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Evaluation of Vibratory Ground Motion for the JRTR Site

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1. Introduction

This paper describes the evaluation of vibratory ground motion for the Jordan Research and Training Reactor (JRTR) site. This evaluation was performed through a Deterministic Seismic Hazard Assessment (DSHA), the results of which are used to determine the Ground Motion Response Spectrum (GMRS) for the JRTR. The GMRS is defined as free-field outcrop motion on the uppermost component material.

Seismic source characterization indicates that sources of significant seismic activity are distant from the JRTR. Most seismicity in the site vicinity is associated with the Dead Sea Transform Fault System (DSTFS). The Jordan Valley fault, which represents the northern fault segment of the DSTFS in Jordan, is located at the western part of the site vicinity at about 40km west of the JRTR site location. The Jordan Valley fault system is an active fault zone, where evidences of vertical and lateral off set were reported and determined by various studies. Historical and instrumental earthquakes have been located along its trend and within its zone.

The vibratory ground motion for the site were evaluated to decide the seismic accelerations for design earthquakes

2. Seismic Hazard Methodology

The site region, site vicinity, site area, and site to describe the specific areas of investigation are the area within a radius of 320 km, 40 km, 8 km and 1 km of the site location. The geologic and seismologic basis for assumptions and inputs to the DSHA were developed. It then implements the Notice of NSSC No. 2012-3 [1] methods of analysis to develop the seismic hazard, and subsequently, the GMRS at the site.

Earthquake hazard can be defined as the probability of the occurrence of a potential damage in relation to an expected earthquake taking place within a specific period of time and within a given area. This hazard is specially distributed in relation to source (zones, linear faults or points), local geology and soil conditions.

The analysis of earthquake hazard incorporates the quantitative evaluation of ground motion at a site or region of interest based on the characteristics of surrounding earthquake sources.

It should be clear enough that earthquake hazard is very technically restricted to the behavior of the ground. The basic methodology of hazard analysis is comprised of source modeling, wave attenuation, and local ground motion amplification.

Seismic hazard assessment can be conducted by two approaches: Probabilistic approach and deterministic approach. Probabilistic method evaluates the possibility of exceeding a particular level of ground motion at a site during a specific time interval. Within this approach, uncertainties in earthquake location, earthquake size and attenuation laws are combined to obtain the probability that a particular ground motion will be exceeded during a particular time period.

Deterministic approach (DSHA) is based on the calculation of ground motion parameters in related to a particular earthquake scenario, which occurs at the closest possible distance from the site of interest, without considering the likelihood of its occurrence during a specified exposure period. This approach requires a thorough analysis of historical and previous records of seismic events of nearby sources.

Alternative definitions of inputs are incorporated within a framework. These are based on the analysis of existing information related to seismic source zonation, maximum magnitude, extend of the fault segmentation model, and ground motion models specific to the seismotectonic environment of the extend site region.

3. Deterministic Seismic Hazard Assessment

DSHA approach tries to characterize the special distribution of the earthquake ground motion that would result from a given earthquake (scenario earthquake). The deterministic methodology involves determination of controlling earthquake, identification of proper ground motion relationships and quantification of seismic wave transmission characteristics.

Ground motion prediction equations (GMPEs) of attenuation relations for the extended site region are selected from those developed around the world. For active regions with shallow crustal seismicity, five attenuation models are selected as ①Abrahamson & Silva (AS2008), ②Boore & Atkinson (BA2008), ③Campbell & Bozorgnia (CB2008) for Next Generation Attenuation (NGA) model using worldwide database, ④Boore et al. (BO1997) appropriate in the Dead Sea Transform region, and ⑤Ambraseys et al. (AM1996) used for the eastern Mediterranean.

Based on the seismic source models of 3 line and 15 area and corresponding potential maximum earthquakes, peak ground accelerations (PGAs) for the JRTR site were calculated using DSHA approach [2]. The various input parameters for the selected ground motion prediction equations are provided. The results of the DSHA analysis are described in Table 1. As described in the table, PGA of AM1996 for Area Source 5

(Jordan Valley) is 0.285 g, while those of other equations are around 0.2 g. For the same equation, PGAs in Area Source 8 (Northern Wadi As-Sirhan) including the JRTR site and Line Source 1 (Jordan Valley Fault) are 0.248 g and 0.245 g, respectively. Also the PGA estimation considering background seismicity of the region gives 0.175 g. Overall the equation of AM1996 produces the highest PGA values compared to the rest of ground motion peak earthquakes used in this study showing higher attenuation of PGA with distance. On the other hand, three PGAs of AS2008, BA2008 and CB2008 give much lower PGA values than BO1997 and AM1996.

Table 1: DSHA Results of the JRTR Site

Source	**AS 2008**	**BA 2008**	**CB 2008**	**BO 1997**	**AM 1996**	**PGA max**
Line sc 1	0.155	0.188	0.124	0.220	0.245	0.245
Line sc 2	0.091	0.085	0.065	0.105	0.101	0.105
Line sc 3	0.008	0.013	0.016	0.023	0.019	0.023
Area sc 1	0.002	0.001	0.008	0.013	0.010	0.013
Area sc 2	0.009	0.003	0.016	0.023	0.020	0.023
Area sc 3	0.040	0.037	0.037	0.049	0.049	0.049
Area sc 4	0.061	0.070	0.055	0.070	0.075	0.075
Area sc 5	0.182	0.212	0.179	0.212	0.285	**0.285**
Area sc 6	0.025	0.040	0.036	0.042	0.042	0.042
Area sc 7	0.073	0.090	0.067	0.084	0.093	0.093
Area sc 8	0.179	0.184	0.237	0.192	0.248	0.248
Area sc 9	0.050	0.050	0.044	0.057	0.059	0.059
Area sc10	0.016	0.008	0.021	0.029	0.027	0.029
Area sc 11	0.010	0.011	0.017	0.024	0.021	0.024
Area sc 12	0.010	0.003	0.016	0.023	0.020	0.023
Area sc 13	0.029	0.023	0.030	0.040	0.039	0.040
Area sc 14	0.018	0.009	0.022	0.030	0.028	0.030
Area sc 15	0.011	0.003	0.017	0.024	0.021	0.024
Background	0.139	0.128	0.149	0.160	0.175	0.175

4. Safe Shutdown Earthquake

The Safe Shutdown Earthquake (SSE) is defined taking into account of a maximum PGA 0.285 g of DSHA analysis. The horizontal PGA of SSE is decided as 0.3g, considering a conservative approach. In view of that PGA of AM1996 is exceptionally high showing difference of about 0.07 g compared to those of other equations employed in the DSHA analyses for Area Source 5 (Jordan Valley), it is recognized that the level of SSE is surely enough conservative.

Design Ground Response Spectra (DGRS) of the JRTR is based on the scaled US NRC RG 1.60 [3]. The vertical design response spectrum values are two-thirds those of horizontal design response spectra according to US NRC RG 1.60. This vertical / horizontal spectral ratio is not dependent of magnitude, distance, site conditions, or tectonic regions.

5. Seismic Design Basis

Ground motion dataset in and around the Dead Sea Transform Fault region including the JRTR site was reflected in the development of GMPEs employed in the DSHA analyses. Especially GMPE of AM1996 with emphasis on the strong ground motion made the highest contribution to the determination of the SSE. Most of the ground motion dataset of the DSTF region was recorded at seismograph stations which are installed on the top of limestone as the bedrock of the region. Therefore, the location of design ground motion is considered as the top of limestone beneath the JRTR site.

Horizontal and vertical seismic accelerations of the JRTR are considered to act simultaneously. The following seismic loads were decided. Damping factors in the US NRC RG 1.61 are applied [4].

a) Safe Shutdown Earthquake (SSE) Load:

The ground accelerations for SSE shall be 0.3g horizontal and 0.2g vertical.

b) Operating Basis Earthquake (OBE) Load:

The ground accelerations for OBE shall be 0.1g horizontal and 0.067g vertical.

6. Conclusions

Vibratory ground motions for the JRTR site were evaluated based on DSHA. The SSE and OBE seismic loads were decided. The number of structures, systems, and components (SSCs) of JRTR is classified on 45 in seismic category I and 45 in seismic category II SSCs. SSCs important to safety had been designed to withstand the effect of above SSE and OBE earthquakes without loss of capability to perform their safety or safety-related functions. Based on the results of the probabilistic safety assessment (PSA)-based seismic margin assessment (SMA), an explicit seismic analysis or design for the OBE was not needed [5].

REFERENCES

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