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Seismic Response of Building Structure Near Tunnel

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Abstract. To research the influence of seismic response of building by the underground tunnel, a high-rise frame structure on the uniform field was analysed by using finite element method (FEM).The results showed that when the tunnel was located below the building the biggest influence on structural seismic response will been emerged, and made the structural displacement and natural vibration period increase and bending moment decrease. Tunnel located elsewhere on the influence of the structure response was not simply decreases with increasing of the distance, but to show some volatility. The tunnel will have little impact on seismic response of the underground part of the structure.

1 Introduction

With the rapid development of economy and the advancement of urbanization in our country, the development and utilization of underground space such as subway and shelter is expanding on a large scale, a lot of buildings are built near the underground tunnels, and the phenomena that tunnels through the structure closely increased obviously. Previous studies mostly focused on the seismic response of the tunnel structure itself, while there are less studies on the tunnel structure's influences to the seismic performance of buildings near the ground [1]. Studies show that seismic waves will interact with the tunnels in the process of transmission, so that any point on the tunnel becomes a new wave source, which send out secondary waves in all directions, forming the seismic wave scattering, and then it will impact the seismic response of surface buildings [2]-[6].

The paper studies the seismic response of surface high-rise buildings near the tunnel by the finite element method, to analyse how the distance between the tunnel and the overground construction impact on the seismic response of the building structure.

2 Structure calculation model and related parameters

The soil parameters of the calculation model have no difference, to simulate and analyze the soil and the structure by plane strain unit, the left and right boundaries are viscoelastic artificial boundary, the bottom is bed rock. The analytic site is uniform field, whose length is 150 meters，depth is 30 meters，elasticity modulus is 40×10^{8}Pa，poisson ratio is 0.3，density is 2049kg/m^3. The surface structures is reinforced concrete frame structure, it has two floors underground and ten floors above, the span is 10 meters, the floor height is 3 meters. Taking a common double span frame to calculate, whose elasticity modulus is 4.83×10^{10}Pa，poisson ratio is 0.2 and density is 2500 kg/m^3. The diameter of tunnel is 10 meters. It locates 15 meters under the ground. Taking five working situations in consideration, project status one is with no tunnel near the building structure, project status two, three, four, five respectively are the horizontal distance between the tunnel center and the axis of surface building is 0, 10, 20, 30meters. Finite element meshing is shown in the Fig. 1, according to the shear wave velocity to determine the grid size, both sides are viscoelastic artificial boundary, simulating by using spring-damper elements, the bottom soil is fixed [7].

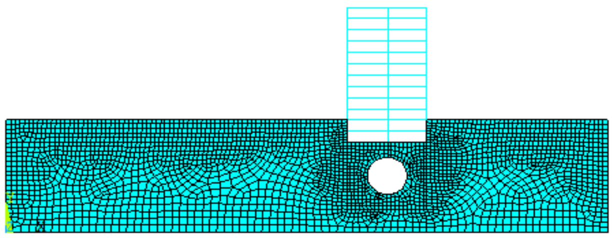

Figure 1. Finite element model of tunnel and structure system

The input seismic waves is EI-Centro waves in north-south, inputing horizontally from the bedrock. In order to compare commodiously, we adjust the peak acceleration of EI-Centro wave to 0.1g, as shown in the Fig. 2.

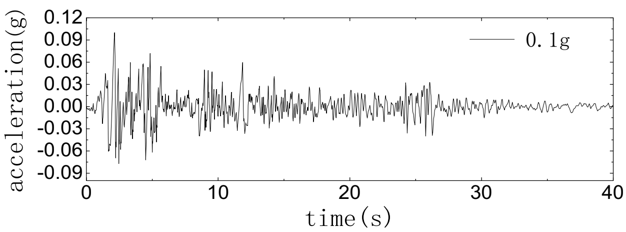

Figure 2. EI-Centro wave with 0.1g peak value

3 Tunnel's influence to building structural frequency

The calculation results of each order mode of vibration frequency of the frame structure under Five kinds of project status as shown in the Table 1 and Fig. 3.

Table 1. Each order modal frequency unit:Hz

mode of vibration	project status 1 (no tunnel)	project status 2 (location 1)	project status 3 (location 2)	project status 4 (location 3)	project status 5 (location 4)
1	2.076	0.62136	1.7966	2.0679	1.7983
2	6.313	1.932	5.7279	6.3043	5.7435
3	7.431	3.4395	7.2652	7.3478	7.2547
4	8.88	4.7793	8.6743	8.7486	8.6892
5	10.155	5.1738	10.856	9.9179	10.978
6	11.618	6.4794	10.991	11.589	11.634
7	12.369	7.1274	12.103	12.081	12.101
8	12.964	7.3324	12.754	12.742	12.886
9	13.483	7.6613	13.424	13.422	13.211
10	13.977	7.7867	13.875	13.625	13.668

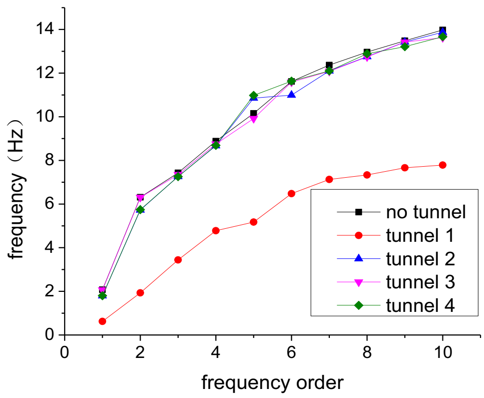

Figure 3. Frequency of structure

It can be seen that when the tunnel under the structure system, that is to say structure frequency decreases more when it is in the project status 2, while other cases are close to the case 1 (without tunnel). compared with the case with no tunnel, the natural frequency of project status 2 dropped by 70% at most.

4 Tunnel's influence to building structural displacement

The calculation results of each floor peak displacement of the structure under five kinds of project status as shown in the Fig. 4, the displacement history response as shown in the Fig. 5.

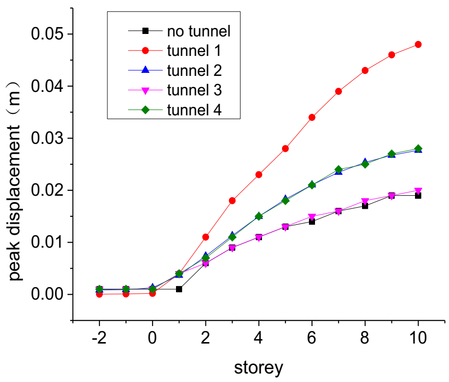

Figure 4. Displacement of the structure

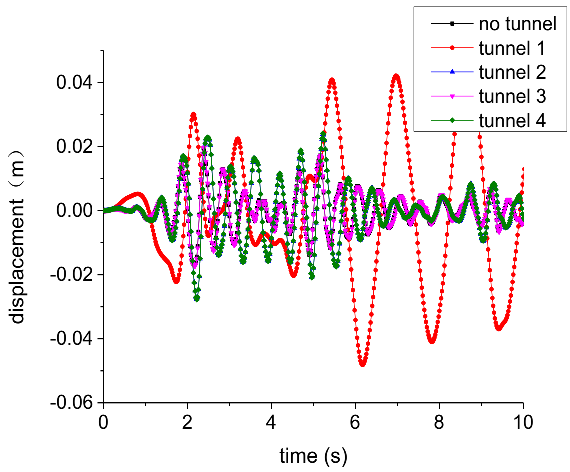

Figure 5. The top floor displacement time history curve

Fig. 4 is the peak displacement curve of the second member across the left beam for each floor of the structure with different project status ， Figure 5 is the displacement history curve of the second member across the left beam for top floor of the structure with different project status，the history curve cut out a period of 1 to 10 seconds.

As shown in the figures above, Tunnel's influence on the structural displacement can be roughly divided into three groups similar curve: project status 2(tunnel under the structure center)is the first group, it is 90% bigger than that of project status 1; project status3 and project status 5 are the second group, its average value is 50% bigger than that of project status 1; project status 4 is the third group, it is 5% bigger than that of project status 1. It is clear that the horizontal distance between the tunnel and the surface building structure has a big influence on the structure displacement response, especially, the influence is bigger than others when the tunnel under the structure. However, we should notice that the structure displacement is not simply decreasing with the increase of the distance, but showing some hop. What's more, positions of the tunnel have little impact on the displacement response of the underground part of structure. From the Fig. 5, the peak displacement response of top floor mainly appear on the later part of the earthquake when the tunnel under the structure.

5 Tunnel's influence to building structural internal force

The calculation results of peak bending moment of the second member across the left beam for each floor of the structure under five kinds of project status as shown in the Fig. 6, the bending moment history response of the second member across the left beam for top floor as shown in the Fig. 7.

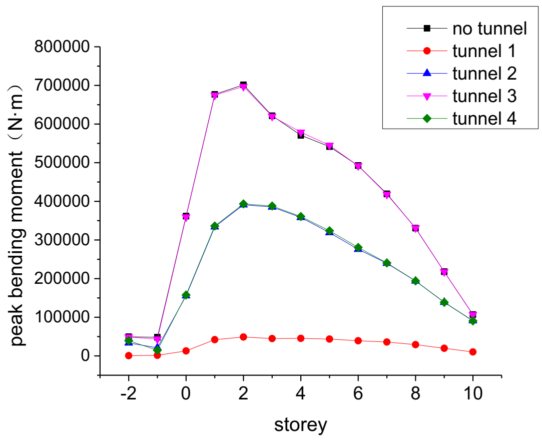

Figure 6. Floor bending moment

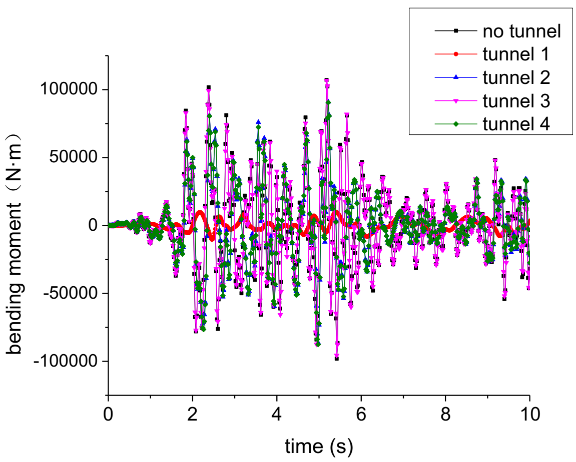

Figure 7. The top floor bending moment time history curve

Fig. 6 is the peak bending moment curve of the second member across the left beam for each floor of the structure with different project status, Fig. 7 is the moment history curve of the second member across the left beam for top floor of the structure with different project status.

As shown in the figures above, Tunnel's influence on the structural bending moment can also be roughly divided into three groups similar curve: project status 2(tunnel under the structure center)is the first group, its value reaches the maximum compared with project status 1, both the status differ by 93% in average;project status3 and project status 5 are the second group, which has larger difference with project status 1, both the status differ by 41% in average;project status 4 is the third group, it differs by 1% in average with project status 1. It is clear that the horizontal position of the tunnel has a big influence on the bending moment in the midpoint of the structure, the bending moment reaches the minimum when the tunnel under the structure, while the value of bending moment in other position is relatively large. However, we should notice that the distance between the tunnel and the building is equal to a diameter of the tunnel which is closed to the case without tunnel. The change of bending moment value shows some volatility. What's more, the tunnel's location has little impact on the bending moment of the underground part of structure.

6 The influence of different seismic waves to building structure

In order to consider the influence of different seismic wave input to architectural structure system, we choose Tianjin wave to excite horizontally from the bedrock, and adjusting the peak acceleration of Tianjin wave to 0.1g. The calculation results of each floor peak displacement of the structure under five kinds of project status as shown in the Fig. 8.

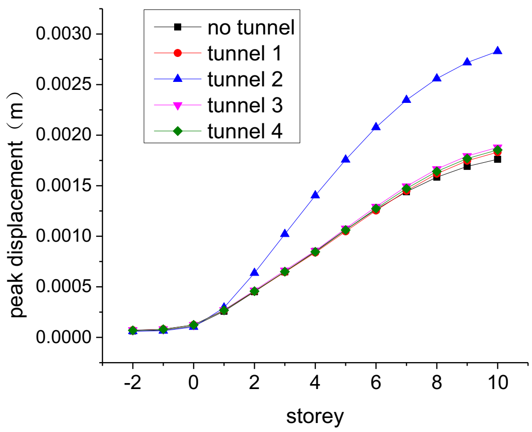

Figure 8. Displacement of the structure when tianjin wave

From Fig. 8, we can see the tunnel's influence to structural displacement when inputting Tianjin wave: project status 3(the tunnel locate in corner of the structure) is 61% bigger than that of project status 1; other project statuses is similar to the project status 1. It is clear that although inputting different earthquake waves, overall, the tunnel's influence to structural displacement response reaches the maximum when it under the building, structural seismic response is relatively small when tunnel located in other status. What's more, the tunnel's location also has little impact on the displacement response of the underground part of structure.

7 Conclusions

1. Tunnel's influence to structural seismic response reaches the maximum when it under the building. At this point, the interaction between tunnel and building structure is the most intense, the natural vibration period of the whole structure increases obviously, it makes the structure displacement increasing and internal force decreasing.
2. Tunnel's influence to structural seismic response is relatively small when tunnel located in other status, but the impact on structural response is not simply decreasing with the increase of distance, it shows some volatility.
3. The tunnel's location has little impact on seismic response of the underground part of structure.

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