Seismic response analysis of Qom sedimentary basin using Spectral Element Method in time and frequency domain

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Abstract

In recent decades, the importance of the geological features of the site on the severity and extent of damages has become apparent in many seismic events. How these properties relate to the amplitude and the frequency content of the movements is studied as the title of site seismic response. In the present study, the seismic response of a two-dimensional section of sediments located in the eastern part of the sedimentary basin Qom city has been investigated. For this purpose, numerical modeling has been performed using Spectral Element Method in time domain and the results also studied and presented in frequency domain by applying Fourier transform. The results in the time domain show that the largest amplitudes of movements can be observed in the southeastern parts of the urban area. These findings are in agreement with previous studies. Also, it is revealed that the main reason for increase of the duration of the movements in the basin is the surface waves originating from the edges of the basin. The results in the frequency domain indicate that the most important amplifications in the basin can be seen from about 0.8 Hz for the southern parts of the profile to about 2 Hz for the northern parts. This amplification range also agrees with previous observations.

Keywords: *Seismic Response, Spectral Element Method, Numerical Modeling, Site effects*

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Extended Abstract:

1. Introduction

Site seismic response, present the relationship between surficial geology and different wave parameters including amplitude, duration and frequency content of received wave. In the last decades, numerous experiences revealed the effects of site condition and surficial topography on the severity, expansion and spatial distribution of damages during earthquake events. Among different factors, the presence of sedimentary basins is considerably significant, given that most population concentration centralized on alluvial basins, especially in seismically active regions. Probably, devastation of the Mexico City during 1985 earthquake is the best-known instance of such a hazardous condition. The alluviums specifically influence the high-period motions. This is an important issue knowing that it mainly affects high-rise buildings. Moreover, vibration duration in long-period motions is considerably longer in sedimentary basins. In general, due to tremendous complexity of dynamic analysis of multi-dimensional media, i.e. sedimentary basins, employing numerical simulation is inevitable. In between, the application of spectral elements modelling (SEM) has been proved in plenty of studies. Here, the main goal of the study is to investigate the seismic response of "Qom" sedimentary basin in central Iran. The reason for importance of this research is high seismic potential of the region, especially regarding to extensive and still ongoing development of the urban area in the last couple of years.

2. Methodology

The study area is a part of Qom sedimentary basin, located in the eastern part of Qom urban area, according to Iranian active faults map, several active and major faults are located within less than 30 Km distance from the down-town. The seismic history of the region indicates the occurrence of more than 80 seismic events, magnitudes larger than 3.0, after 2000. Maghami et al., (2021), based on the results of extensive geophysical surveys on the urban area, and relying on the HVSR inversion of microtremor recordings, have presented the 2D and 3D structure of sediments, down to the bedrock. In the current study, a part of that structure has been employed and the seismic response of the alluviums has been analysed using the well-known time-domain SEM numerical scheme. In this regard an SEM algorithm, named as SEM2DPack, developed by Ampuero, (2008) has been taken advantage of. Generally, numerical analysis consists of three major parts of preparing the SEM model, preparing the code inputs and performing the numerical analysis. Here, the initial SEM model has been achieved and meshed employing Abaqus software package. The inputs include: node coordinates, elements allocation, boundary conditions, incident wave characteristics and some general parameters, namely, the duration of analysis, number of gaussian points, the output definitions and finally engineering parameters of the environment (Vp, Vs, density). Different studies have previously implemented and evaluated the application of the mentioned algorithm and proved its efficiency (Boaga et al., 2012; Majidinejad et al., 2017; Oral et al., 2019). However, here, we analysed the seismic response of a filled semi-circular valley and compared the results with the analytical solution, in literature (Dravinski & Mossessian, 1987; Mossessian & Dravinski, 1987) which once again approved the accuracy and applicability of the code. For the seismic analysis of the 2D profile of sediments in Qom basin, two peak frequencies of 1 and 3 Hz for Ricker incident wave have been considered.

3. Results

In the time domain results of the seismic analysis of 2D profile, the effects of sediments on all aspects of received waves of both peak frequencies is clearly observable. It is also obvious that the main delayed phases of the seismic response consist of two edge-originated waves from both sides of the basin. These signals which are dominantly surface waves, might transfer with different velocity and frequencies and are majorly are under the influence of surficial low-velocity layers. The presence of this late-arrival waves is the main reason for long duration of vibrations on the basin. In both peak frequencies, the southern edge of the basin beside the mountain-ridge (Khezr mountain) the larger amplitudes can be observed. The reason is the increase of thickness in the first two low-velocity layers with velocities lower than 450 m/s and also steeper slope in that part of the basin. Amplifications in this part of the basin, is in agreement with previous reports by IIEES (International Institution of Earthquake Engineering and Seismology) which noted highest amplifications of seismic waves in south-eastern parts of the basin about frequencies of 1.0 Hz. On the sediments, in Fp=1.0 Hz, amplitude of response wave is about five times larger than the incident wave, while this ratio is about 10 for Fp=3.0 Hz. The first and most important amplification range in frequency-domain results can be observed about 0.8 to 2.0 Hz. Although in higher frequencies, a complicated pattern of amplification range can be followed. The Presence of this patterns is related to a combined effect of basin general morphology and surficial structures. In a way that a clear distinction of the effects of different factors is not viable.

4. Conclusion

The presence of low-velocity surface sediments affects the amplitude of the responses at both predominant frequencies of the incident wave. However, the amplification of the surface response, in the predominant frequency of 3 Hz might reach a factor of 10 which is twice the amplification of corresponding waves for frequency of 1.0 Hz. At the southern edge of the section, increasing the thickness of low-velocity sediments and increasing the slope of the edge of the basin, intensify the amplitudes and duration of movements. The effect of the constructive interaction of the waves formed in the corners causes significant movements in the middle parts of the basin. In the frequency domain, the most significant amplification frequencies range from about 0.8 Hz in the southern parts to 2 Hz in the northern parts. The results of this analysis can explain some of the previously reported inconsistencies in seismic amplifications and the results of one-dimensional numerical modelling. The maximum spectral amplification in the conditions studied in this study are about 20. It is important to note that although the underlying amplification frequency of the basin sediments is clearly in the range of 0.8 to 2 Hz, but the frequency amplification in the higher frequency range resulting from the complex structure of the sediments and Layering should not be ignored.

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