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Multibody Dynamics Method for Immersed Tunnel Subjected to Longitudinal Seismic Loading

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The longitudinal dynamic response analysis of immersed tunnel is crucial for seismic design of immersed tunnel [1]. The modeling theory and numerical method of multibody dynamics are introduced to the dynamic response analysis of immersed tunnel. The immersed tunnel can be considered as a multibody system composed of a series of reinforced concrete segments connected with flexible joints. In this paper, a chain dynamic model of multibody system is developed for immersed tunnel under longitudinal seimic excitation, which is a multi-rigid body, elastic damping hinge, and damping hinge model. Schematic plots of an immersed tunnel and multibody dynamics model are shown in Figure 1 and 2, respectively.

The mathematical model is implemented to solve the dynamic response of the system. Firstly the dynamics equations of elements and structure of immersed tunnel are deduced using discrete time transfer matrix method in multibody dynamics (MS-DT-TMM) [2]. The transfer equation of each element and the overall dynamics equation can be expressed as Equation (1) and (2), respectively. Secondly the dynamic response of the overall system is obtained using the boundary condition and initial condition.

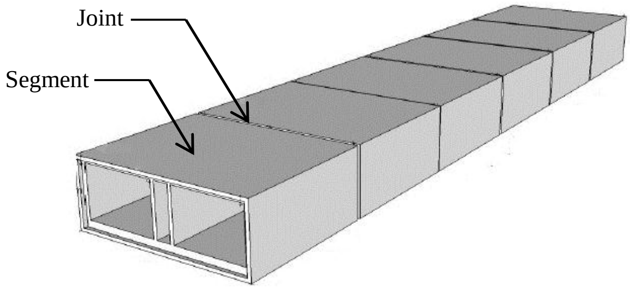


Fig.1 Schematic plot of an immersed tunnel

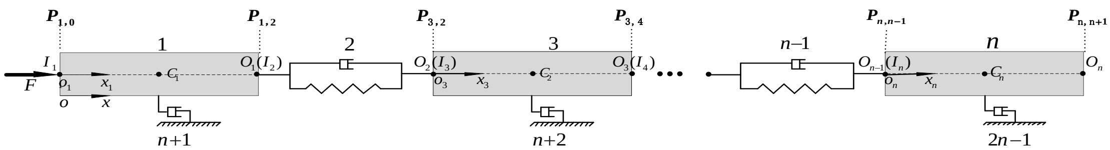


Fig.2 Multi-body dynamics model of an immersed tunnel

$$\boldsymbol{Z}_{n,n+1} = \boldsymbol{U}_n \boldsymbol{Z}_{n,n-1} \quad (1)$$

$$\boldsymbol{Z}_{n,n+1} = \boldsymbol{U}_n \boldsymbol{U}_{n-1} ... \boldsymbol{U}_i ... \boldsymbol{U}_2 \boldsymbol{U}_1 = \boldsymbol{U} \boldsymbol{Z}_{0,1} \quad (2)$$

Where, $\boldsymbol{Z}_{n,n-1}$ and $\boldsymbol{Z}_{n,n+1}$ are the state vectors of the input and output ends of the nth element, respectively, $\boldsymbol{U}_n$ and $\boldsymbol{U}$ are the transfer matrices of the nth element and the overall system, respectively.

Based on a reference dynamic test, an example is conducted with the presented dynamic model and mathematical model. The mechanical model of the test is shown in Figure 3. The solutions are gained using Matlab. Results obtained from MS-DT-TMM are in a good agreement with the tranditional finite element method (FEM) as shown in Figure 4(a) and (b).

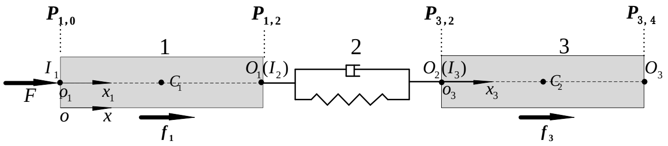
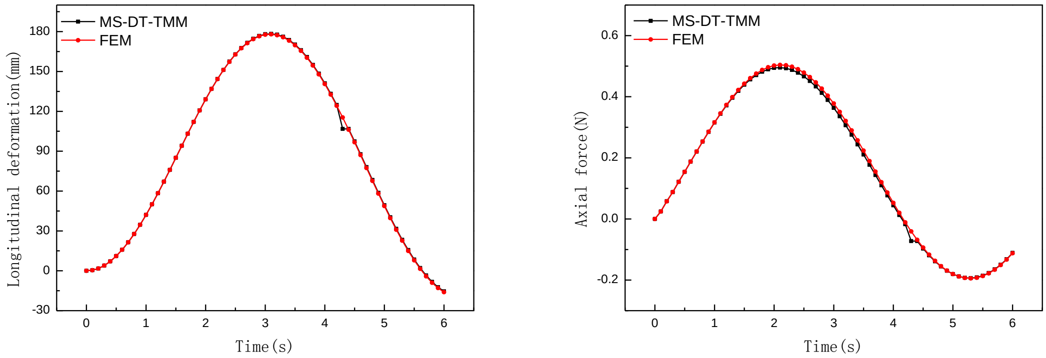


Fig.3 Mechanical model of the test



(a) Time history of the longitudinal deformation (b) Time history of the axial force

Fig.4 Dynamic response of the joint

Results show that the dynamic and mathematical model of mutltibody system are suitable for aseismic design of immersed tunnel. The dynamic modeling process of multibody system for immersed tunnel under earthquake is simple and flexible. The mathematical model using MS-DT-TMM is highly programmatic and efficient. The involved matrix orders are quite small, which greatly increases the computational speed. This research provides a powerful tool for seismic response analysis of immersed tunnel, especially for those superlong immersed tunnel located in seismically active regions.

Acknowledgements

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