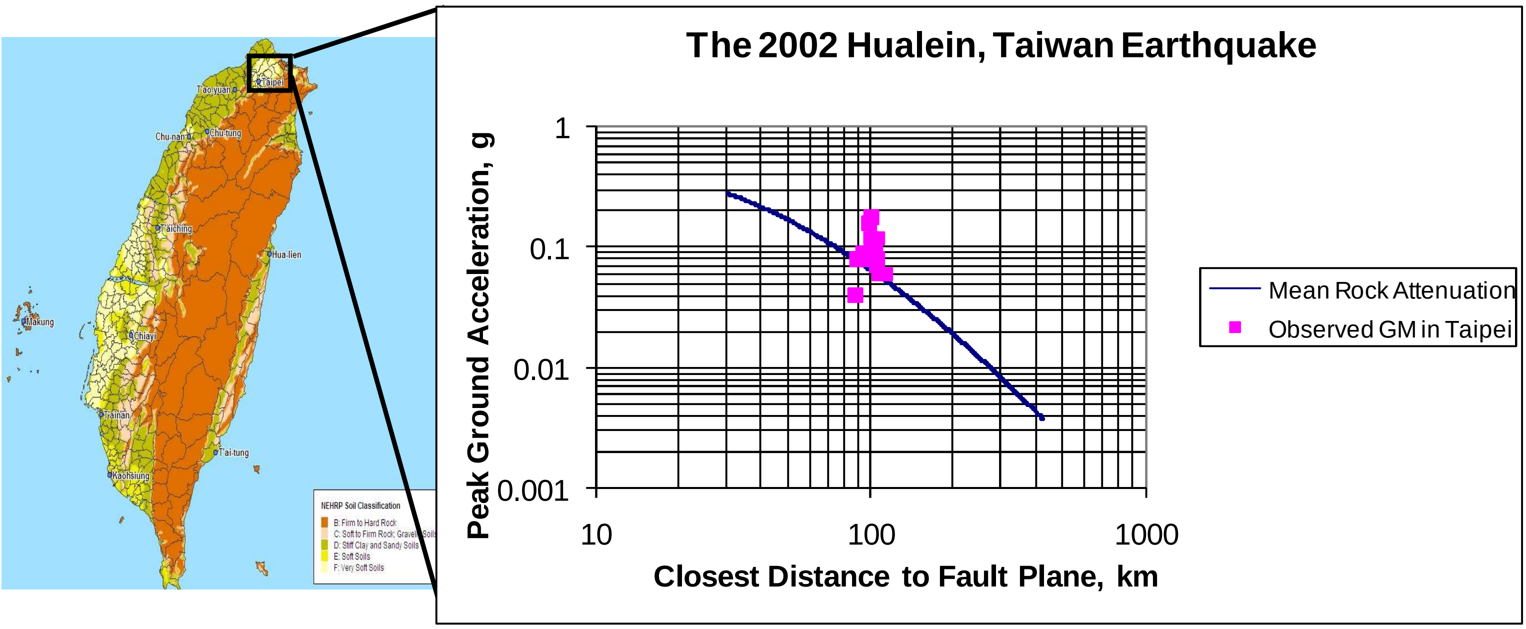

Figure 1. Location of the study area and observed level of ground motion due to the 2002 Hualien earthquake in the Taipei basin region.

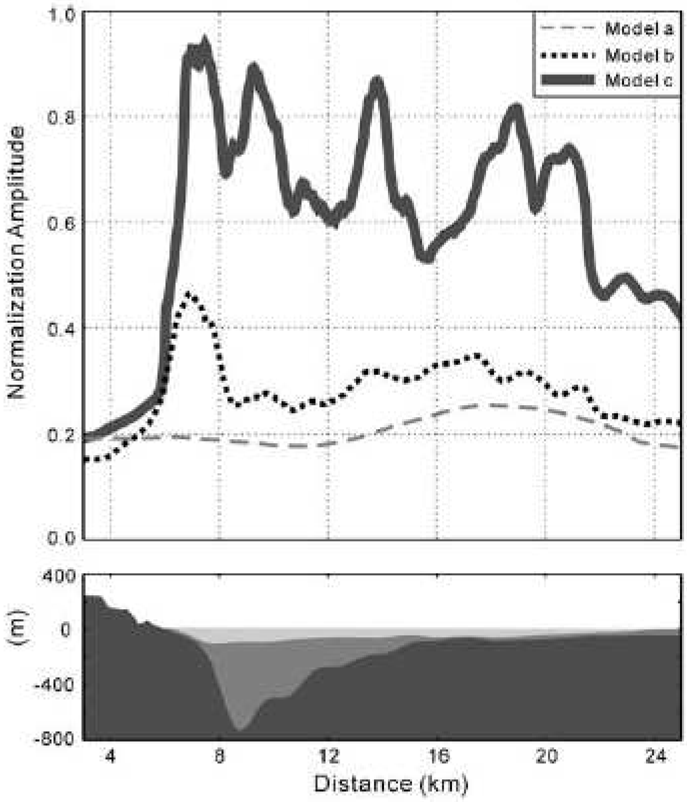

Figure 2. Depth variation of the Taipei Basin and its amplification with respect to a) the layered half-space, b) the Taipei basin structure and c) the Songshan formation with the basin structure models. (Lee at al., 2008).

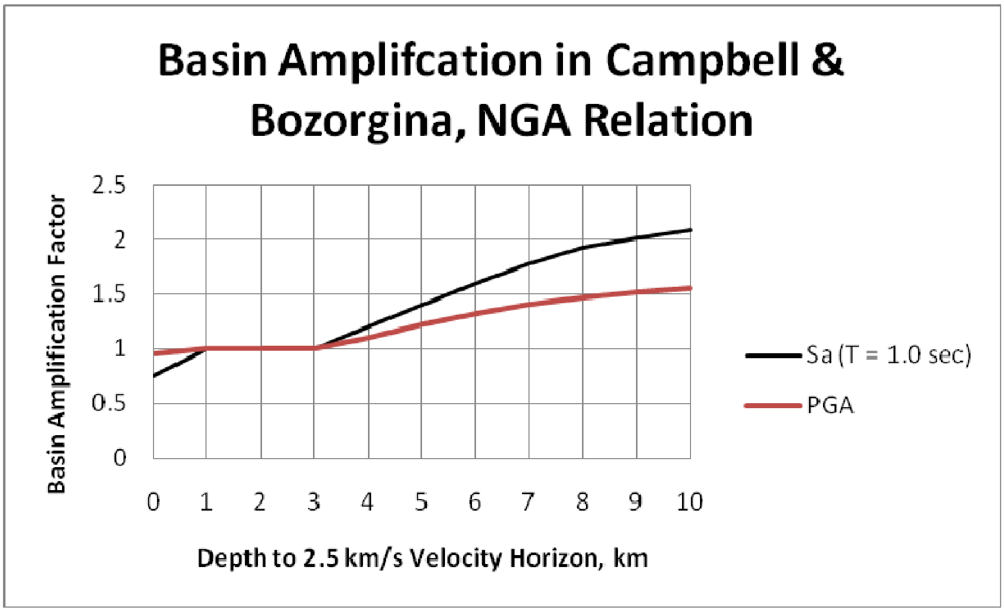

Figure 3. Variation of the Basin Effect in empirical attenuation relations derived by Campbell and Bozorgnia 2008.

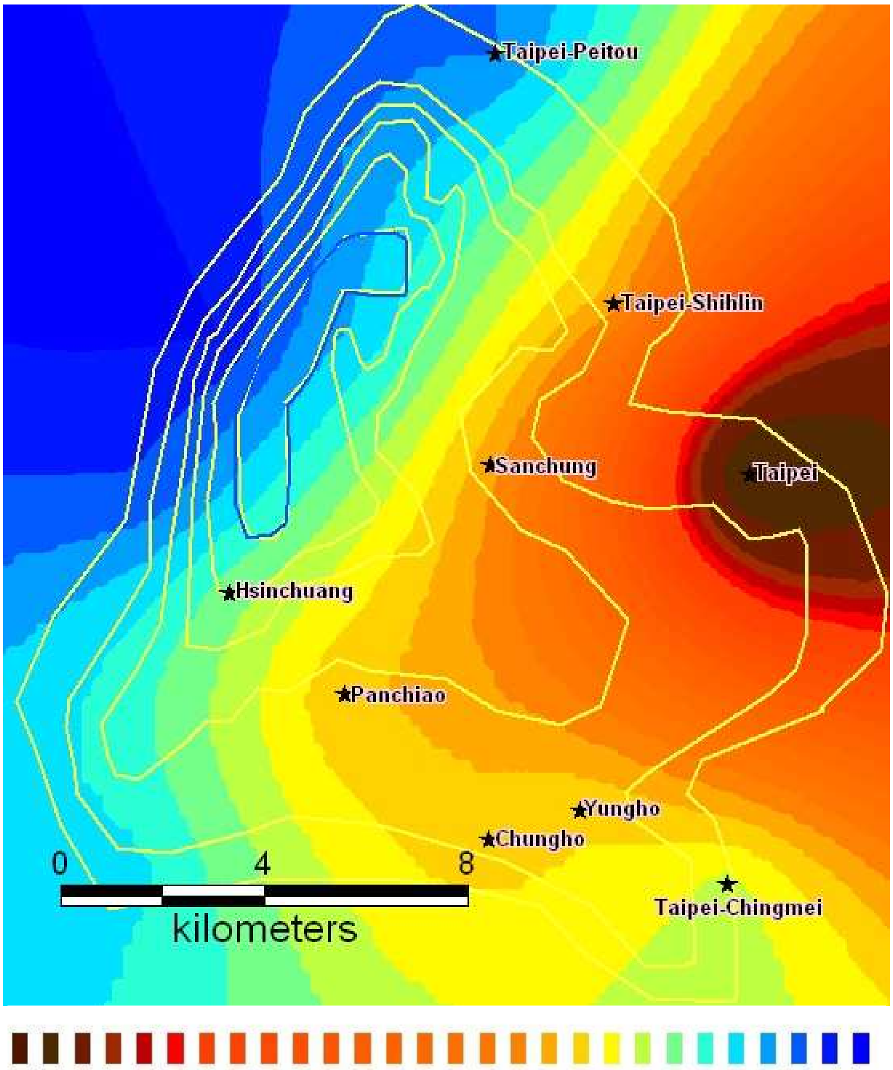

Figure 4. Average annual industrial loss distribution using the NGA relationship. The Taipei basin depth contours are shown in the yellow thin lines. The blue line shows the deepest part of the Taipei basin, which is west of the Taipei metropolitan area.

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