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Site Specific Ground Response Spectra of Bakun

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ABSTRACT

Sarawak has experienced several earthquakes of local origin and was also affected by long-distance earthquake that originated from Southern Philippine and the Straits of Macassar, Sulu Sea and Celebes Sea. The objectives for this study were to conduct site specific ground response analysis and develop design response spectra for Bakun area by using 1-D equivalent linear ground response analysis. The site characterisation was carried out utilising the soil profile and soil property data of the selected site. Local surface fault ruptures were investigated for possible hazards due to intraplate earthquakes. Earthquake ground motion records were selected based on characteristics of the controlling earthquakes for an area and the maximum magnitude faults were considered for risk assessment. The site-specific response spectra represent the predicted surface ground motions that reflect the levels of strong motion amplitude and frequency content at a particular site. The site-specific ground response analysis for Bakun site found that the peak ground acceleration at bedrock was amplified from 0.16 g to 0.33 g at the ground surface

Keywords: Earth ground motions, frequency, peak ground acceleration, risk assessment, site specific ground response spectra

INTRODUCTION

Sarawak has experienced several earthquakes of local origins. In the last 35 years, a total of three earthquakes occurred in Sarawak with maximum observed intensity of IV on Modified Mercalli Scale (MM) scale (Abas, 2001). On 26 January 2006, an earthquake registering 3.2 on Richter scale was detected in Batu Niah and Suai. Sarawak is also affected by long-distance earthquake that originates from Southern Philippine and the Straits of Macassar, Sulu Sea and Celebes Sea. The maximum observed intensity produced by this distant earthquake was V on MM scale (Abas, 2001). As more and more high-rise

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buildings and critical industrial facilities are being built in Malaysia, it should be emphasised that these structures are safe from earthquake threats. Although the earthquake threat in Sarawak is small it still cannot be ignored. The Malaysian government has invested millions to build public infrastructure and amenities. Among them is the Bakun Hydro Dam which cost RM13.5 billion to build and took 20 years to be constructed. Thus, it is important to ensure the Bakun Hydro Dam is safe. The objective of this study was to conduct site specific ground response analysis and develop design response spectra for the Bakun area. This is because the effect of earthquake could result in huge human and monetary losses (Bommer, 2003).

Site-specific ground response analysis of a particular area is important when it involves structures and industrial facilities. The soil conditions can influence the ground motion characteristics such as amplitude of motion, frequency content and duration. The extent of the local site effect at a site depends on the geometry and material properties of the subsurface materials, in-situ topography and characteristics of the input motion. These site effects must be examined on a case-by-case basis at every particular site to account for uncertainties in the ground motion parameters.

The main objectives for conducting site-specific analysis are to identify the PGA for Bakun Hydro Dam and to conduct site-specific ground response analysis by using 1-D equivalent linear ground response analysis.

MATERIALS AND METHODS

Figure 1 shows the general steps involved in the site-specific ground response analysis.

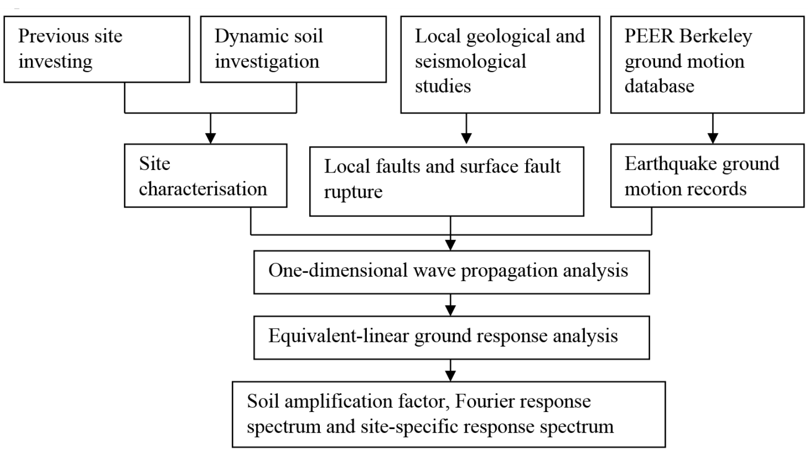

Figure 1. Steps in site-specific ground response analysis

Characterisation of the site

The dynamic site characterisation can be obtained from one or more idealised soil profiles for the site of interest. The characterisation should include the shear wave velocity profile with depth, variation of shear modulus with strain and variation of damping with strain (Tezcan, Kaya, Bal, & Ozdemir, 2002). This parameter can be obtained from a field dynamic test.

Selection of rock motions

The selected earthquake motions at bedrock can either be natural or synthetic acceleration time histories to represent the design motion for the site (Kalkan, 2011). The chosen bedrock motion should be associated with the source areas or provinces having similar ground motion characteristics of the estimated bedrock motions. When using real earthquake time histories, the selected histories should contain: (i) peak ground motion parameters; (ii) response spectral content; and (iii) duration of strong shaking.

Ground response analysis

Ground response analysis was performed using one-dimensional shear wave propagation method. One-dimensional ground response analyses are based on the assumption that all boundaries are horizontal and that the response of a soil deposit is predominantly caused by the shear waves propagating vertically from the underlying bedrock (Kramer, 1996). Thus, this methodology is sufficient to represent the wave propagation in the ground response analysis.

Site specific design spectra for response spectrum analysis

A one-dimensional equivalent linear analysis was performed to investigate the soil amplification problem at a specific site. This is mainly because the equivalent linear analysis considers the effects of earthquake input motion together with the linear properties of the soil profiles. This will include uncertainties involved in the earthquake time history characteristics when interacting with the soil profiles. SHAKE 2000 (Seed & Idris, 1970), was used in the current study for assessment of ground response at Bakun Hydro Dam in Sarawak.

RESULTS AND DISCUSSION

Ground motion characteristics such as amplitude of motion, frequency content and duration can influence local soil condition which could affect the response of industrial component and services at the facility. It is impossible to prevent earthquakes but it is possible to mitigate the effects of strong earthquake and to reduce loss of life, injuries and damages. Site-specific ground response analysis is used to estimate the seismic hazard to improve building design and construction so that the structures possess adequate earthquake resistance capacity. Result for site-specific ground response analysis for Bakun site is presented in Table 1 below. It is found that the PGA at bedrock is amplified from 0.16 g to 0.33 g at the ground surface.

Table 1
Site-specific ground response analysis

Depth (m)	Maximum Acceleration (g)	Time (s)	Mean sq. Fr. (c/sec.)	Acc. Ratio Quiet Zone
0	0.3333	37.6	3.07	0.155
2.50	0.30532	37.6	2.91	0.156
5.50	0.25696	37.6	2.64	0.164
7.00	0.22516	37.59	2.45	0.171
8.50	0.17628	37.58	2.16	0.176
12.00	0.16003	41.65	2.07	0.147

Average response spectrum is plotted for Bakun site, as shown in Figure 2. These response spectra correspond with the 2% POE in 50-year hazard level, with 2475 return periods. Considering the local site condition effects, the average is more accurate to represent the seismic hazard at the Bakun site. Provided the period of Bakun Dam is between 8 to 10 seconds, Bakun Dam is subjected to minimal spectral acceleration which is in the range of 0 g to 0.1 g PGA.

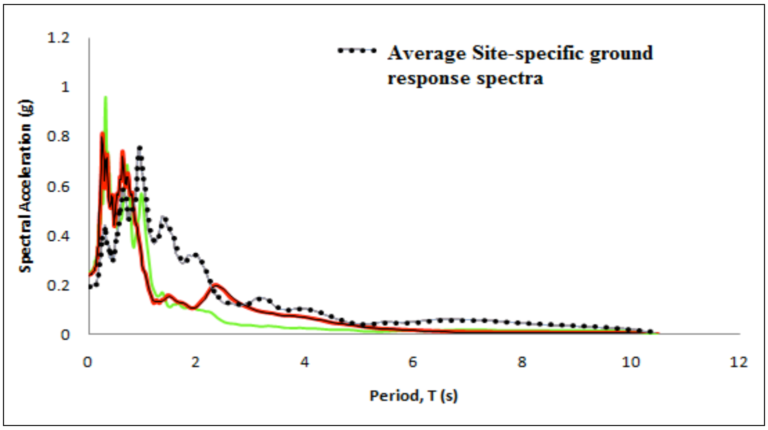

Figure 2. The site-specific response spectra corresponding to 2% POE in 50-year hazard level (2475 return period)

CONCLUSION

The results of this study showed that the authors have achieved the objective of this study which is to identify the PGA for Bakun Hydro Dam and to conduct site-specific ground response analysis by using 1-D equivalent linear ground response analysis. The site-specific ground response analysis for Bakun site shows the PGA at bedrock was amplified from 0.16 g to 0.33 g at the ground surface and the average response spectrum is plotted as shown in Figure 2. The PGA shows the maximum hazard level which is required to estimate seismic risk in critical industrial facilities or infrastructure. These findings are very important for design of any new high-rise buildings and critical industrial facilities development in future.

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