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Review Article

Dynamic Analysis of Railway Bridge under Trainload

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Abstract: In recent years, with the continuous development of science and technology, a large number of railways have been built in our country. Due to various considerations such as geographical factors and land use restrictions, bridges are often needed to be built in the process of railway construction. Railway bridge is an important content in the process of railway engineering construction. The quality of railway bridge will have a direct impact on comfort and safety of the train running. In the process of railway bridge engineering construction, the dynamic situation of railway bridge under trainload should be analyzed in detail to improve the overall quality.

Keywords: *railway bridges; trainload; dynamic analysis*

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0 Introduction

When there is a train passing on the bridge, the vibration coupling of the axle system will be combined together. Therefore, in the actual analysis process, both the bridge and the vehicle should be analyzed as a unified system[1]. As the train runs on the bridge, the actual distribution of the entire mass of the whole power system will change with the passage of time, which will increase the difficulty of analysis. Therefore, it is necessary to strengthen the analysis and research of railway bridge under trainload.

1 Differential equation of vehicle-bridge system vibration

1.1 Cement

The overall differential mode of the axle system can be expressed by equation (1)

$$[M]\{\ddot{X}\}+[C]\{\dot{X}\}+[K]\{X\}=\{F_e\}+\{F_n\} \quad (1)$$

In formula (1), {x} represents the specific displacement vector of the vehicle-bridge system, while $\{\dot{X}\}$ and $\{\ddot{X}\}$ represent the actual speed and acceleration vector of the train during running, respectively, [M], [C], and [K], respectively, represent the actual mass, damping, and stiffness matrices of the whole system. In the process of problem analysis, it is necessary to make sure the accuracy of each data content to ensure the accuracy and rationality of the final analysis result. $\{F_e\}$ indicates some unknown external forces such as wind force; $\{F_n\}$ represents a non-linear external force that has a certain relationship with {x}. In the actual analysis process, the running speed of the train on the railway bridge is V [1]. At this time, the inertia of the whole system and the specific characteristics of the elastic force will constantly change with the passage of time due to the influence of the train running, and eventually, the contents of matrix [m], [c], [k], and vector $\{F_n\}$ will change with the passage of time.

When the overall system of the vehicle bridge is not affected by external force, that is, when the right side of the equal sign in formula (1) is 0, the system is stable. However, from the actual situation, in this case, the system will still have strong vibration; thus, it can be seen that the axle system has self-excitation in terms of actual vibration, and the main reason for this is that there is no certain excitation factor in the axle system.

These exciting factors mainly include uneven mass distribution inside the system, bumpy track, and snake-like train movement, all of which will not work when the train is stationary and will only work when the train is moving[2]. The existence of these excitation factors can cause the vibration of the axle system, but after the vibration of the system, the train and the bridge will affect each other, which will cause the vibration to become more intense, which is what we call the vibration coupling effect of the axle system.

In the concrete analysis process, the vehicle-bridge system is divided into vehicle vibration microequation (2) and bridge structure vibration microequation (3).

[Mvi]{ vi}+[Cvi]{ vi}+[Kvi]{Xvi}={Fvi} (2)

[MB]{ B}+[CB]{ B}+[KB]{XB}={FB} (3)

In formulas (2) and (3), v represents the measurement, and i represents the i^{th} vehicle. i will be omitted for convenience in the following explanation. {xv} represents the appropriate vehicle vector. {XB} represents a unique vector for the bridge node. {FB} represents the magnitude of the equivalent nodal force of the external force acting on the overall structure of the bridge. [MB], [CB], and [KB] represent the mass, damping, and stiffness matrices, respectively.

2 Analysis of vehicle load

The alkali content of low alkali cement is not more than 0.6% (alkali content is calculated as Na_2O + $0.658K_2O$). In the actual analysis of the problem, Zr, YR, φ r, and φ R are used to identify the vertical, lateral, rocking, and rolling displacements correspondingly, which are caused by the irregularity of the track itself and the displacement of the bridge. In the actual analysis, it is assumed that ZW, YW, φ W, and φ W, respectively, represent the vertical, lateral, rocking, and rolling displacements of the wheelset. The specific effects of Zr, YR, φ r, and φ R on the vehicle displacement vector are discussed below.

1. Zr: In the actual analysis, it is assumed that the wheel and rail are in close contact, so it can be considered that Zr and ZW are equal, so the vertical displacement of the bogie with respect to the wheel pair is equal to Zi - Zr.
2. YR: The wheel-rail displacement in the transverse direction is YW - YR, and the angular displacement of the roll relative to the film is λ/A (YW - YR) during the analysis.
3. φ r: The specific displacement of the wheel-rail relative swing angle is φR - φ r.
4. φ R: Assuming that ZR and ZW to be equal during the actual analysis of the problem, φ W and φ R obtained are equal, thus it can be seen that the side roll angle of the bogie relative to the wheel is φ T - φ R.

In discussing the problem, scientific reference to the vehicle vibration mode can determine the specific calculation formula of the load vector on the right side of the vehicle vibration equation with track displacement as a function[2], thus completing the scientific analysis of the vibration situation caused by the vehicle running.

The process of dynamic analysis of railway bridges under trainloads is accomplished. In addition, the vertical force, lateral force, and sway force should be accurately calculated. From the calculation results, the specific load situation of railway bridges should be determined to ensure that the railway bridge project can provide a good traffic environment for people, improve the comfort of trains[3-6] in the specific driving process, and reduce the probability of accidents.

3 Effective measures to avoid phenomenon of axle resonance

The train running on the railway bridge may cause the axle to resonate, but from the actual situation, when the axle resonates, it usually accompanies the accident. In the course of train running, if the tolerance reaches the maximum value and even exceeds the deflection requirements of railway bridges during the application period, it will have a serious impact on the concrete stability of the train and the comfort of passengers during the train running. Therefore, in real life, the occurrence of axle resonance should be avoided as much as possible to avoid accidents [3]. To avoid the occurrence of axle engineering, we can start from the following aspects.

1. In the actual running process of the train, the running speed of the train should be reasonably controlled, and when the train crosses the bridge, it should be properly decelerated according to the requirements to avoid the excessive speed of the vehicle causing the bridge car to resonate.
2. During the construction of railway bridges, if conditions permit, equal span arrangement and small and medium span bridges should be avoided as far as possible, so as to avoid repeated load periodic excitation that can cause serious adverse effects.

3. In the process of train loading, the specific loading frequency actually adopted should be avoided as far as possible to be relative to or close to the natural frequency, to avoid the adverse effect of the train on the bridge during driving, and further avoid the occurrence of bridge - car resonance.

4 Conclusion

The performance and quality of railway bridge projects will have a direct impact on the comfort and safety of trains. Therefore, in the process of analyzing railway bridges, reasonable analysis should be carried out with full consideration of trainloads to ensure the rationality of the final analysis results, so as to provide a good traffic environment for people and facilitate their travel.

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