Effect of Tunnel and Building Interaction on the Seismic Response of Building by Numerical Modeling

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ABSTRACT

In building design codes, no attention has been paid to the interaction effect of underground structures and building, which can change the amount of applied forces on the building. In the present study, by using numerical modeling with FLAC 2D software, the effect of tunnel and building interaction on the seismic response of building stories has been investigated in order to have more accurate assessments of seismic forces on the building when we want to design it. In this study, the model was first stimulated in the case of presence of building alone (SF model) by harmonic shear SV waves and the real earthquake waves. Then, by adding a tunnel to the model (STF model), the system was analyzed. By comparing the result of the maximum acceleration of buildings floors in case of STF to the SF model, the effect of tunnel and building interaction on stories acceleration have been investigated. In low frequencies, the negative effect of tunnel on the acceleration response of the building stories was observed. In high frequencies, the positive effect of tunnel on the acceleration of the stories was observed. It was also concluded that the harmonic waves with the frequency equal to the dominant frequency of the real motions, applied to the models, have created more amplification in acceleration response of buildings.

KEYWORDS

Interaction, Tunnel, Building, Seismic Response, Numerical Modeling, FLAC 2D

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1. Introduction

Underground structures such as tunnels in cities can pass through or adjacent to the buildings, which can lead to complex interaction between buildings and tunnel that can affect the seismic response of tunnel, building and the ground surface [1]. Studies show that seismic waves interact with the tunnel during the transmission process, causing each point in the tunnel to be considered as a new source of seismic waves that cause secondary waves in all directions. This can affect the seismic response of surface structures [2] .In 2014, Pitilakis et al in a numerical study investigated the seismic behavior of circular tunnels by considering the interaction of adjacent structures. They found that viscoelastic analysis in soil increased horizontal acceleration near the tunnel compared to the free field [1]. In 2016, Abate and Massimino in a numerical study have investigated the interaction between tunnel, soil and building and also investigated the effect of tunnel on the response of soil and structure and vice versa. They found that the presence of the building reduced the acceleration amplification compared to the free field mode. Their findings also showed that combination of tunnel and building caused more deamplification of acceleration at the soil surface [3]. In 2017, Wang et al in a numerical study investigated the effect of underground subway stations on the seismic response of aboveground structures. They found that the effect of underground structures on the dynamic properties of the soil surface depends on the dimensions and weight of the structure on the ground surface, which the lighter the structure, the less it is affected by the dynamic properties [4]. In 2020, Mayoral and Mosqueda in a numerical study investigated the interaction of tunnel and building located on soft clay during an earthquake. Their research showed that larger destructive interactions occurs when the tunnel is located just below the building. Higher amplification also occurs when the dominant period of system excitation is closer to the fundamental period of the soil [5]. In previous studies, effect of interaction of building and tunnel on the acceleration amplification is vivid. So, in this study in numerical modeling by FLAC 2D, the effect of exciting the model by different type of earthquake wave, changing the parameters of building's height, axial distance of building and tunnel, soil shear velocity, on building and tunnel interaction is investigated.

2. Methodology

FLAC 2D software was used to investigate the subject of this study. Two modes have been considered in modeling. In the first case, a building which is placed on the ground, is excited by seismic SV waves, and real earthquake wave. which is called SF mode. In the second case a model is constructed by adding tunnel to the SF mode case, and excited by the same seismic waves which is called STF mode case. Figure 1 shows the numerical model of STF model in FLAC 2D.

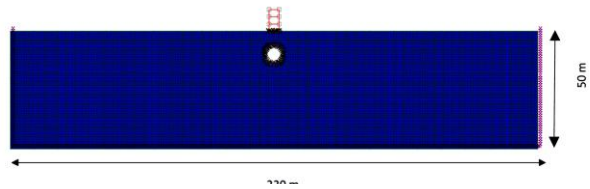

Figure 1. Numerical model created for a three-story building in STF model in FLAC 2D

By dividing the amount of maximum acceleration in the time history diagram of the points which are locate on the building's story, in the STF case to the SF case, we evaluate the effect of amplification or deamplification of the tunnel-building interaction on the ratio of acceleration response of building's story. In order to verify the software results, study of Yiouta-Mitra et al [6] was used. Figure 2 is the comparison the result of amplification of TF to FF of the present study with the study of Yiouta-Mitra et al results and it shows the results are corresponding together.

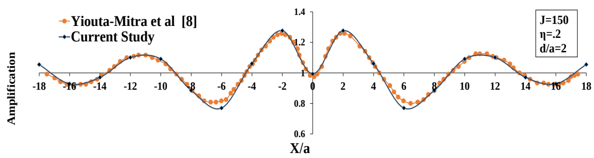

Figure 2. Comparison the result of amplification of TF to FF of the present study with the study of Yiouta-Mitra [6] et al results.

3. Discussion and Results

After model verification, by changing the parameters of building's height, axial distance of building and tunnel, soil shear velocity and at last changing the earthquake wave, the effect of these changes on building and tunnel interaction is investigated. Here are some of the most important results:

- The maximum acceleration amplification due to changing building's height is occurred on the foundation of one-story building about 5% and the maximum deamplification about 30% is occurred on the second story of five story building.
- In the low dimensionless period, increasing the axial distance between building and the tunnel, cause the amplification of acceleration response rate of building's story.

- Changing soil shear velocity can comfort the acceleration response rate of building’s story to amplification or deamplification and these changes pattern isn’t linear.

- Changing earthquake wave shows its effect on the interaction of building and tunnel with the amplification or deamplification of acceleration response rate of building’s story. The result showed that in most earthquake the harmonic SV wave with frequency similar to the predominant frequency of real earthquake, causes more amplification on acceleration response of building's story.

4. Conclusion

According to this study, if a tunnel is adjacent to a building, the dynamic interaction of tunnel and building with each other can cause change in the forces applied to the building during an earthquake. The result of interaction of building and tunnel shows it's effects by the amplification or deamplification of acceleration response rate of building’s story. The amount of these changes relates to many factors such as building's height, axial distance of tunnel and building, soil shear velocity, the frequency of wave which is applied to system and many other factors. Therefore, examining these issues can lead to a more realistic and safer analysis of design of buildings constructed in the vicinity of tunnel.

5. References

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